TESIS DOCTORAL INTERNACIONAL / INTERNATIONAL DOCTORAL THESIS

PROGRAMA OFICIAL DE DOCTORADO EN BIOMEDICINA

UNIVERSIDAD DE GRANADA

INTERACCIÓN DIETA Y ACTIVIDAD FÍSICA EN LA SALUD DE LOS ADOLESCENTES EUROPEOS

REPERCUSIÓN SOBRE LA COMPOSICIÓN CORPORAL, CONDICIÓN FÍSICA Y FACTORES DE RIESGO CARDIOVASCULAR

DIET-PHYSICAL ACTIVITY INTERACTION ON EUROPEAN ADOLESCENT HEALTH

REPERCUSSION ON BODY COMPOSITION, PHYSICAL FITNESS AND CARDIOVASCULAR RISK FACTORS

DEPARTAMENTO DE FISIOLOGÍA

FACULTAD DE MEDICINA

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2013

Editor: Editorial de la Universidad de Granada
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D.L.: GR 1902-2013
ISBN: 978-84-9028-594-7

A mis padres, mis hermanas y Raúl

To my parents, my sisters and Raúl

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La doctoranda MAGDALENA CUENCA GARCÍA y los directores de la tesis Dr. MANUEL J. CASTILLO GARZÓN, Dr. JONATAN RUIZ RUIZ y Dr. FRANCISCO B. ORTEGA PORCEL. Garantizamos, al firmar esta Tesis Doctoral, que el trabajo ha sido realizado por el doctorando bajo la dirección de los directores de la tesis y hasta donde nuestro conocimiento alcanza, en la realización del trabajo, se han respetado los derechos de otros autores a ser citados, cuando se han utilizado sus resultados o publicaciones.

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CONTENIDOS [CONTENTS]

PROYECTOS DE INVESTIGACIÓN [RESEARCH PROYECTS]

El trabajo desarrollado y los artículos que componen la presente memoria de Tesis Doctoral están basados en los siguientes proyectos de investigación:

Estudio principal de la presente memoria de Tesis Doctoral

- Estudio **HELENA** (Healthy Lifestyle in Europe by Nutrition in Adolescence). Proyecto financiado por la Unión Europea: European Union Sixth RTD Framework Programme (Contract FOOD-CT-2005-007034). Página web: www.helenastudy.com

Otros estudios utilizados en la presente memoria de Tesis Doctoral

- Estudio **EYHS** (European Youth Heart Study). Proyecto financiado por Stockholm County Council.
- Estudio **ALPHA** (Assessing Levels of Physical Activity and Fitness). Proyecto financiado por la Unión Europea: Public Health Executive Agency, DG SANCO, Health Information Strand (Ref. 2006120). Página web: www.thealphaproject.net
- Estudio **Physical activity and fitness in children and adolescents with Type 1 diabetes.** Proyecto financiado por la Diabetes UK (Ref: 06/0003396).

BECAS Y FINANCIACIÓN [GRANTS AND FUNDING]

La presente memoria de Tesis Doctoral ha sido posible también gracias a las siguientes becas y subvenciones:

- Beca de **Formación de Profesorado Universitario (FPU)** del Ministerio de Educación y Ciencia (Ref: AP 2008-03806). Departamento de Fisiología, Facultad de Medicina, Universidad de Granada.

- Estancia breve financiada por el Programa Nacional de Formación de Profesorado Universitario:
    - ✓ Departamento de Salud Pública, Universidad de Gante, Bélgica (septiembre - diciembre 2010).

- Estancias breves no financiadas:
    - ✓ Unidad de Nutrición Preventiva en NOVUM, Instituto Karolinska, Estocolmo, Suecia (junio - julio 2011).
    - ✓ Departamento de Ejercicio, Nutrición and Salud Pública, Universidad de Bristol, UK (septiembre - diciembre 2011).
    - ✓ Departamento de Salud Pública (Arnold School Public Health), Universidad de Carolina del Sur, USA (agosto - noviembre 2012).

- Ayudas a Grupos de Investigación de la Junta de Andalucía. Grupo de Investigación en Evaluación Funcional y Fisiología del Ejercicio CTS 262. Universidad de Granada.

LISTA DE PUBLICACIONES [LIST OF PUBLICATIONS]

La presente memoria de Tesis Doctoral está compuesta por los siguientes artículos científicos:

I. Cuenca-García M, Ortega FB, Ruiz JR, González-Gross M, Labayen I, Jago R, Martínez-Gómez D, Dallongeville J, Bel-Serrat S, Marcos A, Manios Y, Breidenassel C, Widhalm K, Gottrand F, Ferrari M, Kafatos A, Molnár D, Moreno LA, De Henauw S, Castillo MJ and Sjöström M. Combined influence of healthy diet and active lifestyle on cardiovascular disease risk factors in adolescents. **Scand J Sci Sports** 2012 [Epub ahead of print].

II. Cuenca-García M, Ortega FB, Huybrechts I, Ottevaere C, Ruiz JR, Vicente-Rodríguez G, González-Gross M, Molnár D, Polito A, Manios Y, Plada M, Vanhelst J, Widhalm K, Moreno LA, Kersting M, Sjöström M and Castillo MJ on behalf of the HELENA study group. Clustering of multiple lifestyle behaviours and its relationship with gender, age and health-related fitness in European adolescents: The Healthy lifestyle in European by Nutrition in Adolescents Study. Accepted in **J Nutr Educ Behav**.

III. Cuenca-García M, Ortega FB, Ruiz JR, Labayen I, Moreno LA, Patterson E, Vicente-Rodríguez G, González-Cross M’ Marcos A, Polito A, Manios Y, Beghin L, Wästlund A, Molnár D, Kidhalm K’ Kafatos A, De Henauw S, Sjöström M, Gutin B, and Castillo, MJ. More physically active and leaner adolescents have higher energy intake: consistent results using different methods and different studies (HELENA and EYHS Studies). Submitted to **J Pediatr**.

IV. Cuenca-García M, Ortega FB, Huybrechts I, Ruiz JR, González-Gross M, Ottevaere C, Sjöström M, Dìaz LE, Ciarapica D, Molnar D, Gottrand F, Plada M, Manios Y, Moreno LA, De Henauw S, Kersting M, Castillo MJ. Cardiorespiratory fitness and dietary intake in European adolescents: The HELENA study. **Br J Nutr.** 2012 Jun; 107 (12):1850-9.

V. Cuenca-García M, Ruiz JR, Ortega FB, Labayen I, González-Gross M, Moreno LA, Gomez-Martinez S, Ciarapica D, Hallstrom L, Wästlund A, Molnar D, Gottrand F, Manios Y, Widhalm K, Kafatos A, De Henauw S, Sjöström M and Castillo MJ on behalf of the HELENA study group. Breakfast Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: The HELENA study. Submitted to **Public Health Nutr**.

VI. Cuenca-García M, Ruiz JR, Ortega FB, Castillo MJ and the HELENA study group. Association between chocolate consumption and fatness in European adolescents. Pending accept of revised version to **Obesity**.

VII. Soriano-Maldonado A, Cuenca-García M, Moreno LA, Leclercq C, Androutsos O, Guerra-Hernández EJ, Castillo MJ and Ruiz JR. [Egg intake and cardiovascular risk factors in adolescents; role of physical activity]. The HELENA study. **Nutr Hosp,** 2013 [Epub ahead of print].

VIII. Cuenca-García M, Jago R, Shield J PH, Burren C P. How does physical activity and fitness influence glycaemic control in young people with type 1 diabetes?. **Diabet Med**. 2012 Oct 29 (10): e369-76.

IX. Cuenca-García M, Jiménez-Pavón D, España-Romero V, Artero EG, Castro-Piñero J, Ortega FB, Ruiz JR, Castillo MJ. [Health-related fitness and eating habits in children and adolescents: proposal for an addendum to the Report of School Health]. **Revista de Investigación en Educación**. 2011 Nov; 9 (2): 35-50.

RESUMEN

Durante la adolescencia se desarrollan y afianzan comportamientos que tienen una importante repercusión sobre la salud de las personas, tanto a corto como a largo plazo, y que serán difíciles de modificar en la vida adulta. Los hábitos de vida poco saludables (ej.: el bajo nivel de actividad física, una alimentación poco saludable o el consumo de tabaco y alcohol) son determinantes en el desarrollo de enfermedades no transmisibles en la edad adulta y cuyos factores de riesgo se pueden identificar durante la edad infanto-juvenil. Conocer la relación entre dieta, actividad física y salud cardiovascular en adolescentes resulta de interés para prevenir futuras enfermedades, así como reducir el gasto sanitario.

La presente memoria de Tesis Doctoral tiene como objetivo estudiar la relación entre factores relacionados con el estilo de vida (dieta y actividad física) y marcadores de salud (composición corporal, condición física y factores de riesgo cardiovascular) en adolescentes.

Los trabajos que componen la presente memoria de Tesis Doctoral están basados principalmente en datos procedentes del proyecto HELENA pero también se incluyen datos del EYHS, de un estudio en jóvenes británicos con diabetes Tipo 1 y del estudio ALPHA. Un total de 2.148 adolescentes de 9 países europeos (HELENA), 321 adolescentes suecos (EYHS), 60 niños y adolescentes con diabetes (Estudio británico), y 138 niños y adolescentes de la provincia de Granada (ALPHA) han sido evaluados en la presente memoria de Tesis.

Los principales resultados sugieren que: *a)* La combinación de una dieta saludable y un estilo de vida físicamente activo se asocia con una mejor salud cardiovascular en adolescentes. Además, un estilo de vida físicamente activo puede atenuar los efectos negativos de una dieta poco saludable. *b)* Se han observado patrones de comportamiento o agrupaciones de múltiples componentes de estilos de vida; dichos patrones difieren en función del género o la edad, y se relacionan con la condición física. *c)* Los adolescentes más activos y delgados tienen un mayor consumo de energía que los menos activos y delgados. *d)* Un mayor consumo de productos lácteos y pan/cereales y menor ingesta de bebidas endulzadas se asocia con una alta capacidad aeróbica. *e)* Tomar el desayuno no parece estar relacionado con la actividad física, el sedentarismo y algunos componentes de la condición física en adolescentes (fuerza muscular y habilidad motora). Sin embargo, tomar el desayuno se asocia con una mayor capacidad aeróbica. *f)* Un mayor consumo de chocolate se asocia con una menor adiposidad central y total en adolescentes. *g)* El consumo de huevo no se asocia con factores de riesgo cardiovascular en adolescentes. *h)* La actividad física de intensidad moderada a vigorosa se asocia con un mejor control de la glucemia en niños y adolescentes con diabetes Tipo 1. *i)* Hábitos alimentarios, composición corporal y condición física pueden ser evaluadas periódicamente en el ámbito escolar y dicha información puede incluirse en el Informe de Salud Escolar.

La presente memoria de Tesis Doctoral muestra que una dieta saludable y ser físicamente activo se asocia con una menor obesidad, un alto nivel de condición física (entendida como un indicador fisiológico de salud) y un perfil cardiovascular favorable en adolescentes. Además, los resultados muestran que un estilo de vida físicamente activo puede reducir las consecuencias adversas de una dieta poco saludable. La presente tesis muestra que la actividad física de intensidad moderada a vigorosa se asocia con un mejor control glucémico en jóvenes con diabetes Tipo 1. Finalmente, se propone un addendum al Informe de Salud Escolar basado en el estudio de la dieta, la composición corporal y la condición física, que permitirá detectar a niños y adolescentes con una dieta poco saludable, sobrepeso y/o baja condición física. Los datos confirman la necesidad de fomentar una dieta equilibrada y la práctica regular de actividad física de intensidad moderada a vigorosa desde los sistemas educativos para alcanzar un estado óptimo de salud cardiovascular en los adolescentes.

SUMMARY

Adolescence is a period in which important behaviours are settled and they have a significant impact on the health of people in a short and long term. Some of these behaviours will be difficult to change in adulthood. An unhealthy lifestyle (e.g.: low level of physical activity, unhealthy diet, smoking or alcohol consumption) are crucial in the development of non-communicable diseases in adulthood and these risk factors might be identified early in life. To know the relationship between diet, physical activity and cardiovascular health in adolescents is of interest in order to prevent future disease and reduce health care costs.

In this context, the overall aim of this Doctoral Thesis was to study the relationship between factors related to lifestyle (diet and physical activity) and markers of health (body composition, fitness and cardiovascular risk factors) in adolescents.

The current Doctoral Thesis was based primarily on data from the HELENA project, yet some data come from the EYHS. In addition, a study in British young people with Type 1 diabetes and the ALPHA study were also included. A total of 2148 adolescents from 9 European countries (HELENA), 321 Swedish adolescents (EYHS), 60 children and adolescents with diabetes (British Study), and 138 children and adolescents from Granada (Spain) (ALPHA) have been studied in this Thesis.

The main findings indicate that*: a)* A combination of healthy diet and active lifestyle is related to a healthier cardiovascular profile in adolescents. In addition, an active lifestyle may attenuate the adverse consequences of an unhealthy diet. *b)* Clustering of different lifestyle behaviours are observed in adolescents and this clustering differs by gender and age, and are associated with physical fitness. *c)* More physically active and leaner adolescents have higher energy intakes than less active and fatter adolescents. *d)* A higher intake of dairy products and bread/cereals, and a lower consumption of sweetened beverages is associated with a high cardiorespiratory fitness. *e)* Breakfast consumption does not seem to be related to physical activity or sedentary time of European adolescent, neither some physical fitness components as muscular fitness or speed-agility. Breakfast consumption, however, is associated with cardiorespiratory fitness. *f)* A higher chocolate consumption is associated with lower central and total fatness in adolescents. *g)* Egg intake is not associated with cardiovascular disease risk factors in adolescents. *h)* Moderate-to-vigorous physical activity is associated with better glycaemic control in young people with Type 1 diabetes. *i)* Dietary habits, body composition and physical fitness can be assessed at school and this information be include into the Report of Health delivered at the School.

This Doctoral Thesis shows that a combination of healthy diet and active lifestyle is associated with lower adiposity (thus less risk of obesity), a higher level of physical fitness (which is a physiological indicator of health) and a more favorable cardiovascular profile in adolescents. It also suggests that an active lifestyle can reduce the adverse consequences of an unhealthy diet. Moreover, moderate-to-vigorous physical activity is related with better glycaemic control in young people with Type 1 diabetes. Finally, this Thesis proposes an addendum to the Report of School Health based on the evaluation of food habits, body composition and physical fitness; which will be able to identify children and adolescents with an unhealthy diet, overweight and/or low physical fitness. These data support the need to promote a balanced diet and regular moderate to vigorous physical activity at education settings in order to achieve an optimal cardiovascular health in adolescents.

ABREVIATURAS [ABBREVIATIONS]

ADA	American Diabetes Association
ALPHA	Assessing Levels of Physical Activity and Fitness
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
BF %	Body fat percentage
BIA	Bioelectrical impedance analysis
BMI	Body mass index
CI	Confidence interval
CRF	Cardiorespiratory fitness
CVD	Cardiovascular diseases
DQI	Diet Quality Index
DQI-A	Diet Quality Index for Adolescents
DT	Desviación típica
DXA	Dual-energy X-ray Absorptiometry
EYHS	European Youth Heart Study
FAS	Family affluence scale
FFM	Fat-free mass
FITNESSGRAM	Fitness program for children
HbA1	Haemoglobin A1c
HBSC	Health Behaviour in School-aged Children Study
HDLc	High-density lipoprotein cholesterol
HDLc/LDLc ratio	High-density lipoprotein cholesterol/ low-density lipoprotein cholesterol ratio
HELENA-CSS	Healthy Lifestyle in Europe by Nutrition in Adolescence Cross Sectional Study
HELENA-DIAT	Healthy Lifestyle in Europe by Nutrition in Adolescence-DIetary Assessment Tool
HOMA	Homeostasis model assessment
IFIS	International Fitness Scale
ISPAD	International Society for Pediatric and Adolescents Diabetes
LDLc	Low-density lipoprotein cholesterol
IPAQ-A	International Physical Activity Questionnaire for Adolescents
LSD	Least significant difference
MSM	Multiple Score Method

MVPA	Moderate to vigorous physical activity
OR	Odds ratio
PA	Physical activity
PWC_{170}	Physical work capacity at a heart rate of 170 beats/min
SD	Standard deviation
SE	Standard error
SRT	Shuttle run test
TC	Total cholesterol
TC/ HDLc ratio	Total cholesterol/high-density lipoprotein cholesterol ratio
TG	Triglycerides
VO_{2max}	Maximal oxygen uptake
WHO	World Health Organization
YANA-C	Young adolescents’ Nutrition Assessment on Computer

INTRODUCTION

[INTRODUCCIÓN]

INTRODUCTION [INTRODUCCIÓN]

Non-communicable diseases, such a cardiovascular diseases, cancer, diabetes and chronic respiratory diseases, are still the most common causes of death in European countries and are decisively affected by lifestyle choices[1-2]. Unhealthy diet, physical inactivity and other lifestyle behaviours are associated with the development of serious and highly prevalent diseases such as cancer, heart disease, stroke, and diabetes[3]. Diet and nutrition are important factors in the promotion and maintenance of good health throughout the entire life course. Both single dietary recommendation (e.g.: to increase the intake of fruit and vegetables) and dietary indices or dietary patterns, as a measure of overall dietary quality, have been associated with health outcomes, major chronic diseases and mortality[4-6]. Regular physical activity is also associated with many health benefits (e.g.: high cardiorespiratory fitness, low fatness, a healthier lipid profile and blood pressure, and a lower insulin resistance) and reduced risk of mortality[7]. Moreover, combination of these and other risk factors such as tobacco and alcohol increases the risk of early death[8]. Based on this evidence, the World Health Organization supports that the key for health promotion and disease prevention in the 21st century is to establish policies and environments that support positive health behaviours and a healthy lifestyle[9].

Non-communicable diseases have their origin during childhood and adolescence[10], but the complex relationship between all of these processes and the development of non-communicable diseases is poorly understood. Adolescence is a crucial period in life and implies multiple maturational, physiological and psychological changes that affect nutritional needs and habits choices. It is during adolescence when lifestyle behaviours tend to consolidate. Recent studies suggest that the prevalence of negative health behaviours among adolescents has increased dramatically over the past few decades[11-12], which may have a significant impact on the health of adolescents both in a short and long term. Thus, the promotion of a healthy lifestyle in childhood and adolescence may reduce the development of diseases in adulthood. However, there is a need to better understand how the interaction of lifestyle behaviours affects markers of health in young people. These findings would be of interest to develop strategies for prevention of unhealthy habits. The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study, a multi-center study conducted in ten European cities, was carried out to address this issue[13]. The overall aim of the HELENA cross-sectional study was to obtain a reliable and comparable data on nutritional and health-related parameters such as obesity indicators, blood lipid profile, blood pressure, insulin resistance or physical fitness, among others, in European adolescents.

Diet, physical activity and cardiovascular disease

The traditional cardiovascular disease risk factors are high levels of total cholesterol together with low levels of high-density lipoprotein cholesterol, high levels of triglycerides, insulin resistance, blood pressure, as well as an excess of total and central body fat[14]. Moreover, low levels of cardiorespiratory and/or muscular fitness have more recently also been considered a strong cardiovascular disease risk factors in adolescents[14-15]. Although independent associations of diet and physical activity with cardiovascular disease risk factors have been reported in adolescents[14, 16], little is known about the combined influence of both on cardiovascular disease risk. *To know the combined influence of diet quality and physical activity on cardiovascular disease risk would provide interesting findings on the interaction between lifestyle behaviours and cardiovascular health status in adolescents (Paper I).*

Clustering of lifestyle behaviours and health status

Most studies in young people have focused on the importance of independent lifestyle behaviours, despite the fact that research suggests the coexistence (i.e., clustering) of different behaviours. Moreover, studies report that healthy lifestyles do not always come together among young people[17].Thus, identify clustering of multiple health behaviours (e.g.: physical activity, types of sedentary behaviours and dietary patterns as a measure of overall dietary quality) is needed to inform effective intervention programs. On the other hand, studies investigating on the clustering of behaviours and their combined effect on markers of health is inconsistent (e.g., body composition) or limited (e.g., aerobic capacity) in adolescents[18-20]. *Consequently, there is a need to better understand how the clustering of lifestyle choices affects cardiovascular health markers in adolescents (Paper II).*

Diet, physical activity and body composition

The prevalence of pediatric obesity has increased for decades and although a plateau has been observed in some countries, the prevalence is still high and is a main public health concern[21]. It is important to enhance our understanding of the etiology of obesity so that we can institute effective public health preventive efforts. Dietary factors (e.g. amount of energy intake and diet quality) and physical activity have great influence on development of healthy bodies, that is, the amount of fat, muscle and bone tissue[11]. Positive energy balance mainly driven by relatively high energy intake has traditionally explained the modifiable cause of obesity[22]. However, restriction of energy intake, in young people may make it difficult to meet the nutritional needs of growth and may also lead to dangerous eating disorders[23]. On the other hand, an increase in energy expenditure through physical activity is likely to be one of the major factors contributing to the global epidemic of overweight and obesity or, on the contrary, developing healthy bodies[24-25]. *Should we promote physical activity rather than energy restriction to prevent overweight in young people? (Paper III).*

Diet, physical activity, physical fitness and cardiovascular risk factors

Physical fitness is a marker of health both during adolescence[26] and later in adulthood[27]. Higher levels of fitness are associated with many positive health outcomes (e.g., improved cardiovascular profile)[26]. Although physical fitness is in part genetically determined[28], it is also influenced by environmental factors, particularly physical activity, and it is at present unknown how it is associated with nutrition. Active adolescents have higher levels of cardiorespiratory fitness and identifying which dietary behaviours are related or co-exist with high levels of cardiorespiratory fitness is also of Public Health interest. In fact, dietary patterns have been associated with the overall cause of mortality, but diet-disease relationship was largely confounded by cardiorespiratory fitness[29].On the other hand, specific diet habits, such skipping breakfast, has been associated with less healthful behaviours, including poorer overall dietary quality or food choose and inactive lifestyle in adolescents[11, 30-32], which may lead to an unfavorable cardiovascular profile[33]. Other example is eggs intake, traditionally eggs intake has been associated with an unhealthy cardiovascular profile due to its high cholesterol content; however, recent studies have not observed this relationship[34-35]. *Thus, it is of interest to know the relationships between specific dietary factors and physical fitness (as physiological health indicators) and cardiovascular profile in adolescents (Papers IV-VII).*

Physical activity and metabolic diseases

Improving lifestyle strategies, such as healthy diet and regular physical activity, are recommended in the management of diabetes in adults (e.g.: optimize glycaemic control)[36]. However, there is inconsistent information about the association between physical activity and glycaemic levels among young people with Type 1 diabetes. For example, some researchers have suggested that physical activity may account for some of the variance in HbA1c levels[37-39], while other research groups have reported no association between physical activity and HbA1c[40-42]. *In order to better educate families living with young people with diabetes, more evidence on how physical activity influence medium-to long-term glycaemic control is needed (Paper VIII).*

Proposal for an addendum to the Report of School Health

A periodic control of the health status and lifestyle behaviours in early life may be an effective tool to reduce the incidence of major diseases in adulthood. The key of the prevention is linked to a multidisciplinary approach including the individual and their environment. The school is adequate environment to promote healthy lifestyle habits as healthy diet and physical activity among other. The physical education teachers are qualified to evaluate markers of health related to body composition and physical fitness and to identify unhealthy lifestyle behaviours[43]. This information can be incorporated into the Report of School Health so providing a better health control during childhood and adolescence. Consequently, it could identify young people with high risk, that is, poorer diet, overweight and/or low level of fitness. The long-term goal should be that the young people reach maturity being able to maintain a healthy lifestyle that will maintain a state of optimal health for as long as possible. *It is interest regularly evaluate lifestyle behaviours and markers of health, easy to assess, and done by the physical education teacher and to show them as an addendum to the Report of School Health to inform both family and primary health care physicians(Paper IX).*

Based on the aforementioned evidence, the present Doctoral Thesis contributes to the current knowledge on the interaction of diet and physical activity on cardiovascular health of European adolescent, especially its association with body composition, physical fitness and cardiovascular risk factors. The relationships among the main topics studied in this Doctoral Thesis are displayed in the Figure 1.

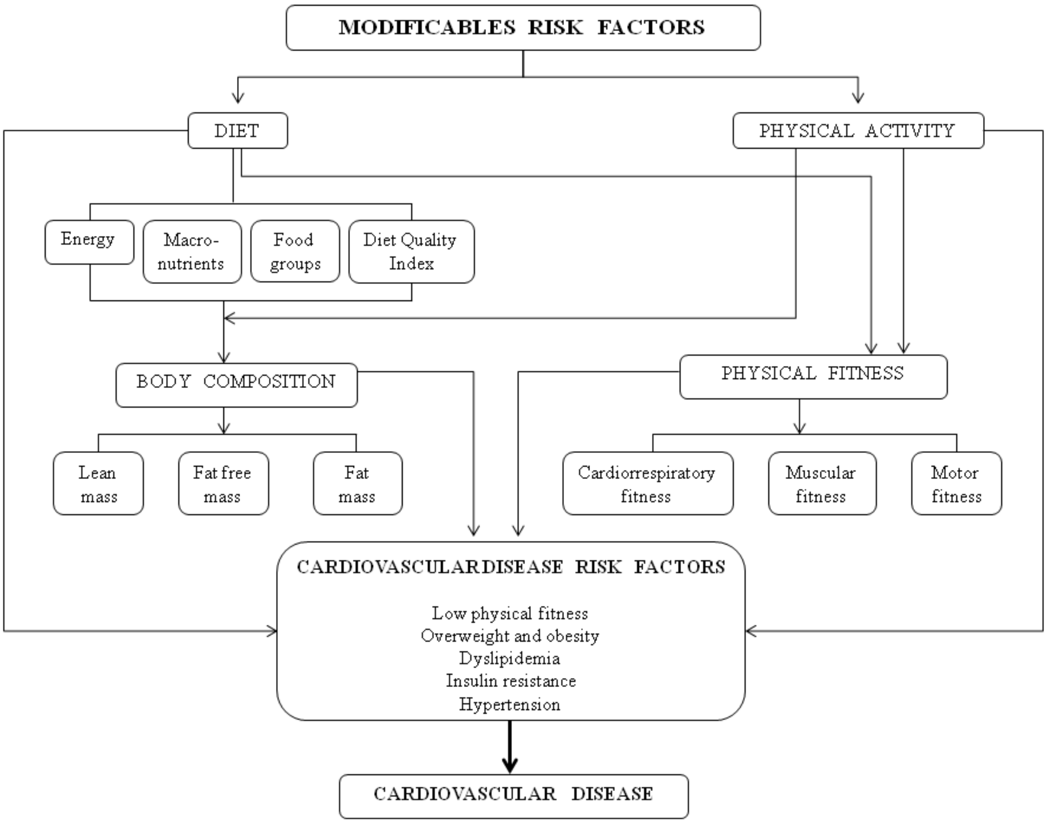

Figure 1. Conceptual model illustrating the combined and independent association of diet and physical activity with body composition, physical fitness and other cardiovascular disease risk factors.

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7. ACTIVIDAD FÍSICA EN NIÑOS Y ADOLESCENTES

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ACTIVIDAD FÍSICA EN NIÑOS Y ADOLESCENTES

En: Ejercicio físico y salud en poblaciones especiales. EXERNET. Volumen I. Pp. 123-145. CSD. Madrid, 2011 diciembre.

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Resumen

La práctica de actividad física previene el desarrollo de factores de riesgo cardiovascular ya desde la infancia y adolescencia. Entre esos factores de riesgo se encuentra la obesidad, la dislipidemia, la hipertensión o la resistencia a la insulina. Es más, una baja condición física, tanto en su vertiente de capacidad aeróbica como de fuerza muscular también se consideran factores de riesgo cardiovascular en sí mismos. Respecto a la actividad física, existe hoy suficiente evidencia científica como para afirmar la existencia de una relación inversa entre nivel de actividad física y cada uno de los factores de riesgo antes mencionados. Esta relación es más consistente cuando se trata de actividad física de vigorosa intensidad que cuando se trata de actividad física de menor intensidad. En cualquier caso, hay que señalar que cualquier nivel de actividad física es mejor que ninguna pues, como mínimo, ayuda a regular el equilibrio entre la ingesta y el gasto energético. La práctica de actividad física, y que ésta tenga un componente de intensidad moderada-vigorosa, debe estar presente ya desde la infancia o la adolescencia. Para ello, programas de prevención y educación pueden ser la principal y más efectiva herramienta para instaurar un patrón de vida saludable entre los jóvenes de cara a alcanzar una salud óptima presente y futura.

Introducción

El estilo de vida de una persona está influenciado por los múltiples cambios madurativos, fisiológicos y psicológicos que en gran parte tienen lugar durante la infancia y la adolescencia. Es más, estos hábitos de estilo de vida pueden tener una importante repercusión sobre la salud en la vida adulta. Los hábitos que se instauran en la adolescencia tales como hacer actividad física, tomar frutas o verduras, beber alcohol o fumar suelen persistir durante mucho tiempo. Es más, un hábito o estilo de vida instaurado desde esas edades tempranas de la vida suele ser de difícil modificación en la edad adulta.

Estudios recientes sugieren que tanto la falta de actividad física como una dieta no saludable son dos claros factores determinantes no sólo de enfermedad cardiovascular sino también de muchas otras enfermedades. Entre los factores de riesgo para desarrollar enfermedad cardiovascular se incluye la resistencia a la insulina, alteraciones del perfil lipídico, la hipertensión o la obesidad. Además, tanto la inactividad física como unos bajos niveles de capacidad aeróbica o fuerza muscular son también factores asociados con el desarrollo de la enfermedad cardiovascular tanto en adultos como en jóvenes[1-3].

Las enfermedades cardiovasculares suelen hacer su aparición clínica en la edad adulta tardía. Sin embargo, numerosos estudios muestran que dichas enfermedades se inician en edades más tempranas teniendo durante muchos años un curso subclínico[4]. El fomento e incremento de los niveles de actividad física pueden jugar un papel fundamental en la prevención de patologías asociadas a la enfermedad cardiovascular no sólo en la vida adulta sino durante la propia infancia y adolescencia.

La prevención va ligada a un enfoque multidisciplinar que implica al individuo y a su entorno. En este sentido, la escuela juega un papel fundamental ayudando a promover la actividad física, entre otros hábitos de vida saludables. De hecho, estos contenidos están presentes en la programación curricular dentro de la asignatura de Educación Física. Por otro lado, el docente de esta especialidad está perfectamente capacitado para evaluar la condición física de sus alumnos y observar su evolución a lo largo del periodo de escolarización[5-6]. En consecuencia, resulta posible llevar un registro tanto de la condición física como del nivel de actividad física practicado a lo largo del período de escolarización y ser estos datos incorporados al informe de salud escolar[7]. Esta información es relevante en términos de salud y ello en base a una importante y reciente evidencia científica, lo cual vamos a mostrar a lo largo de este capítulo. En base a todo ello, establecer estos registros periódicamente puede ayudar a detectar a aquellos jóvenes con un bajo nivel de condición física y/o problemas de sobrepeso, como consecuencia de un alto nivel de sedentarismo y/o una inadecuada alimentación. El objetivo a largo plazo debería ser que los jóvenes alcancen la madurez siendo capaces de mantener hábitos de vida saludables que permitan mantener un estado de salud óptimo por el mayor tiempo posible. Programas que fomenten hábitos saludables, desarrollados en los centros escolares y abalados por los docentes de la especialidad de Educación Física, pueden ser una herramienta efectiva para reducir la incidencia de las principales patologías que aparecen en la edad adulta como consecuencia de un estilo de vida poco saludable.

En este capítulo se revisan los estudios epidemiológicos más recientes donde se pone de manifiesto la relación entre la actividad física y diversos factores de riesgo para la salud cardiovascular presente y futura en niños y adolescentes (Figura 2).

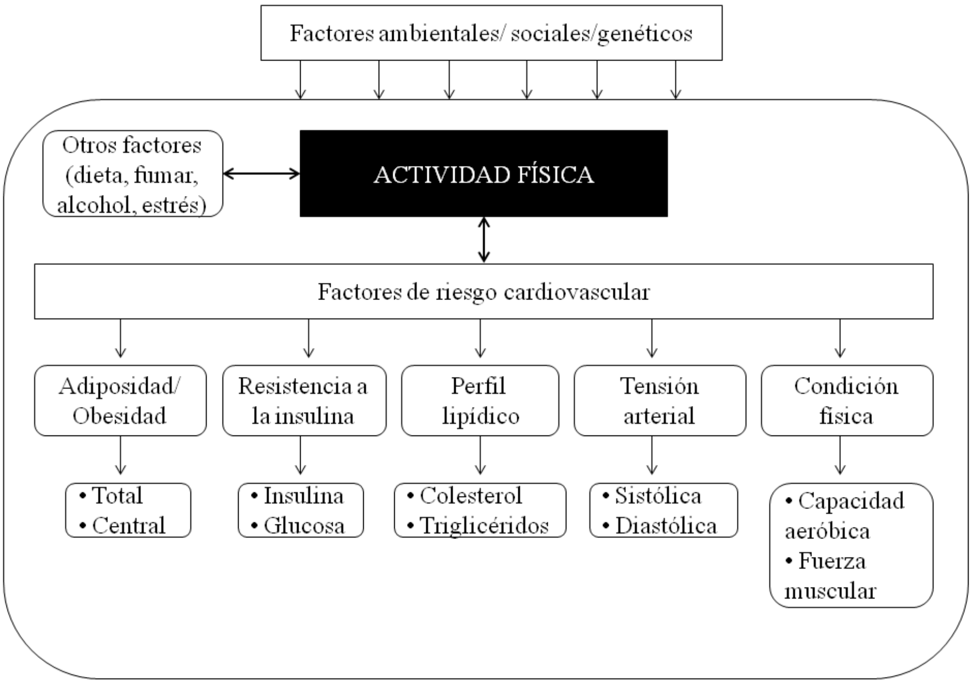

Figura 2. Representación gráfica de las asociaciones entre actividad física y diversos parámetros de salud. Adaptado de Ruiz y Ortega 2009[8].

Actividad física y Condición física

Los conceptos de Actividad Física y Condición Física, aunque inter-relacionados e inter-influenciables, son claramente diferentes.

Actividad Física. La actividad física hace referencia a cualquier movimiento corporal producido por la contracción de los músculos esqueléticos y que implica un cierto gasto energético. Puede corresponder a las distintas actividades que se realizan a lo largo del día y que incluyen: el desplazamiento o transporte, la actividad escolar o laboral, la participación en actividades domésticas o extraescolares y las actividades de ocio que se tienen. Aquella actividad física practicada de manera intencionada, repetitiva y estructurada es lo que conocemos hoy día por ejercicio físico.

La valoración de la actividad física que una persona practica es especialmente difícil en niños/adolescentes. Existen diferentes métodos para evaluar la actividad física descritos en la literatura, entre ellos destacan: métodos objetivos (monitorización de la frecuencia cardiaca, acelerometría, etc.) y métodos subjetivos (entrevistas, cuestionarios, etc.). Entre los métodos objetivos disponibles, están los sensores de movimiento, también conocidos como acelerómetros, que han demostrado ser un método viable y válido capaz de ofrecer información útil acerca de la duración, frecuencia e intensidad de la actividad física que se lleva a cabo. Por otro lado, los métodos subjetivos son los más usados en estudios poblacionales por su bajo coste, sin embargo, se sabe que son poco precisos para evaluar el nivel de actividad física, especialmente en niños.

Condición física. Un factor íntimamente ligado al nivel de actividad física y/o ejercicio que se practica es el estado de condición física que tiene la persona. La condición física (o forma física) se define como la capacidad que una persona tiene para realizar actividad física y/o ejercicio, y constituye una medida integrada de todas las funciones y estructuras que intervienen en la realización de actividad física o ejercicio. Estas funciones son la músculo-esquelética, cardio-respiratoria, hemato-circulatoria, endocrino-metabólica y psico-neurológica. Un alto nivel de condición física implica una buena respuesta concatenada y fisiológica de todas ellas. Por el contrario, tener una mala condición física podría indicar un malfuncionamiento de una o varias de esas funciones.

La evaluación de la condición física en estudios epidemiológicos es relativamente reciente, y su aplicación al ámbito de la salud ha originado el sobrenombre de condición física relacionada con la salud (en inglés *health-related physical fitness*). Según directrices del American College of Sport Medicine[9] la condición física relacionada con la salud comprende un conjunto de cualidades físicas tales como la capacidad aeróbica, fuerza y resistencia muscular, movilidad articular, velocidad de desplazamiento, agilidad, coordinación, equilibrio y composición corporal. De todas las cualidades que componen la condición física, la capacidad aeróbica, la fuerza muscular y composición corporal han sido las que han adquirido una mayor relevancia científica en el ámbito sanitario.

El nivel de condición física se puede evaluar objetivamente mediante distintos test, dependiendo de la cualidad que queramos evaluar. Estos test pueden ser de laboratorio o de campo. Los test de laboratorio tienen la ventaja de que se realizan bajo unas condiciones muy controladas, sin embargo su uso se limita en la mayoría de los casos a estudios de fisiología del ejercicio.

Tres pruebas de condición física ampliamente utilizadas son la prueba de esfuerzo máxima, el estudio de la fuerza muscular y el estudio de la composición corporal. La prueba de esfuerzo máxima permite conocer el nivel de capacidad aeróbica máxima (también conocido como consumo máximo de oxígeno) de la persona evaluada. En jóvenes, el test de campo más utilizado para estimar la capacidad aeróbica es el test de 20 metros de ida y vuelta, también conocido como test de *Course Navette* o *Shuttle-Run*, en terminología francesa e inglesa, respectivamente.

La fuerza muscular del tren inferior se ha evaluado tradicionalmente mediante el test de salto a pies juntos. Para evaluar la fuerza en el tren superior podemos emplear un test muy sencillo usando un dinamómetro manual que determinará la fuerza máxima de prensión que se puede aplicar con la mano. El test de dinamometría manual ha sido extensamente utilizado en adultos y nuestro grupo ha hecho un gran trabajo para minimizar el índice de error de medida en jóvenes y adultos[10-12]. Entre los test más utilizados para medir la velocidad de desplazamiento, agilidad y coordinación en niños y adolescentes destaca el test de la carrera de ida y vuelta de 4 x 10 metros.

La composición corporal puede ser evaluada usando diversos métodos que van desde los más sofisticados equipamientos de laboratorio (como los métodos de referencia) a los métodos más sencillos y ampliamente utilizados como son los métodos antropométricos. Los métodos de referencia, como por ejemplo, la absorciometría dual de rayos X (DXA) o BodPod, se utilizan en estudios epidemiológicos e implican un elevado coste para su uso. Por otro lado, los métodos antropométricos han sido ampliamente empleados, son de fácil aplicación y bajo coste. Entre los métodos antropométricos destacamos el índice de masa corporal (IMC = $Peso\ (kg)/Talla\ (m)^2$), perímetro de cintura o el porcentaje de grasa corporal mediante la medida del espesor de los pliegues subcutáneos. Mientras que las limitaciones de la medida de IMC son bien conocidas, el uso del perímetro de cintura (como indicador de obesidad central o abdominal) o el porcentaje de grasa (como indicador de grasa total) han sido ampliamente utilizados para evaluar la composición corporal en estudios epidemiológicos debido a su fiabilidad, rápida evaluación y bajo coste. Las ecuaciones de Slaughter et al.[13] permiten obtener el porcentaje de grasa corporal mediante la evaluación de tan sólo dos pliegues cutáneos (tríceps y subescapular) en niños y adolescentes.

Recientemente se han realizando importantes esfuerzos para disponer de baterías de test validadas que reporten información válida y fiable sobre la mejor forma de evaluar la condición física relacionada con la salud tanto en la población adulta como joven. En este sentido, nuestro grupo ha participado en el proyecto ALPHA (**A**ssesing **L**evels of **Ph**ysical **A**ctivity and Fitness) (www.thealphaproject.net), un estudio multicéntrico que ha proporcionado una serie de instrumentos para evaluar los niveles de actividad física y de condición física de forma comparable en los países miembros de la Unión Europea[14]. En este marco, nuestro grupo ha realizado varios estudios metodológicos en personas jóvenes y revisiones sistemáticas para determinar aquellos test que permiten evaluar la condición física relacionada con la salud y ha seleccionado aquellos que cumplieron con los siguientes requisitos: ser indicadores del estado de salud en la edad adulta[15], ser válidos (esto es, medir lo que se pretende medir)[16], ser fiables (es decir, cuando la evaluación se realiza varias veces el resultado es consistente)[17] y ser sencillos de realizar, poco costosos y viables para ser utilizados tanto en estudios poblacionales como en el ámbito escolar[6].

Como consecuencia de la evidencia científica, hemos proporcionado una batería de test de campo para la evaluación de la condición física relacionada con la salud en niños y adolescentes: ALPHA-Fitness[5]. La batería desarrollada incluye los siguientes test: (1) test de ida y vuelta de 20 metros para evaluar la capacidad aeróbica, (2) test de fuerza de prensión manual y (3) test de salto de longitud a pies juntos para evaluar la capacidad músculo-esquelética, y (4) el IMC, (5) el perímetro de la cintura, y (6) los pliegues cutáneos (tríceps y subscapular) para evaluar la composición corporal (Figura 3). Además, se incluyen 2 variantes: la batería ALPHA-Fitness primaria, o de alta prioridad, y la batería ALPHA-Fitness extendida. La batería ALPHA-Fitness de alta prioridad incluye todos los test excepto la medida de pliegues cutáneos y se aconseja en aquellas situaciones en las que no se disponga de mucho tiempo. En el caso de que el tiempo no sea una limitación se recomienda utilizar la batería ALPHA-Fitness extendida, que incluye todos los test y además del test de velocidad y agilidad de 4x10 m.

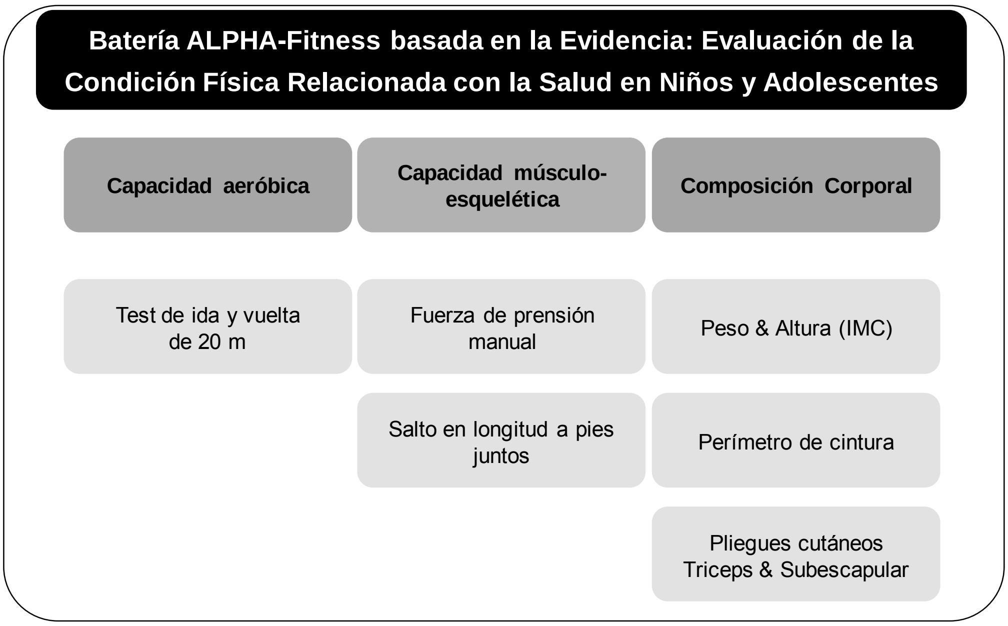

Figura 3. Batería ALPHA-Fitness basada en la evidencia científica. IMC indica índice de masa corporal (peso en kilogramos dividido por el cuadrado de la altura en metros, kg/m^2).Traducido de Ruiz y colaboradores [5].

Actividad física y salud. Evidencia científica

Actividad física y adiposidad

El sobrepeso y la obesidad suponen actualmente un problema de salud de gran transcendencia que afecta tanto a adultos como a niños y adolescentes. Las consecuencias del exceso de grasa corporal son bien conocidas, además se ha demostrado que tener un exceso de peso a edades tempranas aumenta el riesgo de padecer enfermedades cardiovasculares futuras[18].

Independientemente de la cantidad total de masa grasa que una persona posee, la forma como ésta se distribuye en el cuerpo es también relevante para la salud. Un exceso de grasa en la zona del tronco y en la zona abdominal (también conocida como obesidad central, abdominal o androide) se asocia a una mayor incidencia de factores de riesgo cardiovascular y síndrome metabólico en niños y adolescentes[19].

Se ha demostrado que la actividad física está inversamente relacionada con el sobrepeso y la obesidad. Estudios recientes han puesto de manifiesto la importancia que tiene la intensidad a la que se practica actividad física para la prevención del sobrepeso y obesidad [20]. Además, los estudios transversales realizados en niños y adolescentes han mostrado en su mayoría que solo la actividad física practicada de forma vigorosa se asocia con una menor cantidad de grasa corporal, tanto cuando se evalúa la grasa total[21-24] como abdominal[21, 25-29]. Los resultados obtenidos por nuestro grupo, tanto en aquellos niños que participaron en el *European Youth Heart Study* (EYHS) como los adolescentes implicados en el estudio HELENA (*Healthy Lifestyle in Europe by Nutrition in Adolescence*, www.helenastudy.com), también muestran una asociación negativa entre actividad física vigorosa y grasa corporal. Por ejemplo, en el estudio llevado a cabo en una sub-muestra de 223 adolescentes Españoles de 12,5 a 17,5 años que participaron en el estudio HELENA[21], se observó la relación entre actividad física y la grasa corporal total medida con métodos de referencia (DXA y BodPod) y antropométricos (masa grasa abdominal y perímetro de cintura). Los resultados mostraron que la actividad física vigorosa parece tener un mayor efecto sobre la grasa total y central que la actividad física de menor intensidad. Además, de este estudio se desprende que, aunque existen diversos y sofisticados métodos para la evaluación de la grasa abdominal, el perímetro de cintura es un índice preciso y fiable para evaluar la grasa abdominal. Más recientemente, hemos observado que en aquellos niños y adolescentes con una baja forma física, el tiempo empleado en actividad física vigorosa parece ser el componente clave para reducir la adiposidad abdominal[29]. Además, cumplir con las actuales recomendaciones para la práctica de actividad física (al menos 60 min/día de actividad física de moderada a vigorosa de intensad) es suficiente para tener un porcentaje de grasa corporal más saludable[30].

Se puede concluir que existe suficiente evidencia científica como para afirmar una relación inversa entre nivel de actividad física y grasa corporal y que esta relación es más consistente cuando se trata de actividad física de vigorosa intensidad comparada con la actividad física de menor intensidad. Sin embargo, en cualquier caso, cabe destacar el efecto positivo de la práctica regular de actividad física con el fin de regular el equilibrio energético entre la ingesta y el gasto energético, así como contrabalancear el efecto negativo de un alto nivel de actividades sedentarias que, en ocasiones de forma inexorable hay que realizar. En este sentido cabe señalar la existencia de una asociación positiva entre el tiempo empleado en actividades sedentarias y la cantidad de grasa total y grasa abdominal, y ello independientemente de la actividad realizada[31-32]. Se puede afirmar, por tanto, que aunque la actividad física vigorosa ejerce una fuerte y favorable influencia sobre la cantidad de grasa corporal, disminuir el tiempo dedicado a actividades sedentarias también es importante.

Actividad física y resistencia a la insulina

La resistencia a la insulina es la falta de respuesta del tejido adiposo, muscular e incluso hepático a la acción de la insulina. Esto se acompaña de hipersinsulinemia (en un intento por vencer esa falta de respuesta) e incluso de hiperglucemia. La resistencia a la insulina se asocia a una mayor incidencia de diabetes así como al desarrollo de enfermedad cardiovascular y sus factores de riesgo asociados. La resistencia a la insulina puede resultar de una combinación de factores genéticos y estilo de vida, entre ellos, falta de actividad física, estrés y una inadecuada alimentación, en particular si todo ello se acompaña de sobrepeso u obesidad.

Numerosos estudios epidemiológicos han mostrado una relación inversa entre actividad física y resistencia a la insulina. Así, los niños más activos tienen menores niveles de insulino-resistencia [33-36]. Rizzo y colaboradores[34]examinaron la relación entre la actividad física de baja, moderada y vigorosa intensidad con dicha resistencia en adolescentes que participaban en el estudio EYHS. Los autores concluyeron que la actividad física de moderada y/o vigorosa intensidad reduce los valores de resistencia a la insulina en adolescentes. Además, como dato a diferenciar con el resto de los estudios examinados, mostraron que la relación inversa entre la actividad física y la resistencia a la insulina era más acentuada en aquellos adolescentes con sobrepeso u obesidad. Estos hallazgos sugieren que la actividad física puede resultar especialmente beneficiosa en aquellos adolescentes que tienen mayor riesgo a presentar resistencia a la insulina, es decir aquellos con obesidad.

El tiempo empleado en actividades sedentarias ha sido directamente relacionado con la resistencia a la insulina en adultos de media edad, independientemente de la actividad física practicada de moderada y/o vigorosa intensidad[37]. Estos resultados también fueron encontrados en un estudio de niños Portugueses de entre 9 y 10 años, es decir, los niños más sedentarios presentaban mayores niveles de resistencia a la insulina[33].

Un estudio longitudinal, realizado a lo largo de 6 años, evaluó el cambio en el volumen de actividad física que practicaban adolescentes de 15 años y observó un descenso del volumen de actividad física que realizaban. Este descenso se asociaba a mayores niveles de insulina, o sea, más resistencia [38]. Este hallazgo pone de manifiesto la importancia de promover un estilo de vida activo especialmente en la adolescencia, ya que se ha demostrado que, en esta etapa, se produce un descenso considerable del tiempo empleado en la práctica de actividad física.

Tompkins y colaboradores[39] realizaron una extensa revisión con el propósito de identificar los estudios que específicamente examinaban el efecto de la actividad física (sin la intervención de la dieta) sobre los marcadores de resistencia a la insulina en los jóvenes con sobrepeso y obesidad. En este estudio se concluye que las mejoras en los marcadores de resistencia a la insulina en los jóvenes con sobrepeso y obesidad fueron inducidas por la actividad física, teniendo la dieta un papel más secundario.

Podemos concluir, por tanto, que la actividad física es importante en la prevención de la resistencia a la insulina ya que, debido al aumento de la tasa metabólica, quemamos más calorías con la consecuente disminución del peso corporal. Además, cuanto mayor es la intensidad a la que se practica la actividad física (e.j. moderada y/o vigorosa) menores son los niveles de resistencia a la insulina y por tanto mayor es el beneficio para la salud. Siendo estos resultados observados tanto en jóvenes con peso normal como con sobrepeso.

Actividad física y perfil lipídico

El perfil lipídico de riesgo aterogénico se caracteriza por: presentar altos niveles de triglicéridos y colesterol, con aumento de LDL-colesterol (LDLc, el más nocivo) y descenso de HDL-colesterol (HDLc, beneficioso). La práctica regular de actividad física a intensidad moderada ejerce un claro efecto positivo sobre el perfil lipídico. De manera inmediata se produce un aumento de los niveles de HDLc en un 10-20% y disminuyen los niveles de triglicéridos. El colesterol total y la LDLc, no se ven alterados de forma inmediata después de la práctica de actividad física, pero sí en la acumulación semanal de actividad física (1200 a 2200 kilocalorías/semana). Además, cuanto mayor es la duración del ejercicio, y por tanto mayor el gasto calórico, mayor es el efecto [40] anteriormente explicado.

La relación entre actividad física y el perfil lipídico en niños y adolescentes no es tan evidente como en adultos, disponiéndose también de menos estudios. Hurtig-Wennlöf y colaboradores[41] estudiaron a 590 niños de 9-10 años y 535 adolescentes de 15-16 años que participaron en el estudio EYHS y observaron la asociación negativa entre la actividad física y los niveles de colesterol total en ambos grupos de edad y para ambos sexos[41]. Un segundo estudio en una sub-muestra de 273 niños de 9 años y 256 adolescentes de 15 años concluyó que la actividad física total se relaciona de forma negativa con un índice de factores de riesgo metabólico, calculado en base a los niveles de insulina basal, glucosa, triglicéridos totales, HDLc, presión arterial y grasa corporal. Además, en este estudio se demuestra que el nivel la capacidad aeróbica que posee la persona es el principal determinante de índice de riesgo metabólico más saludable[42]. Luepker y colaboradores[43] observaron mayores niveles de HDLc y menores niveles de triglicéridos en niños americanos de 7-8 años. Sin embargo, otros estudios en niños no observaron asociación entre actividad física y perfil lipídico[44].

Podemos concluir que la práctica de actividad física de forma adecuada y regular podría mejorar la capacidad aeróbica en niños y adolescentes y, en consecuencia, ambas ayudar a mantener los niveles de lipídos y lipoproteínas dentro de los rangos considerados como saludables.

Actividad física y tensión arterial

La hipertensión arterial es una enfermedad asintomática y relativamente fácil de detectar, sin embargo, cursa con complicaciones graves y letales si no se trata a tiempo. La hipertensión es uno de los más importantes factores de riesgo de enfermedad cardiovascular. Esta puede aparecer en la infancia y mantenerse durante la edad adulta. Se considera hipertensión cuando la tensión arterial sistólica y/o diastólica supera el percentil 95 para edad, sexo y altura.

Datos del estudio británico *Avon Longitudinal Study of Parents and Children* realizado en una población de más de 5.000 niños de entre 11 y 12 años[45] mostraron una asociación inversa entre la actividad física y la tensión arterial sistólica, esto es, los niños más activos presentan niveles de tensión arterial sistólica más bajos comparados con sus compañeros menos activos. Igualmente, otro estudio realizado en adolescentes norteamericanos mostró una asociación inversa entre la actividad física y la tensión arterial sistólica, además puntualizó que este efecto era mayor en aquellos que tenían la tensión arterial alterada[46]. Además, estudios de intervención realizados tanto en adultos[47] como en jóvenes[48] hipertensos igualmente sugieren un efecto beneficioso de la actividad física sobre la tensión arterial.

El tiempo empleado en actividades sedentarias, como ver la televisión más de 2 horas al día, ha sido directamente relacionado con un incremento de la tensión arterial en niños obesos de 12 años. Además, la fuerza de la relación aumentó en aquellos niños que dedicaban más de 4 hora al día a ver la televisión, aunque este estudio no controló la participación en actividades físicas[49].

Se puede concluir, pues, que tanto el descenso de la actividad sedentaria como el aumento de la práctica de actividad física ayuda a mantener los niveles de tensión arterial dentro de los rangos de normalidad en niños y adolescentes, además esto puede ocurrir tanto en jóvenes sanos como hipertensos.

Actividad física y síndrome metabólico

El síndrome metabólico se define como la coexistencia de múltiples factores de riesgo cardiovascular y diabetes, la prevalencia de los cuales se ha incrementado dramáticamente en la población adulta en las últimas décadas. El mismo grupo de factores de riesgo metabólicos también ha sido reconocido en niños y adolescentes. Los componentes a incluir dentro de la clasificación de esta patología en edades tempranas no están claramente establecidos aunque la mayoría de estos estudios han usado un índice estandarizado incluyendo las variables que han sido relacionadas con el síndrome metabólico (por ejemplo: triglicéridos, HDLc, grasa total, perímetro de cintura, tensión arterial, insulina, glucosa, HOMA, etc.).

Existen evidencias del positivo impacto de la actividad física (total, ligera, moderada y vigorosa) sobre el síndrome metabólico en niños y adolescentes, independientemente del nivel de condición física, y ello a través de diferentes vías causales siendo la obesidad un factor importante[50]. Esto quiere decir que aquellos jóvenes más activos presentan menos factores de riesgo para el síndrome metabólico, independientemente de otros factores. De los estudios analizados se desprende que desde una perspectiva de salud pública y ante la evidente asociación entre el aumento de los niveles de actividad física y la reducción de factores de riesgo del síndrome metabólico, fomentar la práctica de la actividad física puede ser factible para combatir los múltiples factores relacionados con el síndrome metabólico.

Actividad física y capacidad aeróbica

La capacidad aeróbica es una de las cualidades más importantes de la condición física relacionada con la salud. La capacidad aeróbica es un marcador directo del estado fisiológico de la persona y refleja la capacidad general de los sistemas cardiovascular y respiratorio para proveer oxígeno durante una actividad sostenida en el tiempo. También hace referencia a la capacidad para realizar un ejercicio físico prolongado y hasta la extenuación[51].

La capacidad aeróbica se ha asociado inversamente con distintos parámetros de salud en jóvenes, tales como el perfil lipídico, la resistencia a la insulina, la masa grasa, parámetros relacionados con el síndrome metabólico y la tensión arterial[1]. Recientes investigaciones han puesto de manifiesto que tener un nivel medio-alto de capacidad aeróbica durante la infancia y adolescencia se asocia a un mejor perfil cardiovascular en la edad adulta[15]. Estos hallazgos son de gran importancia, ya que también se ha demostrado que adultos con un elevado nivel de capacidad aeróbica disminuyen el riesgo de desarrollar enfermedad cardiovascular y aumentan la esperanza de vida[52]. La relación entre el nivel de actividad física y la capacidad aeróbica no siempre es evidente en personas jóvenes, sin embargo, recientes estudios epidemiológicos muestran que la actividad física de alta intensidad se asocia con una alta capacidad aeróbica.

Nuestro grupo evaluó el nivel de actividad física en 780 niños de 9-10 años de Estonia y Suecia que participaban en el EYHS, y observamos que la actividad física se asociaba positivamente con los niveles de condición física. Esta asociación era más fuerte cuanto más intensa era la actividad física practicada[22]. En otro estudio realizado por nuestro grupo[53] observamos que las niñas que cumplen las recomendaciones actuales de actividad física (al menos 60 min/día de moderada a vigorosa intensidad) presentaban 3 veces más probabilidad de tener un nivel de capacidad aeróbica alto que aquellas que no cumplían tales recomendaciones. En el caso de los niños, aquellos que cumplían las recomendaciones de actividad física presentaban 8 veces más probabilidad de tener un nivel de capacidad aeróbica alto que los que no las satisfacían. La figura 4 muestra de forma gráfica la relación entre actividad física y capacidad aeróbica. Podemos observar el porcentaje de adolescentes con baja capacidad aeróbica según el nivel de actividad física. Estos resultados coinciden con los encontrados en otros estudios[23, 27, 54], por lo que podemos concluir que la actividad física de intensidad vigorosa se asociaba de una forma más evidente con la capacidad aeróbica que las actividades de menos intensidad de los niños y adolescentes.

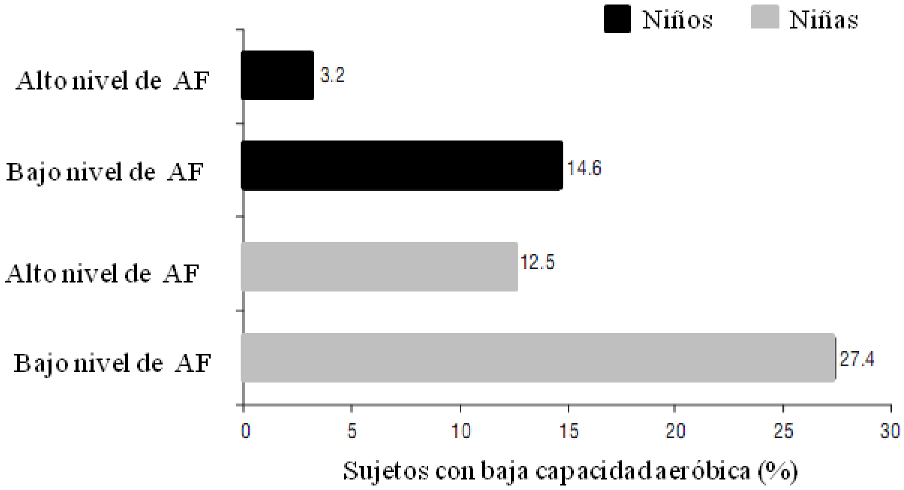

Figura 4. Porcentaje de adolescentes con baja capacidad aeróbica según el nivel de actividad física (AF) en niños y niñas. Traducido de Ortega y colaboradores [53].

Actividad física y fuerza muscular

Otro índice definitorio de la condición física relacionada con la salud es la fuerza muscular. En adultos, mantener una buena forma física en lo que a fuerza muscular se refiere se ha demostrado que es un potente predictor de calidad de vida[55-56] y se ha asociado con el riesgo de muerte por cualquier causa[57-60].

Son todavía insuficientes los estudios transversales que han observado la relación existente entre la fuerza muscular y diferentes marcadores de salud, sobre todo si comparamos su número con aquellos que han estudiado los beneficios de una mayor capacidad aeróbica. No obstante, recientes estudios epidemiológicos muestran una clara asociación entre una mayor condición física, en lo que a fuerza muscular se refiere, y el riesgo metabólico. Además, esta relación es evidente tanto en adultos como en jóvenes. En este sentido, nuestro grupo [61] evaluó la asociación entre la fuerza muscular y el riesgo metabólico en 709 adolescentes europeos participantes en el estudio HELENA. De los resultados se desprende que la fuerza muscular (fuerza de prensión manual medida mediante dinamometría y fuerza explosiva de piernas evaluada por el salto horizontal a pies juntos) se asoció con un menor riesgo metabólico, independientemente del nivel de capacidad aeróbica. Steene-Johannessen y colaboradores [62], estudiaron a 2.818 niños de 9-15 años de Noruega, y determinaron que la fuerza muscular (en sus diferentes representaciones: explosiva, isométrica y fuerza-resistencia) también se asoció con un menor riesgo metabólico. Estos hallazgos coinciden con los encontrados en otros estudios en adultos[63-64].

La relación entre el nivel de actividad física y la fuerza muscular ha sido recientemente demostrada, sin embargo, son escasos los estudios científicos que abordan esta hipótesis y serían necesarios nuevos hallazgos que nos permitieran contrastar los existentes, siempre desde una medida objetiva de la actividad física. Martínez-Gómez y colaboradores [65] estudiaron la asociación entre la actividad física y la aptitud muscular en 211 adolescentes españoles. Los resultados confirman que la actividad física vigorosa está asociada positivamente con el nivel de fuerza muscular, independientemente del estado madurativo, el índice de masa corporal y la capacidad aeróbica. En la misma línea, nuestro grupo[66] estudió la asociación de la actividad física con la fuerza muscular y la masa libre de grasa en 363 adolescentes españoles y, observamos que sólo la actividad física vigorosa se asocia positivamente con la fuerza muscular, especialmente del tren inferior, en los chicos.

Resumiendo, mayores niveles de fuerza muscular se han relacionado con un menor riesgo metabólico en jóvenes tanto durante la propia juventud como durante la edad adulta. Una mayor práctica de actividad física vigorosa parece estar asociada con mayores niveles de fuerza muscular. La fuerza muscular unida a la capacidad aerobia parece disminuir el riesgo cardiometabólico, tal y como se muestra en la figura 5[61]. En base a ello, apoyamos las recomendaciones actuales de actividad física para los jóvenes, pero resaltamos no olvidar incluir actividades de fortalecimiento muscular, además de ejercicio aeróbico.

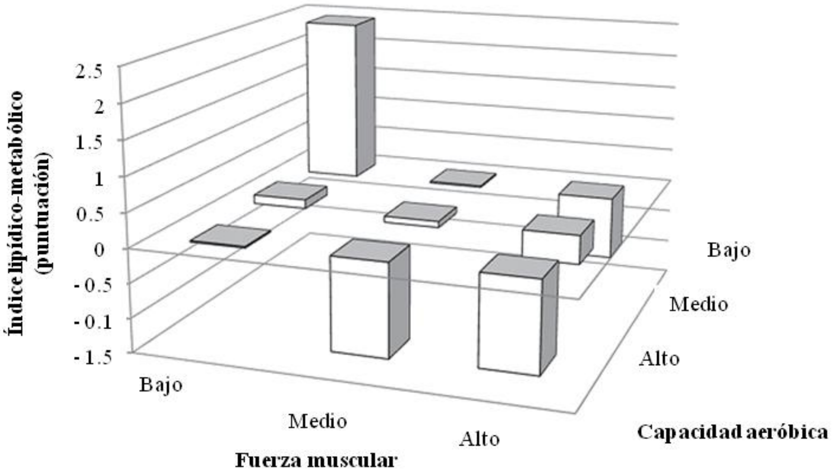

Figura 5: Efecto combinado de capacidad aeróbica y fuerza muscular sobre el perfil lipídico-metabólico en adolescentes. Traducido de Artero y colaboradores [61].

Recomendaciones de actividad física en niños y adolescentes

La cantidad mínima de actividad física necesaria para garantizar una buena salud cardiovascular en niños y adolescentes es de al menos 60 min/día de actividad física de moderada a vigorosa intensidad, según recomendaciones del Departamento de Salud y de Estados Unidos junto con otras Instituciones Mundiales relevantes en materia de salud pública (http://www.health.gov/paguidelines/). Además, indican que tanto reducir el tiempo empleado en actividades sedentarias como aumentar la cantidad de actividad física total y el tiempo empleado en actividades físicas moderadas y vigorosas pueden tener efectos beneficiosos sobre el perfil cardiovascular y metabólico en niños y adolescentes. Las recomendaciones generales insisten en la combinación de actividades de ejercicio aeróbico y fortalecimiento muscular.

Conclusiones

A lo largo de este capítulo hemos constatado cómo la actividad física puede influir en la salud durante la infancia y la adolescencia. Por lo que podemos concluir que: (1) La actividad física contribuye al aumento del gasto energético, mejora el control del peso y la prevención de la obesidad. (2) Niveles elevados de actividad física en la infancia o la adolescencia, especialmente de actividad física de alta intensidad, se asocian con un perfil metabólico y cardiovascular más saludable, lo cual ocurre tanto en ese momento como en el futuro. (3) La capacidad aeróbica, fuerza muscular y composición corporal, son los componentes más importantes de la condición física relacionada con la salud y, todos ellos han demostrado estar positivamente relacionados con la actividad física. (4) La condición física relacionada con la salud puede ser evaluada de forma sencilla y fiable mediante la batería de test ALPHA-Fitness, además, esta evaluaciones pueden ser efectuadas por el docente de educación física en los centros escolares. Un control periódico puede ayudar a detectar a aquellos jóvenes con un bajo nivel de condición física y/o problemas de sobrepeso. (5) Información sobre el nivel de condición física relacionado con la salud y otros hábitos de un estilo de vida saludable puede ser incorporada al informe de salud escolar.

La probabilidad de que los factores de riesgo que están alterados en edades tempranas persistan alterados en edades más tardías es muy alta. Por otro lado, un estilo de vida saludable en la infancia y en la adolescencia también puede persistir a lo largo de la vida. Con todo ello se alerta sobre la necesidad de establecer campañas de prevención y educación orientadas a promover un estilo de vida más activo en los más jóvenes, desde las edades más tempranas, para garantizar su salud cardiovascular presente y futura. Pero el objetivo no debe ser sólo luchar contra los bajos niveles de actividad física sino “insistir” en que dicha actividad física sea de intensidad suficiente como para conseguir mejorar el estado de forma física, esto es: obtener un peso corporal, capacidad aeróbica y fuerza muscular suficiente para alcanzar y/o mantener un estado de salud óptimo.

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OBJETIVOS

[AIMS]

OBJETIVOS

General:

El objetivo general de la presente memoria de Tesis Doctoral ha sido analizar la relación entre factores relacionados con el estilo de vida (dieta y actividad física) y marcadores de salud (composición corporal, condición física y factores de riesgo cardiovascular) en adolescentes.

Específicos:

I. Analizar el efecto combinado de una dieta saludable y un estilo de vida físicamente activo sobre factores de riesgo cardiovascular en adolescentes.
II. Identificar la agrupación de múltiples factores que originan diferentes estilos de vida o patrones de comportamiento entre adolescentes y observar si dichos patrones difieren según género y edad, y se relacionan con la composición corporal y la condición física.
III. Estudiar la asociación entre la ingesta energética, la actividad física y la composición corporal en adolescentes.
IV. Analizar la relación entre la ingesta dietética y la capacidad aeróbica en adolescentes.
V. Examinar la asociación del hecho de tomar el desayuno con la actividad física, el sedentarismo y la condición física, medidos de forma objetiva y subjetiva, en adolescentes.
VI. Analizar si un mayor consumo de chocolate se asocia con un menor índice de masa corporal, así como otros indicadores de grasa corporal total y central en adolescentes.
VII. Estudiar la asociación entre el consumo de huevo y factores de riesgo cardiovascular en adolescentes y si dicha relación está influenciada por la actividad física.
VIII. Investigar la asociación entre la actividad física, la condición física y el control glucémico (HbA1c) en niños y adolescentes con diabetes tipo 1.
IX. Evaluar los hábitos nutricionales, la composición corporal y la condición física en el ámbito escolar, y diseñar y proponer un addendum al Informe de Salud Escolar.

AIMS

Overall:

The overall objective of this Doctoral Thesis was to analyze the relationship between factors related to lifestyle (diet and physical activity) and markers of health (body composition, fitness and cardiovascular risk factors) in adolescents.

Specific:

I. To investigate the combined influence of diet quality and physical activity on cardiovascular disease risk factors in adolescents.
II. To explore the clustering of different lifestyle behaviours and whether this clustering differs by gender and age, and are related or not to body composition and physical fitness.
III. To study the association of energy intake with both physical activity and adiposity in adolescents.
IV. To investigate the association between dietary intake and cardiorespiratory fitness in adolescents.
V. To examine the association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in adolescents.
VI. To test whether higher chocolate consumption is associated with lower body mass index, as well as other markers of total and central body fat in adolescents.
VII. To examine the association between eggs intake and cardiovascular disease risk factors in adolescents and whether this relationship is influenced by physical activity.
VIII. To investigate the association between physical activity, physical fitness and glycaemic control (HbA1c) in young people with Type 1 diabetes.
IX. To assess eating habits, body composition and physical fitness in the school setting and to design and propose an addendum to the Report of School Health.

MATERIAL AND METHODS

[MATERIAL Y MÉTODOS]

MATERIAL AND METHODS [MATERIAL Y MÉTODOS]

The current Doctoral Thesis is based mainly on data from the HELENA study but data from the EYHS, a study in British young people with Type 1 diabetes and the ALPHA study have also been used. The abstracts or extracts of different sections of the methodological papers are provided. In addition, the most relevant methodological information for papers **I** to **IX** has been summarized in **Table 1**.

NUTRITIONAL STATUS AND LIFESTYLES OF ADOLESCENTS FROM A PUBLIC HEALTH PERSPECTIVE. THE HELENA PROJECT-HEALTHY LIFESTYLE IN EUROPE BY NUTRITION IN ADOLESCENCE

S. De Henauw, F. Gottrand, I. De Bourdeaudhuij, M. Gonzalez-Gross, C. Leclercq, A. Kafatos, D. Molnar, A. Marcos, M. Castillo, J. Dallongeville, C. C. Gilbert, P. Bergman, K. Widhalm, Y. Manios, C. Breidenassel, M. Kersting, L. A. Moreno & on behalf of the HELENA Study Group. *J Public Health* (2007) 15:187–197

Abstract

The HELENA Project—Healthy Lifestyle in Europe by Nutrition in Adolescence—is a European, collaborative research project financed by the EU Sixth Framework Programme in the area of nutrition-related adolescent health. The basic objective of the HELENA project is to obtain reliable and comparable data from a random sample of European adolescents (boys and girls aged 13–16 years) on a broad battery of relevant nutrition and health-related parameters: dietary intake, food choices and preferences, anthropometry, serum indicators of lipid metabolism and glucose metabolism, vitamin and mineral status, immunological markers, physical activity, fitness and genetic markers. The HELENA project is conceived as a scientific construction with four complementary sub-studies that are elaborated through 14 well-defined work packages. Sub-studies are focused, respectively, on “a cross-sectional description of lifestyles and indicators of nutritional status (HELENA-CSS)”, “a lifestyle education intervention programme (HELENA-LSEI), “a metabolic study with cross-over design (HELENA-COMS)” and a “study on behaviour, food preferences and food development” (HELENA-BEFO). The project unites 20 research centres from 10 European countries. In addition, the consortium comprises five SMEs (small and medium-sized enterprises) that are actively involved in the research activities. The core of the HELENA project study material is an overall European cohort of 3,000 adolescents, equally recruited in ten cities from nine countries. Standardization of methods among partners is a key issue in the project and is obtained through the development of standard protocols, training sessions, validation sub-studies and pilot projects. Health-related problems have a tendency to evolve in cycles, with ever new problems emerging in ever new contexts that call for appropriate and tailored actions. The HELENA project is expected to offer essential elements for use in the overall machinery of required public health nutrition cycles. It is of the greatest importance for its results to prove useful that it can communicate with other initiatives on the level of science and society.

FIELD-BASED FITNESS ASSESSMENT IN YOUNG PEOPLE: THE ALPHA HEALTH-RELATED FITNESS TEST BATTERY FOR CHILDREN AND ADOLESCENTS.

Ruiz JR, Castro-Piñero J, España-Romero V, Artero EG, Ortega FB, Cuenca-García M, Jiménez-Pavón D, Chillón P, Girela-Rejón MJ, Mora J, Gutiérrez A, Suni J, Sjöström M, Castillo MJ. *Br J Sports Med.* 2010 Oct 19.

Extract from the Introduction Section

The ALPHA (Assessing Levels of Physical Activity) study was initiated with the aim of providing a set of instruments for ALPHA and its underlying factors (eg, built environment, transport and worksites) as well as health-related physical fitness in a comparable way within the European Union. The aim of the Work Package 6 (Assessing Health-Related Physical Fitness) was to provide a set of valid, reliable, feasible a safe field-based fitness tests for the assessment of health-related physical fitness in children and adolescents to be used in public health monitoring in a comparable way within the European Union.

Abstract

The present study summarises the work developed by the ALPHA study and describes the procedures followed to select the tests included in the ALPHA health-related fitness test battery for children and adolescents. The authors reviewed physical fitness and health in youth findings from cross-sectional studies. The authors also performed three systematic reviews dealing with (1) the predictive validity of health-related fitness, (2) the criterion validity of field-based fitness tests and (3) the reliability of field-based fitness tests in youth. The authors also carried out 11-methodological studies to determine the criterion validity and the reliability of several field-based fitness tests for youth. Finally, the authors performed a study in the school setting to examine the reliability, feasibility and safety of the selected tests. The selected fitness tests were (1) the 20 m shuttle run test to assess cardiorespiratory fitness; (2) the handgrip strength and (3) standing broad jump to assess musculoskeletal fitness, and (4) body mass index, (5) skinfold thickness and (5) waist circumference to assess body composition. When there are time limits, the authors propose the high-priority ALPHA health-related fitness test battery, which comprises all the evidence-based fitness tests except the measurement of the skinfold thickness. The time required to administer this battery to a group of 20 youth by one physical education teacher is less than 2 h. In conclusion, the ALPHA fitness tests battery is valid, reliable, feasible and safe for the assessment of health-related physical fitness in children and adolescents to be used for health monitoring purposes at population level.

SAMPLING PROCEDURE, PARTICIPATION RATES AND REPRESENTATIVENESS IN THE SWEDISH PART OF THE EUROPEAN YOUTH HEART STUDY (EYHS).

Wennlöf AH, Yngve A, Sjöström M. *Public Health Nutr.* 2003 May;6(3):291-9.

Abstract

Objective: The European Youth Heart Study (EYHS) is a cross-sectional, school-based population study on risk factors for future cardiovascular disease in children, with an overall participation rate in Sweden of about 50%. To study the representativeness of the participants in the Swedish part of EYHS, a comprehensive non-participant follow-up study was carried out. Design: A structured multilevel analysis model was developed, addressing each level in the sampling procedure. The income, educational and occupational categories of the geographical regions of the study (level I), school catchment areas (level II) and parents (level III) were compared with official data. Participating and non-participating pupils (level IV) were compared through a questionnaire. Setting: Thirty-seven state schools in two regions of Central Sweden (Orebro and southern Stockholm) were visited during the school year 1998/1999. Subjects: Boys and girls aged 9 and 15 years were randomly sampled through a multiphase sampling procedure. Results: Data for socio-economic status for levels I and II corresponded well to national and regional official data. At level III, non-manually working parents were slightly over-represented among parents of participating children. At level IV, non-participating subjects corresponded in most respects to participants with a few exceptions-mainly more interest in physical exercise among participants. Conclusions: Based on the knowledge from the non-participant study, we do not foresee problems regarding interpretation of the outcomes in the EYHS, despite the low participation rate.

HOW DOES PHYSICAL ACTIVITY AND FITNESS INFLUENCE GLYCAEMIC CONTROL IN YOUNG PEOPLE WITH TYPE 1 DIABETES?

Cuenca-García M, Jago R, Shield JP, Burren CP. *Diabet Med.* 2012 Oct; 29(10):e369-76.

Extract from the Material and Methods Section

This is a case–control cross-sectional study. Participants with Type 1 diabetes were recruited from the three clinics in the Bristol and Weston Paediatric Diabetes Service at Bristol Royal Hospital for Children, Southmead Hospital, and Weston General Hospital. Patients and families were approached if the index child was aged 8–16 years and did not manifest any of the exclusion criteria such as current hypoglycaemia unawareness, co-morbidities such a severe asthma or physical disability. Control group participants were siblings of the participants with diabetes, who were aged 8–16 years without diabetes. Of a total of 422 patients in the diabetes service, 240 patients were aged 8–16 years with Type 1 diabetes, 25 of whom had one or more exclusion criteria, leaving 215 eligible patients [mean HbA1c of eligible group 65 mmol ⁄ mol (8.1%)]. The 60 patients who were then recruited (i.e. 28% of 215) were in the numbers who then agreed to participate. Recruited patients with Type 1 diabetes were asked if they had a sibling, aged 8–16 years without diabetes, who could be invited to participate in the study. In total, 97 participants were recruited, of which 60 participants (40 male, 20 female) had Type 1 diabetes and 37 participants (20 male, 17 female) were siblings without diabetes (control subjects). The following magnitudes were studied: physical examination and anthropometry, diabetic assessments (age at diagnosis and duration of diabetes, insulin dose requirements and insulin regimen -type and number of injections), blood glucose level and objectively measured physical activity and fitness. The study was approved by Southmead Ethics Committee (REC ref. 07⁄H0102 ⁄ 73) and informed parental consent was obtained for all participants (those with diabetes and control subjects).

Table 1. Summary table of the methodology used in the current Doctoral Thesis

Project	**Paper**	**Study design**	**Participants**	**Main variables studied**	**Methods**
HELENA	**I**. Combined influence of healthy diet and active lifestyle on cardiovascular disease risk factors in adolescents	Cross-sectional	N:1513 adolescents Age: 12.5-17.5 y	Dietary intake, physical activity, cardiorespiratory fitness, adiposity markers, blood lipid profile, blood pressure and insulin resistance	24h dietary recall, accelerometry, VO_{2max} by the Léger's equation, anthropometry, blood sampling, and oscillometry
HELENA	**II**. Clustering of multiple lifestyle behaviours and health-related fitness in European adolescents	Cross-sectional	N:2084 adolescents Age: 12.5-17.5 y	Diet quality index, physical activity, sedentary time, cardiorespiratory fitness, muscular fitness, motor fitness and body composition	24h dietary recall, IPAQ-A and HELENA sedentary behaviour questionnaires, 20m SRT, handgrip strength, standing broad jump, 4x10m SRT and anthropometry
HELENA, EYHS	**III**. More physically active and leaner adolescents have higher energy intake: consistent results using different methods and different studies (HELENA and EYHS)	Cross-sectional	N:1450 adolescents Age: 12.5-17.5 y from HELENA N:321 adolescents Age: 14.5-16.5 y from EYHS	Physical activity, fatness and energy intake	24h dietary recall, accelerometry, anthropometry, BIA, DXA and BodPod

Table 1 (cont). Summary table of the methodology used in the current Doctoral Thesis.

Project	**Paper**	**Study design**	**Participants**	**Main variables studied**	**Methods**
HELENA	**IV**. Cardiorespiratory fitness and dietary intake in European adolescents: The HELENA study	Cross-sectional	N: 1492 adolescents Age: 12.5-17.5 y	Dietary intake (energy, nutrients and food groups) and cardiorespiratory fitness	24h dietary recall and VO_{2max} by the Léger's equation
HELENA	**V**. Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: The HELENA study	Cross-sectional	N: 2148 adolescents Age: 12.5-17.5 y	Breakfast consumption and self-reported and objectively measured: physical activity, sedentary time. Cardiorespiratory fitness, muscular fitness and motor fitness	Self-reported: 24h dietary recalls and 'Food Choice and Preferences' questionnaire, IPAQ, 'HELENA sedentary behaviours' questionnaire and IFIS Objectively measured: accelerometry, 20m SRT, handgrip strength, standing broad jump and 4x10m SRT
HELENA	**VI**. Association between chocolate consumption and fatness in European adolescents	Cross-sectional	N: 1458 adolescents Age: 12.5-18.5 y	Chocolate intake and adiposity markers (weight status, fat mass and waist circumference)	24h dietary recall, anthropometry and BIA

Table 1 (cont). Summary table of the methodology used in the current Doctoral Thesis.

Project	Paper	Study design	Participants	Main variables studied	Methods
HELENA	**VII**. Egg intake and cardiovascular risk factors in adolescents; role of physical activity. The HELENA study	Cross-sectional	N: 380 adolescents Age: 12.5-17.5 y	Dietary intake, physical activity, cardiorespiratory fitness, adiposity markers, blood lipid profile, blood pressure and insulin resistance	24h dietary recall, accelerometry, VO_{2max} by the Léger's equation, anthropometry, blood sampling and oscillometry
BRITISH STUDY	**VIII**. How does physical activity and fitness influence glycaemic control in young people with Type 1 diabetes?	Cross-sectional	N: 60 children and adolescents Age: 8-16 y	Body composition (BMI and fat mass) physical activity, physical fitness (PWC_{170}) and glycaemic control	Anthropometry, accelerometry and sub-maximal bicycle ergometer test. HbA1c by venipuncture
ALPHA	**IX**. Health-related fitness and eating habits in children and adolescents: proposal for an addendum to the Report of School Health	Cross-sectional	N: 138 children and adolescents Age: 6-18 y	Food habits, cardiorespiratory fitness, muscular fitness and body composition (BMI, waist circumference and fat mass)	Food Frequency Questionnaire, 20m SRT, handgrip strength, standing broad jump and anthropometry

ALPHA: Assessing Levels of Physical Activity and Fitness; BIA: Bioelectrical impedance analysis; BMI: Body mass index; BodPod: Air-displacement plethysmography; DXA: Dual-energy x-ray Absorptiometry; HbA1: Haemoglobin A1c; HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; IFIS: International Fitness Scale; IPAQ-A: International Physical Activity Questionnaire from Adolescents; SRT: Shuttle run test; PWC_{170}: Physical work capacity at a heart rate of 170 beat/min; VO_{2max}: maximal oxygen uptake; y: years.

RESULTS AND DISCUSSION

[RESULTADOS Y DISCUSIÓN]

RESULTS AND DISCUSSION [RESULTADOS Y DISCUSIÓN]

The results and discussion of the present Doctoral Thesis are shown as a compilation of scientific papers. They are enclosed in the form they have been published or submitted. In addition, the most relevant findings for papers I to IX has been summarized in Spanish below.

Los resultados obtenidos en la presente Tesis Doctoral se presentan a continuación en la forma en que han sido publicados o se encuentran pendientes de publicación en formato de artículos científicos. Estos artículos se presentan a continuación. Como es de rigor, cada artículo cuenta con su introducción correspondiente, descripción de la metodología utilizada, exposición de los resultados, discusión de los mismos y bibliografía. A continuación se presenta, en español, un extracto de dichos resultados.

En el artículo I, publicado electrónicamente en *Scandinavian Journal of Medicine & Science in Sports* en diciembre de 2012, se examinó el efecto combinado de una dieta saludable y un estilo de vida físicamente activo sobre factores de riesgo cardiovascular en los adolescentes que participaron en el estudio HELENA. Para este propósito se crearon 4 grupos de estudio atendiendo a diferentes combinaciones: (1) dieta saludable y ser físicamente activo, (2) dieta saludable y ser físicamente inactivo, (3) dieta poco saludable y ser físicamente activo y (4) dieta poco saludable y ser físicamente inactivo. Los resultados publicados en este artículo muestran que aquellos adolescentes que siguieron una dieta saludable y un estilo de vida físicamente activo presentaron un perfil de riesgo cardiovascular más favorable particularmente en su capacidad aeróbica, índice de masa grasa, concentración sanguínea de triglicéridos y HDL-colesterol y ratio colesterol total/HDL-colesterol. Además, se observó que los adolescentes físicamente activos mostraron mayor capacidad aeróbica, menor adiposidad total y central, perfil lipídico y tensión arterial más favorables, y menor resistencia a la insulina que sus compañeros físicamente inactivos, independientemente de la calidad de su dieta. En general, aquellos adolescentes con una dieta saludable y físicamente activos mostraron un menor riesgo de enfermedad cardiovascular. Tradicionalmente se ha estudiado por separado la asociación de la dieta y la actividad física en la salud cardiovascular, pero no el efecto combinado de ambas. El presente estudio supone, por tanto, una novedosa contribución científica en el ámbito de la Salud Publica.

En el artículo II, aceptado en *Journal of Nutrition Education and Behavior* en febrero de 2013, se analizó la agrupación de múltiples factores que se asocian a diferentes estilos de vida o patrones de comportamiento entre los adolescentes que participaron en el estudio HELENA. También se estudió si dichos patrones difieren según género, edad y diferentes componentes de salud como la composición corporal, capacidad aeróbica, fuerza muscular y habilidad motora. Se observaron 5 patrones de comportamiento diferentes en base a minimizar las diferencias intra grupo y maximizarlas entre grupos en base a cuatro factores: (1) la calidad de la dieta, (2) el tiempo dedicado a actividades sedentarias diferenciando entre aquellas que implican el uso de televisión, video juegos y/u ordenado por motivos lúdicos y (3) aquellas otras que se refieren a actividades académicas extraescolares; y por último (4) el tiempo dedicado a practicar actividad física. Además, los resultados de este artículo muestran que los más jóvenes (12.5-14.9 años) son más activos y siguen una dieta más saludable que los más mayores (15-17.5 años). Entre los más mayores, los niños emplearon más tiempo en actividades sedentarias lúdicas, mientras que las niñas lo emplearon en actividades académicas extraescolares. Los diferentes patrones de comportamiento observados se asociaron con el nivel de condición física pero no con la composición corporal. En este estudio se constata que un patrón de comportamiento saludable no siempre se caracteriza con un perfil 100% saludable siendo posible su conexión con hábitos no saludables.

En el artículo III, actualmente sometido en *Journal of Pediatrics*, se analizó la asociación entre actividad física, adiposidad y consumo energético en los adolescentes que participaron en dos estudios independientes: el estudio HELENA y la parte sueca del estudio EYHS. La finalidad de este estudio fue testar la hipótesis deducida de una teoría alternativa que postula que los jóvenes que practican actividad física de intensidad vigorosa desarrollan cuerpos delgados, mientras que su ingesta energética es relativamente elevada. Los resultados mostraron que los jóvenes más delgados tienen una mayor ingesta energética que los menos delgados. Además, los jóvenes que practicaron más actividad física de intensidad relativamente alta tuvieron un mayor consumo de energía. Estos resultados se mantuvieron consistentes después de excluir del análisis a los adolescentes obesos por su posible infravaloración del registro dietético real. Además, estudios previos derivados del estudio HELENA y del EYHS observaron que la actividad física intensa se asoció inversamente con la adiposidad. Estos resultados no son consistentes con la teoría de que la obesidad es consecuencia de un desequilibrio energético inducido por una mayor ingesta energética; en cambio sustentan la teoría de que la actividad física de intensidad vigorosa promueve el desarrollo de cuerpos delgados, mientras que cumplen con las necesidades energéticas y nutritivas propias de la etapa de crecimiento. Estos hallazgos podrían contribuir a frenar el sobrepeso y la obesidad entre los adolescentes; apoyando la promoción de la actividad física junto con una dieta equilibrada en lugar de una restricción energética que podría provocar trastornos de alimentación.

En el artículo IV, publicado en *British Journal of Nutrition* en agosto de 2011, se examinó la asociación entre la capacidad aeróbica y la ingesta dietética en los adolescentes que participaron en el estudio HELENA. Los resultados mostraron que aquellos adolescentes con mayor capacidad aeróbica tuvieron un mayor consumo de productos lácteos. Una mayor capacidad aeróbica también se relacionó con un mayor consumo de pan/cereales en los niños, y una menor ingesta de bebidas azucaradas en las niñas. Estudios previos independientes mostraron que tanto una alta capacidad aeróbica como una dieta saludable se asocian con un perfil cardiovascular favorable e incluso con un menor riesgo de mortalidad por diversas causas. Otros autores que estudiaron a un grupo de adultos observaron que la relación entre dieta y salud estuvo influenciada por el nivel de condición física. Existen pocos estudios que analicen la posible asociación entre condición física y dieta, siendo este estudio el primero desarrollado en adolescentes. Estos hallazgos suponen una importante contribución científica y ayudan a entender la relación entre factores dietéticos e indicadores fisiológicos de salud como es la capacidad aeróbica.

El artículo V, actualmente sometido en *Public Health Nutrition*, analizó la asociación del hecho de tomar el desayuno con la actividad física, el sedentarismo y la condición física de los adolescentes que participaron en el estudio HELENA. Los resultados de este artículo muestran que tomar el desayuno no está asociado con la actividad física. Estos resultados fueron consistentes a través de los diferentes métodos utilizados para evaluar el consumo de desayuno (dos recordatorios de 24 horas y un cuestionario sobre '*Food Choice and Preferences*') y la actividad física (medida mediante acelerometría y cuestionarios). Sin embargo, se observó una asociación entre tomar el desayuno y tiempo dedicado a actividades sedentarias en niños y niñas, aunque los resultados no fueron consistentes a través de los diferentes métodos empleados. Referente a la condición física, aquellos varones que tomaron el desayuno habitualmente mostraron una mayor capacidad aeróbica, mientras que no se observaron diferencias en los otros componentes de la condición física estudiados, fuerza muscular y habilidad motora. Un análisis adicional donde se dividió a los participantes en tener una capacidad aeróbica baja o alta siguiendo los criterios establecidos por el Grupo *FITNESSGRAM* del *Cooper Institute*, mostraron que aquellos niños y niñas que no tomaron el desayuno tuvieron menor probabilidad de tener una capacidad aeróbica alta (independientemente de los métodos utilizados para evaluar el desayuno o la capacidad aeróbica). Estos resultados amplían los hallazgos previos observados en el estudio HELENA. Tomar el desayuno habitualmente regula el apetito que a largo plazo contribuirá al control del peso corporal. El hecho de tomar el desayuno parece estar relacionado, además, con diversos hábitos de vida saludables, entre ellos seguir una correcta alimentación y/o un estilo de vida físicamente activo. Sin embargo, los resultados desprendidos de este artículo no confirman la asociación entre tomar el desayuno y ser físicamente más activo, a pesar de la diferente metodología empleada.

En el artículo VI, pendiente de aceptación tras someter la versión revisada en *Obesity*, se analizó si un mayor consumo de chocolate se asocia con un menor índice de masa corporal, así como otros indicadores de grasa corporal total y central en los adolescentes que participaron en el estudio HELENA. Los resultados de este artículo mostraron que un mayor consumo de chocolate se asoció con niveles más bajos de grasa total y central, según lo estimado por el índice de masa corporal, el porcentaje de grasa corporal (a partir de plicometría e impedancia bioeléctrica) y el perímetro de cintura. Estos resultados fueron independientes del sexo, la edad, la madurez sexual, la ingesta energética total, la ingesta de grasas saturadas, fruta y verdura, el consumo de té y café, y la actividad física. Tal y como queda reflejado en la discusión del presente artículo, un estudio en adultos observó que una mayor frecuencia en el consumo de chocolate también se asoció con un menos índice de masa corporal. Estos hallazgos son relevantes desde el punto de vista clínico ya que contribuye a entender los factores que subyacen en el control y mantenimiento del peso optimo.

En el artículo VII, publicado en *Nutrición Hospitalaria* en diciembre de 2012, se estudió la relación entre la ingesta de huevo y factores de riesgo cardiovascular, así como el papel de la actividad física en esta posible asociación, en una submuestra de 380 adolescentes que participaron el en estudio HELENA. Los principales hallazgos sugieren que no existe asociación entre la ingesta de huevo y los factores de riesgo cardiovascular estudiados, tampoco con el índice de riesgo cardiovascular calculado. Además, esta falta de asociación no estuvo influenciada por el nivel de actividad física. Estos hallazgos suponen un cambio de paradigma ya que tradicionalmente la ingesta de huevo ha tendido a asociarse indirectamente con un mayor riesgo de enfermedad cardiovascular por su alto contenido en colesterol. Tal y como se menciona en la discusión de este artículo, no existen evidencias científicas que confirmen nuestros resultados en jóvenes, sin embargo recientes estudios en adultos sanos han confirmado que no hay asociación entre una ingesta inferior a siete huevos por semana e incidencia de enfermedad cardiovascular.

El artículo VIII, publicado en *Diabetic Medicine* en octubre de 2012, analizó la asociación entre la actividad física, la condición física y el control glucémico (evaluado mediante la hemoglobina glucosilada (HbA1c)) en jóvenes con diabetes tipo 1 que participaron en un estudio británico en el que ha participado la doctoranda durante una estancia de formación en la Universidad de Bristol. Los principales resultados mostraron que aquellos niños y adolescentes que practicaron más actividad física de intensidad moderada a vigorosa presentaron un mejor control glucémico (es decir, valores inferiores de HbA1c), independientemente de su sexo, edad, estado de maduración, composición corporal, dosis de insulina y régimen de insulina. No se ha comprobado que una mejor condición física (evaluada mediante una prueba submáxima en cicloergómetro) estuviera también relacionada con un mejor control glucémico. Como se puede observar en la discusión del este artículo, estos resultados coinciden con algunos otros publicados pero contradicen otros. En este artículo se sugiere que la intensidad con la que se practica la actividad física podría ayudar a mejorar el control glucémico a medio-largo plazo en niños y adolescentes con diabetes tipo 1.

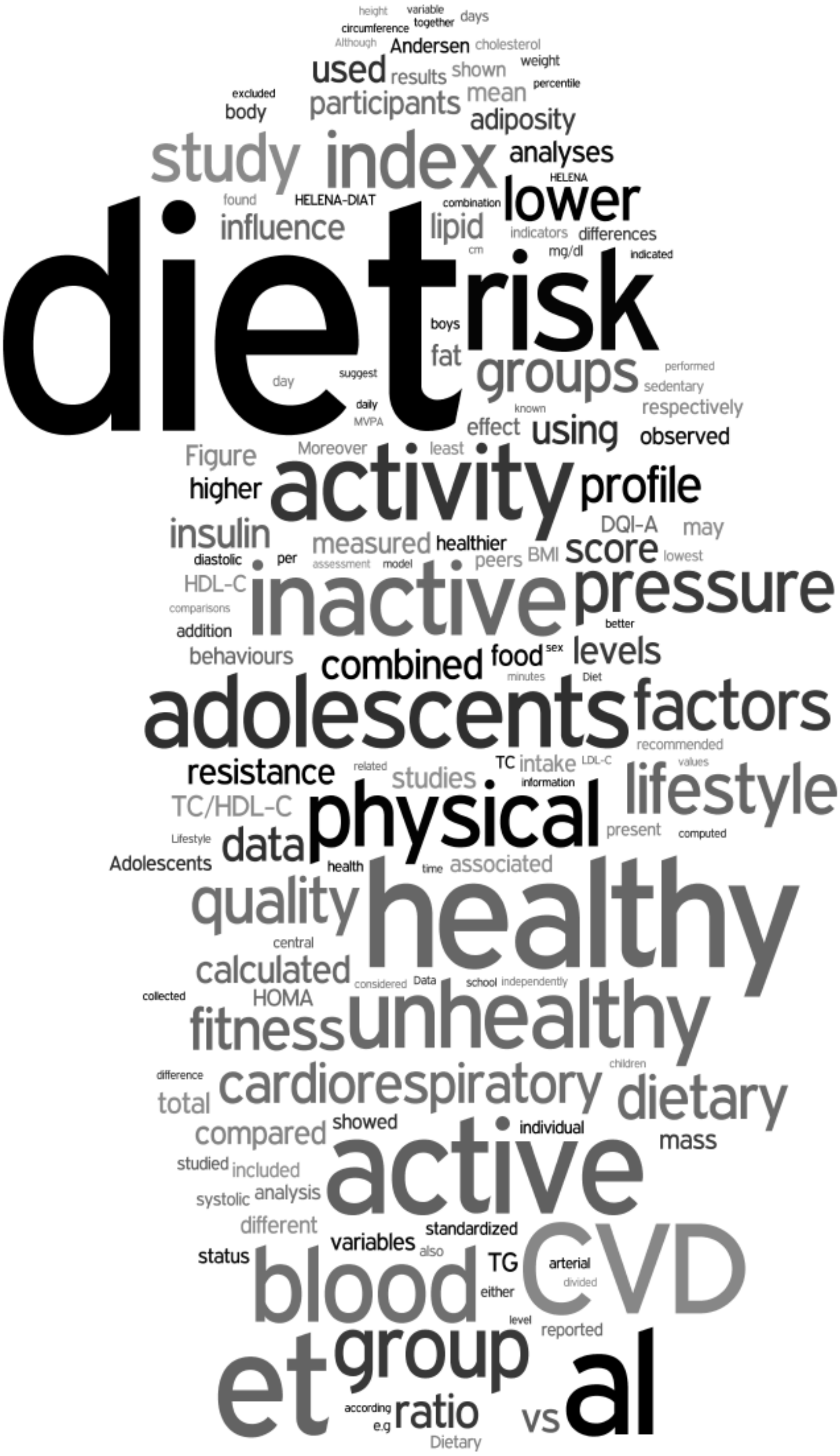
En el artículo IX, publicado en la *Revista de Investigación en Educación* en 2011, se aplicó la batería de test ALPHA-fitness (desarrollada y estandarizada en el proyecto europeo ALPHA-Assessing Levels of Physical Activity and Fitness) para evaluar la composición corporal y la condición física, complementándola con un estudio de hábitos de alimentación, en el ámbito escolar. En base a ello, se diseñó una propuesta de addendum al Informe de Salud Escolar. Los resultados de este estudio muestran que la medida de la composición corporal, la condición física y los hábitos alimentarios, es factible de ser evaluada en el ámbito escolar e incorporada en el Informe de Salud Escolar. Un seguimiento individualizado en niños y adolescentes a lo largo del periodo de escolarización puede ayudar a detectar a aquellos alumnos con un bajo nivel de condición física y/o problemas de sobrepeso. Este informe de salud individualizado es informativo para la escuela, la familia y el personal sanitario, todos ellos implicados en un crecimiento sano y un desarrollo adecuado del niño y del adolescente, y debería ser de utilidad para mejorar comportamientos poco saludables entre los más jóvenes. Este trabajo supone una implicación práctica en base a la evidencia científica mostrada a lo largo de la presente memoria de Tesis Doctoral, que informa acerca de la influencia de unos hábitos de vida saludables para prevenir la enfermedad y mantener un estado de salud cardiovascular óptimo a corto y largo plazo.

1. Diet and physical activity on cardiovascular disease risk factors

[Dieta, actividad física y factores de riesgo cardiovascular]

Study I *[Artículo I]*

Study I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Scand J Med Sci Sports 2012: ••: ••–••
doi: 10.1111/sms.12022

Published by Blackwell Publishing Ltd

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Combined influence of healthy diet and active lifestyle on cardiovascular disease risk factors in adolescents

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Accepted for publication 22 October 2012

To investigate the combined influence of diet quality and physical activity on cardiovascular disease (CVD) risk factors in adolescents, adolescents ($n = 1513$; 12.5–17.5 years) participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence study were studied. Dietary intake was registered using a 24-h recall and a diet quality index was calculated. Physical activity was assessed by accelerometry. Lifestyle groups were computed as: healthy diet and active, unhealthy diet but active, healthy diet but inactive, and unhealthy diet and inactive. CVD risk factor measurements included cardiorespiratory fitness, adiposity indicators, blood lipid profile, blood pressure, and insulin resistance. A CVD risk score was computed. The healthy diet and active group had a healthier cardiorespiratory profile, fat mass index (FMI), triglycerides, and high-density lipoprotein cholesterol (HDL-C) levels and total cholesterol (TC)/HDL-C ratio (all $P \leq 0.05$). Overall, active adolescents showed higher cardiorespiratory fitness, lower FMI, TC/HDL-C ratio, and homeostasis model assessment index and healthier blood pressure than their inactive peers with either healthy or unhealthy diet (all $P \leq 0.05$). Healthy diet and active group had healthier CVD risk score compared with the inactive groups (all $P \leq 0.02$). Thus, a combination of healthy diet and active lifestyle is associated with decreased CVD risk in adolescents. Moreover, an active lifestyle may reduce the adverse consequences of an unhealthy diet.

Cardiovascular diseases (CVDs) are the leading cause of global mortality (Smith et al., 2006). CVD events occur most frequently during or after the fifth decade of life; however, there is evidence that the precursors of CVD originate in childhood (Kavey et al., 2003). Adverse CVD risk factors during childhood have been shown to track into adulthood (Raitakari et al., 2005). The most recognized CVD risk factors are high levels of total cholesterol (TC), triglycerides (TGs), insulin resistance, blood pressure, as well as total and central body fat together with low levels of high-density lipoprotein cholesterol (HDL-C) and cardiorespiratory fitness (Andersen et al., 2006).

A poor diet together with sedentary lifestyle may result in body fat accumulation, hyperlipidemia, hypertension, and insulin resistance (WHO, 2003; Andersen et al., 2006). In addition, diet quality indexes have been associated with reduced risk of CVD (Arvaniti & Panagiotakos, 2008). On the other hand, moderate to vigorous physical activity (MVPA) has been related to high

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*The names of people involved in the HELENA Study Group can be found online as Appendix 1.

cardiorespiratory fitness, low fatness, a healthier lipid profile and blood pressure, and a lower insulin resistance (Andersen et al., 2006).

Although independent associations of diet and physical activity with CVD risk factors have been reported (WHO, 2003; Andersen et al., 2006), limited information is available about the combined influence of diet quality and physical activity on CVD risk factors, particularly when using objective methods to assess physical activity. Several studies report that healthy diet and active lifestyles do not always come together (Jago et al., 2010; Ottevaere et al., 2011), thereby active adolescents may have a healthy diet, but also the opposite. It is of public health interest to explore differences in CVD risk factors among adolescents who are active and have a healthy diet vs those who are inactive and have an unhealthy diet. It is also important to examine whether low levels of activity combined with a healthy diet have a larger effect on CVD risk factors than high levels of activity with unhealthy diet. These analyses would provide a better understanding of the interaction between lifestyle behaviors and individual health status.

The purpose of this study was to examine the combined influence of diet quality and physical activity on CVD risk factors (i.e., cardiorespiratory fitness, adiposity indicators, blood lipid profile, blood pressure, and insulin resistance) in European adolescents participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study.

Subjects and methods

Study design

Data were derived from the HELENA-Cross-Sectional Study (HELENA-CSS). HELENA-CSS is a multicenter study conducted in 10 European cities: Stockholm in Sweden, Dortmund in Germany, Ghent in Belgium, Lille in France, Pecs in Hungary, Vienna in Austria, Rome in Italy, Athens (inland city) and Heraklion (Mediterranean island city) in Greece, and Zaragoza in Spain. A total of 3528 adolescents (age range 12.5–17.5 years) were assessed at schools between 2006 and 2007 (Moreno et al., 2008), of whom 1089 participants were randomly selected to give a blood sample (Gonzalez-Gross et al., 2008). All procedures involving human participants were approved by the Ethics Committee (Beghin et al., 2008) of each city involved. Written informed consent was obtained from both adolescents and their parents.

Participants

The participants with valid accelerometry data and who completed at least on 2 days 24-h dietary recalls were included in the study. Only eight centers were included in the present study because incomplete information was obtained for the 24-h dietary recall analyses in both Heraklion and Pecs. Based on these criteria, a total of 1513 adolescents (45% boys) were finally included in the study, of whom 481 (45% boys) had blood analysis. Age, sex, body weight, height, and body mass index (BMI) were lower in the excluded participants than in the included participants (all $P < 0.002$).

Measurements

Dietary intake

The HELENA-DIAT (Dietary Assessment Tool) 24-h dietary recall software was used to obtain dietary intake data (Vereecken et al., 2008). Dietary intake was divided into six meal occasions. Adolescents completed the program autonomously in the computer classroom during schooltime and dietary intake was referred to the day before the interview. Fieldworkers were present to give assistance if necessary. Every participant was asked to fill in the HELENA-DIAT on two nonconsecutive days, a time span of 2 weeks. The days of data collection in each school were chosen arbitrarily. Because the questionnaire was filled in during schooltime, no data could be collected about the dietary intake on Fridays and Saturdays. The HELENA-DIAT tool has been indicated as a good method to collect detailed dietary information from adolescents and was received well by the study participants (Vereecken et al., 2005). A validation study indicated that the Young Adolescents' Nutrition Assessment on Computer (YANA-C), a former version of the HELENA-DIAT, showed good agreement with an interviewer-administered YANA-C interview (Vereecken et al., 2005).

The Diet Quality Index for Adolescents (DQI-A) was developed using the data derived from the HELENA-DIAT and calculated based on the diet quality index in preschool by Huybrechts et al. (2010). The daily diet was divided into nine recommended food groups (VIG, 2006): (a) water; (b) bread and cereals; (c) grains and potatoes; (d) vegetables; (e) fruit; (f) milk products; (g) cheese; (h) meat, fish, eggs, and substitutes; and (i) fats and oils. For each of these food groups a range of recommended daily intakes was provided (VIG, 2006). The DQI-A consists of three pillars based on the principles of a healthy diet: dietary equilibrium, dietary diversity, and dietary quality (VIG, 2006). Dietary equilibrium indicated to what extent the consumed portion sizes of the different food groups corresponded to the daily quantities recommended in the food-based dietary guidelines taking into account both under- and overconsumption. Dietary diversity expresses the degree of variation in the diet (when at least one serving of food per day from each of the nine recommended food groups was consumed). Finally, dietary quality components represent the optimal food quality choice within a food group and was represented by a "preference group" (e.g., fresh fruit and cereal/brown bread, fish products, and low-fat meat), a "moderation group" (e.g., white bread, vegetables conserved with added salt, sugared milk products, eggs), and a "low-nutrient, energy-dense group" (e.g., soft drink, sweet snacks, fried meat). These three components of the DQI-A were presented in percentages. The dietary quality component ranged from −100% to 100% while dietary diversity and dietary equilibrium ranged from 0% to 100%. To compute the overall DQI-A, the score is calculated as the mean of the three above-mentioned pillars and ranges from −33% to 100%, with a higher score correlating with a higher diet quality. The score was calculated for each day and a mean of the daily scores was taken as a global index score of the individual. The validity of DQI-A has been confirmed, DQI-A was related to food and nutrient intakes and some concentration biomarkers in blood by Vyncke et al. (2012). Because there is no well-established cut-point for the diet quality index used, we arbitrarily dichotomized the variable using the 25th percentile, so that 25% of the population would be in the risk group of poor diet quality. The same percentile has been used in different health-related variables (e.g., waist circumference, BMI, TG, TC/HDL-C ratio, plasma leptin, insulin levels, systolic blood pressure, cardiorespiratory fitness, etc.) in a number of population-based studies to define subjects at lower vs higher risk (Chu et al., 2000; Wyszynski et al., 2005; Ruiz et al., 2007).

Physical activity

Physical activity was assessed during 7 consecutive days using accelerometers (Actigraph GT1M, Manufacturing Technology Inc., Pensacola, Florida, USA). Adolescents wore the accelerometers on the lower back during the waking hours. For the present study, data were saved in 15-se intervals (epochs). Data with periods of continuous zero values for more than 20 min were considered "accelerometer non-wear" periods and were therefore excluded from the analyses. Likewise, registers of more than 20 000 counts/min were interpreted as a potential malfunction of the accelerometer and were also excluded from the analyses. Data were considered as valid if the adolescents had accelerometer counts for at least 3 days with at least 8 h of recording time per day (Ruiz et al., 2011). Data were analysed and minutes per day spent in at least moderate physical activity intensity were calculated according with the standardized cutoff point of ≥ 2000 counts/min (Ruiz et al., 2011). MVPA was dichotomized into < 60 and ≥ 60 min/day according to the guidelines (WHO, 2010).

Cardiorespiratory fitness

Cardiorespiratory fitness was measured with the 20-m shuttle run test (Leger et al., 1988). Participants were required to run between two lines 20 m apart, while keeping pace with audio signals emitted from a prerecorded compact disc. The initial speed is 8.5 km/h, which is increased by 0.5 km/h/min (1 min equals one stage). The test was performed once, and the last half-stage fulfilled by the adolescent was recorded. Maximal oxygen uptake [VO_{2max} (ml/kg/min)] was estimated using the equations reported by Leger et al. (1988).

Anthropometry

Anthropometric measurements were collected by trained researchers in a standardized format with participants barefoot and in underwear (Nagy et al., 2008). Height was measured with a telescopic stadiometer (SECA 225) to the nearest 0.1 cm and weight was measured with an electronic scale (SECA 861) to the nearest 0.1 kg. BMI was calculated as body weight (kg) divided by height (m) squared. Waist circumference was measured in triplicate at the midpoint between the lowest rib and the iliac crest using an anthropometric tape (SECA 200). Waist–height ratio was computed dividing waist circumference (cm) by height (cm). The biceps, triceps, subscapular, and suprailiac skinfold thickness were measured on the left side of the body to 0.2 mm using a Holtain Caliper (Crymych, UK). Body fat percentage was calculated by the equation described by Slaughter et al. (1988), and fat mass index was calculated as fat mass (kg) divided by height (m). Sexual maturation was measured by a physician during a medical examination, according to the methods described by Tanner and Whitehouse (1976).

Blood analyses

A detailed description of the blood sampling procedures has been published by Gonzalez-Gross et al. (2008). Briefly, fasting blood samples were collected by venipuncture at school, between 8:00 and 10:00 h, and were analysed in centralized laboratories. Serum TG, TC, HDL-C, low-density lipoprotein cholesterol (LDL-C), and glucose were measured on the Dimension RxL clinical chemistry system (Dade Behring, Schwalbach, Germany) with enzymatic methods that used the manufacturer's reagents and instructions. TC/HDL-C ratio was calculated. Insulin was measured from heparin plasma by a solid-phase two-site chemiluminescent immunometric assay with an Immulite 2000 analyser (DPC Biermann GmbH, Bad Nauheim, Germany). The homeostasis model assessment (HOMA) index was also calculated as: insulin (μLU/mL) × glucose (mmol/L)/22.5 (Matthews et al., 1985).

Blood pressure

Systolic and diastolic blood pressures were measured with an automatic oscillometric device (OMRON M6). Two measures were taken 5 min apart on the right arm (in an extended position) and the lowest value was recorded in millimeter of mercury (mmHg). After the measurement, adolescents rested for 5 min. The mean arterial pressure, defined as the average arterial pressure during a single cardiac cycle, was calculated using the following equation: diastolic blood pressure + [0.333 (systolic blood pressure – diastolic blood pressure)] (Zheng et al., 2008).

Socioeconomic status

A self-reported questionnaire was used to collect data about socioeconomic status and clinical assessment (Iliescu et al., 2008). Maternal education level, as a marker of the socioeconomic status, adolescents' birth weight, and duration of breastfeeding were collected from participants and their parent and used as potential confounders.

Lifestyle groups and CVD risk factors

Both diet (< 25th vs ≥ 25th percentile of the DQI-A, unhealthy and healthy diets, respectively) and physical activity (<60 vs ≥60 min MVPA, inactive and active, respectively) categories were combined to create four different lifestyle groups: (a) healthy diet and active; (b) unhealthy diet but active; (c) healthy diet but inactive; and (d) unhealthy diet and inactive.

Cardiorespiratory fitness, adiposity indicators (BMI, fat mass index, and waist–height ratio), blood lipid profile (TG, TC, HDL-C, LDL-C, and TC/HDL-C ratio), blood pressure (systolic, diastolic, and mean arterial pressure), and insulin resistance (HOMA index) were considered as individual CVD risk factors. Each of these variables was standardized as follows: standardized value (z-score) = [(value − mean)/SD], separately for sex and by 1 year age groups. Z-score for each variable was estimated in the complete sample in order to show a representative z-score and then the study sample was selected according to the criteria inclusion aforementioned. Z-score values were used instead of the original units of measurement to make the results for different risk factors easily comparable. In addition, we computed a CVD risk score (mean of z-scores) that included the following individual CVD risk factors: cardiorespiratory fitness (multiplied by −1), sum of four skinfolds, TG, TC/HDL-C ratio, systolic blood pressure, and HOMA index (Andersen et al., 2006). A lower CVD risk score is indicative of a better CVD risk profile.

Statistical analysis

Descriptive statistics (mean ± SD, percent) were calculated. Fat mass index, sum for four skinfolds, waist–height ratio, TG, and HOMA index variables were transformed to the natural logarithm. Sex differences were examined by analysis of variance and chi-square tests. Interaction analysis by sex between lifestyle groups and CVD risk factors indicated no gender difference. All remaining analyses were conducted with boys and girls combined.

To examine the differences among lifestyle groups – (a) healthy diet and active; (b) unhealthy diet but active; (c) healthy diet but inactive; and (d) unhealthy diet and inactive – in CVD risk factors we used mixed model analysis (also known as multilevel analysis). Lifestyle group was considered as an independent variable and

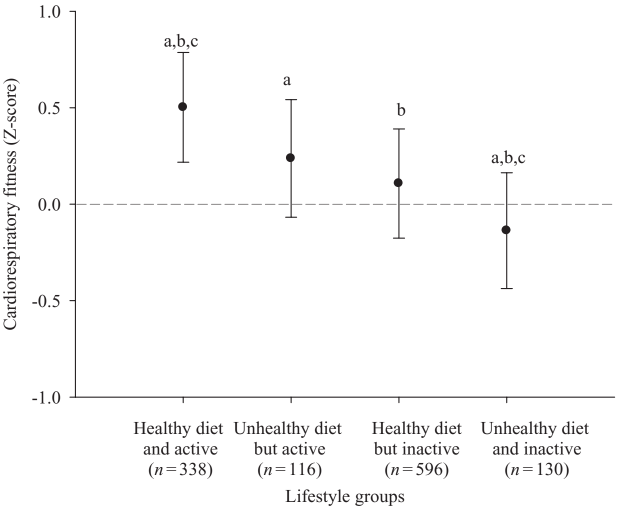

Fig. 1. Differences in cardiorespiratory fitness according to lifestyle groups in European adolescents ($n = 1230$). Values are shown as means and 95% CI. Z-score for cardiorespiratory fitness was adjusted by sex and age. Mixed model analysis was adjusted for sex, age, sexual maturation, and center. ^{a,b,c}Common superscripts indicate a significant difference (all $P \leq 0.04$).

CVD risk factors (i.e., cardiorespiratory fitness, adiposity indicators, blood lipid profile, blood pressure, and insulin resistance) and CVD risk score as dependent variables (outcome). Sex, age, and sexual maturation were entered as covariates and the study center was included as a random intercept. Pairwise comparisons between groups were performed with least significant difference (LSD), which is equivalent to multiple individual *t*-test between all pairs of groups. The LSD method was used in order to avoid the limitations attributed to multiple compilations test (e.g., Bonferroni) (Perneger, 1998). All analyses were performed using the statistical software PASW for Windows version 18 (PASW Inc., Chicago, Illinois, USA). Alpha was set at $P < 0.05$.

Results

A total of 1513 adolescents aged 12.5–17.5 years (45% boys) from the HELENA study participated in this study, of whom 481 (45% boys) had blood analysis. Overall, sex differences were found in the different variables under study (Supporting Information Table S1).

All the analyses were done using standardized values (z-score) in order to facilitate visual comparisons in the figures (Figs 1, 2, 3 and 4). Although the analyses were done using z-scores, here in the text we present adjusted

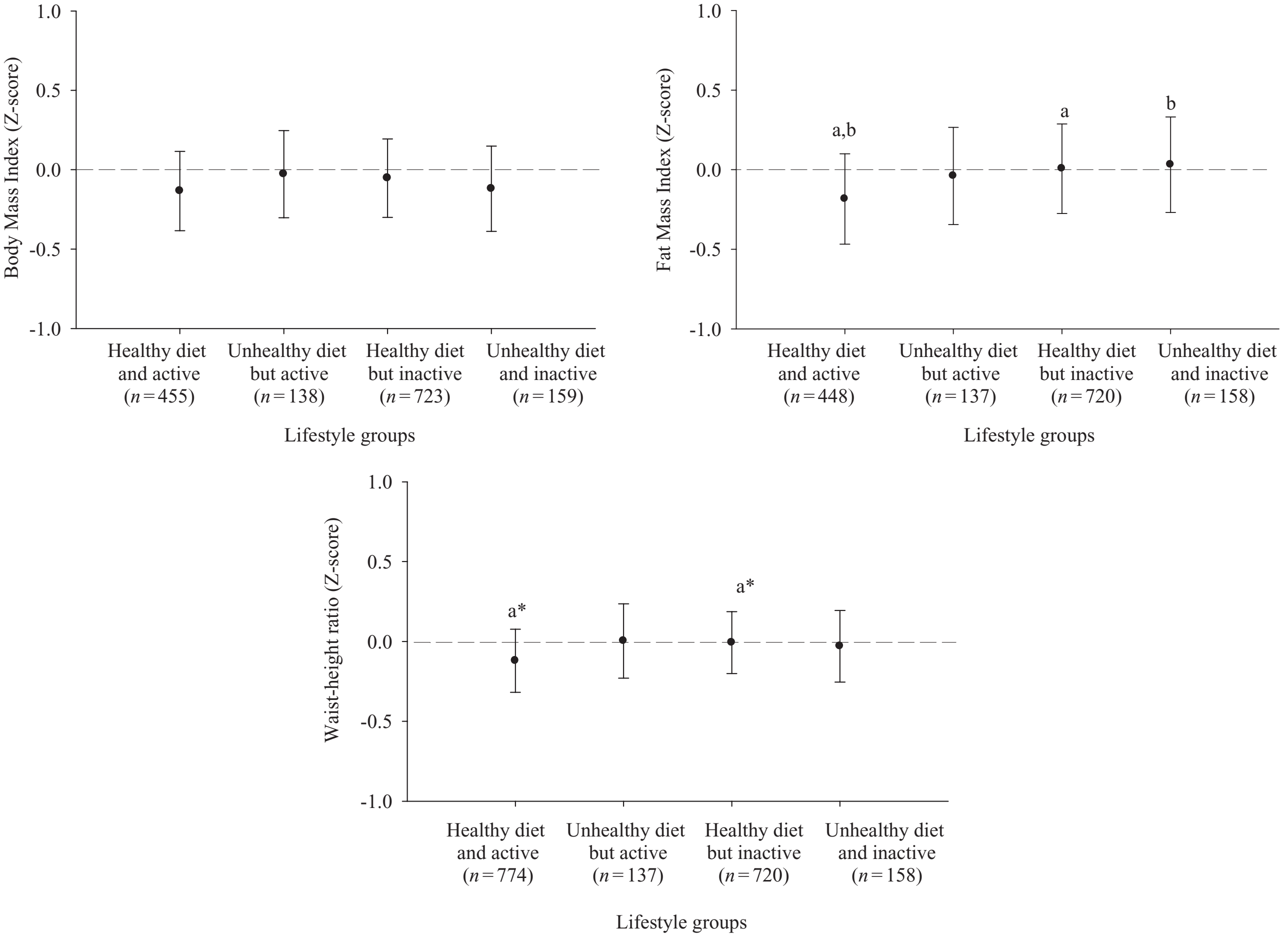

Fig. 2. Differences in adiposity indicators – i.e., body mass index, fat mass index, and waist–height ratio – according to lifestyle groups in European adolescents ($n = 1475$; 1463 and 1462, respectively). Values are shown as means and 95% CI. Z-score for adiposity indicators was adjusted by sex and age. Mixed model analyses were adjusted for sex, age, sexual maturation, and center. ^{a,b}Common superscripts indicate a significant difference (all $P \leq 0.02$). ^{a*}Common superscripts indicate a borderline difference ($P = 0.06$).

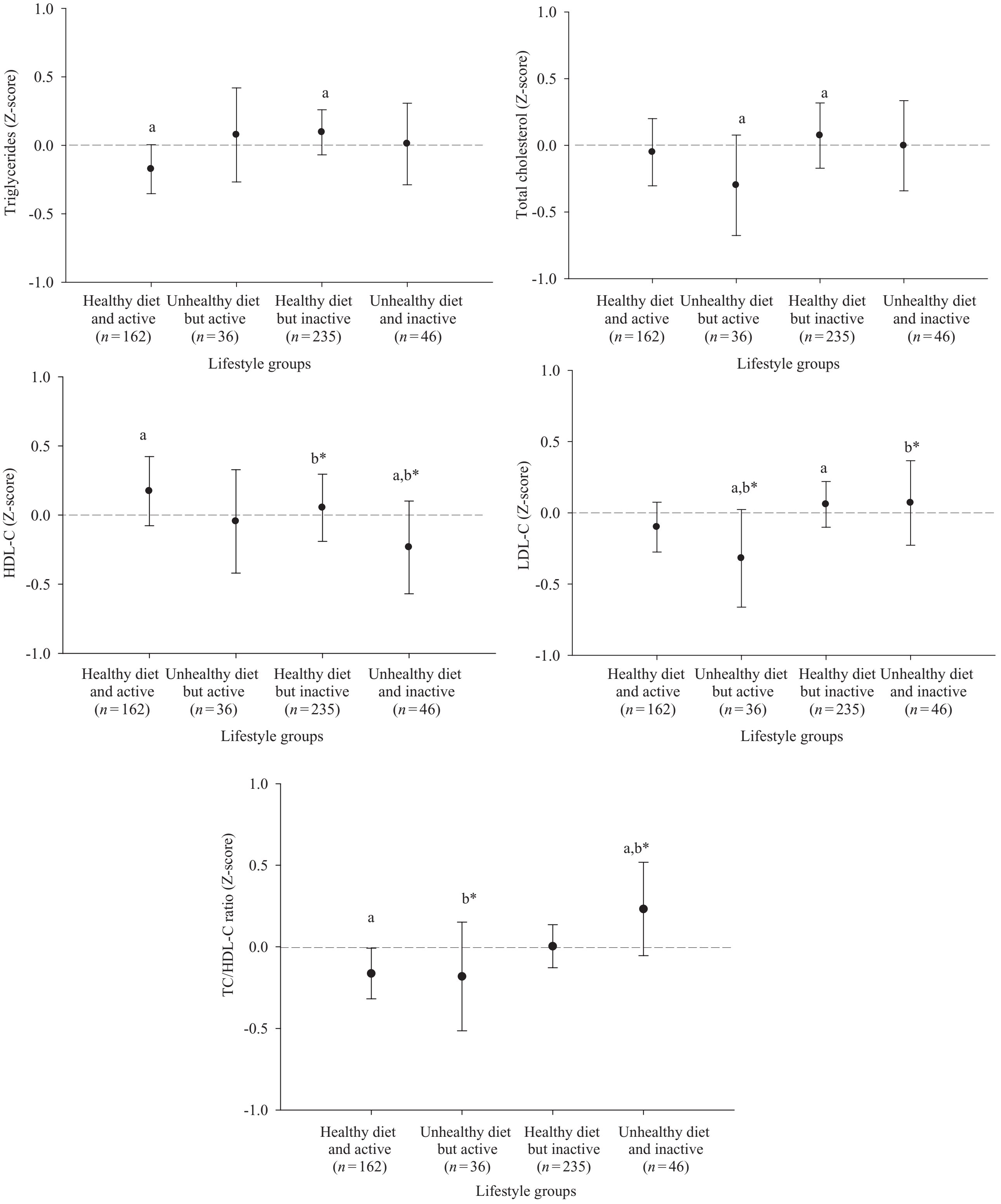

Fig. 3. Differences in blood lipid profile – i.e., triglycerides, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and TC/HDL-C) – according to lifestyle groups in European adolescents ($n = 479$). Values are shown as means and 95% CI. Z-score for lipid profile variables was adjusted by sex and age. Mixed model analyses were adjusted for sex, age, sexual maturation, and center. ^{a}Common superscripts indicate a significant difference (all $P \leq 0.04$). ^{b*}Common superscripts indicate a borderline difference (all $P \leq 0.09$).

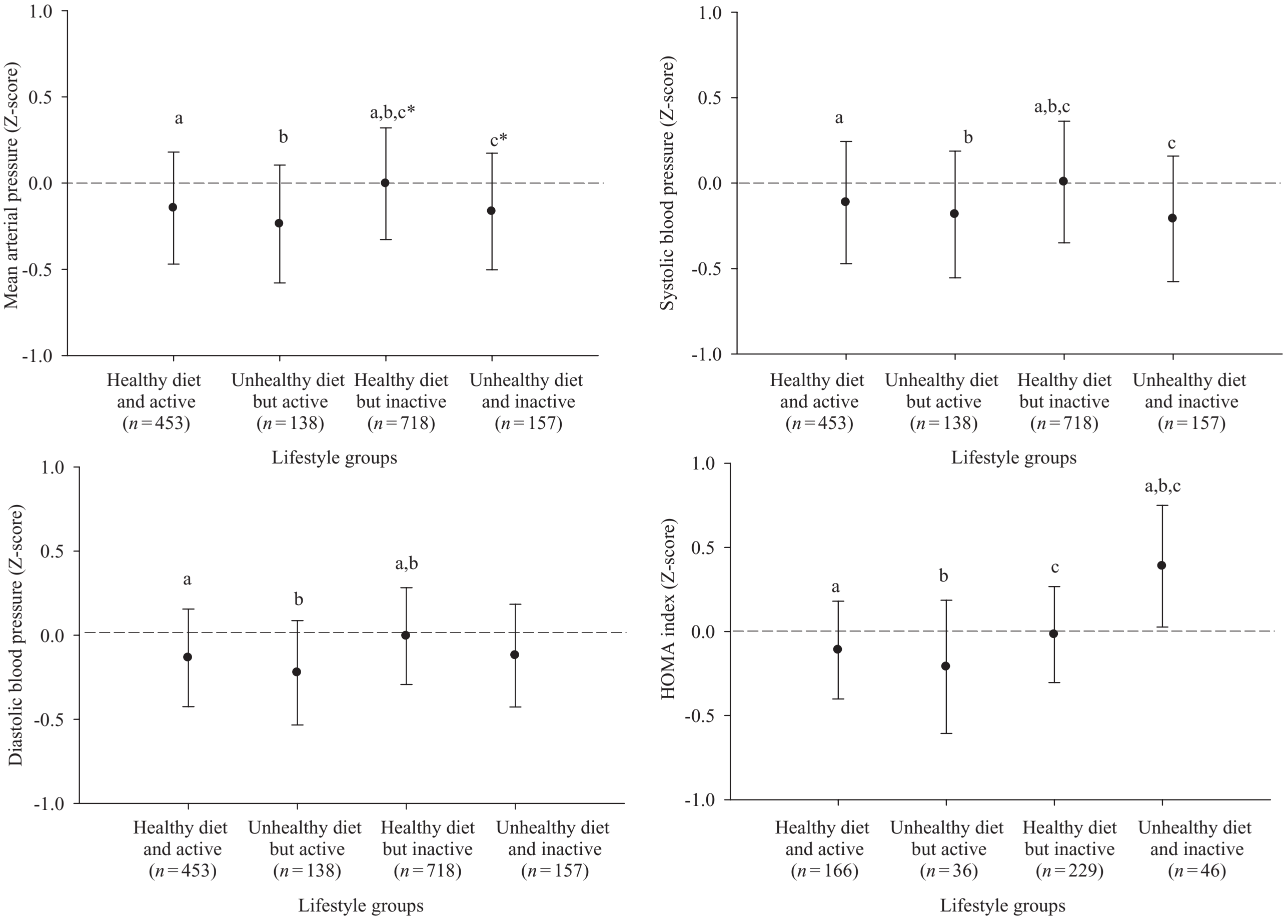

Fig. 4. Differences in blood pressure (mean arterial pressure and systolic and diastolic blood pressures, $n = 1466$) and insulin resistance [homeostasis model assessment (HOMA) index, $n = 471$] according to lifestyle groups in European adolescents. Values are shown as means and 95% CI. Z-score for blood pressure variables and HOMA index was adjusted by sex and age. Mixed model analyses were adjusted for sex, age, sexual maturation, and center. ^{a,b,c}Common superscripts indicate a significant difference (all $P \leq 0.04$). ^{c}*Common superscripts indicate a borderline difference ($P = 0.06$).

means ± SE expressed in their original units of measurement, so that the values can be clinically interpreted.

The healthy diet and active group had a more favorable cardiorespiratory profile compared with the rest of the groups (all $P \leq 0.004$). The healthy diet and active group had better cardiorespiratory fitness (ml/kg/min) compared with the unhealthy diet but active group, the healthy diet but inactive group, and the unhealthy diet and inactive group (44.4 ± 0.782, 42.7 ± 0.906, 41.8 ± 0.767, and 40.2 ± 0.883, respectively) (Fig. 1).

Adolescents with healthy diet and were active had lower fat mass index (kg/m) (4.7 ± 0.312) than those who were inactive with either a healthy or unhealthy diet (5.3 ± 0.303, $P = 0.002$ and 5.4 ± 0.361, $P = 0.017$, respectively) (Fig. 2). Moreover, adolescents with healthy diet and were active had lower waist–height ratio (cm) compared with those with a healthy diet but who were inactive (0.43 ± 0.006 vs 0.44 ± 0.004, with a borderline difference of $P = 0.06$). Nonsignificant differences appeared for BMI (Fig. 2).

The blood lipid profile (i.e., TG, TC, HDL-C, LDL-C, and TC/HDL-C ratio) differed among lifestyle groups (Fig. 3). The healthy diet and active group had a lower TG levels (mg/dL) compared with the healthy diet but inactive group (63.3 ± 2.867 vs 70.0 ± 2.576; $P = 0.011$). Adolescents with an unhealthy diet but were active had lower TC (mg/dL) and LDL-C levels (mg/dL) than their peers with a healthy diet but who were inactive (151.7 ± 5.062 vs 162.1 ± 2.903, $P = 0.043$; and 85.8 ± 4.266 vs 95.7 ± 1.825, $P = 0.043$, respectively). The healthy diet and active group had a higher HDL-C level (mg/dL) compared with their peers with an unhealthy diet and who were inactive (57.2 ± 1.216 vs 52.5 ± 1.757; $P = 0.013$). Active adolescents with healthy diet had a lower TC/HDL-C ratio (mg/dL) compared with their inactive peers with an unhealthy diet (2.8 ± 0.05 vs 3.0 ± 0.09; $P = 0.018$). Moreover, the unhealthy diet but active group had a lower TC/HDL-C ratio than the unhealthy diet and inactive group (with a borderline difference of $P = 0.07$) (Fig. 3).

Active participants with either healthy or unhealthy diet had lower mean arterial pressure (mmHg) than inactive adolescents with healthy diet (84.1 ± 1.249, $P = 0.016$ and 83.3 ± 1.389, $P = 0.011$, respectively, vs

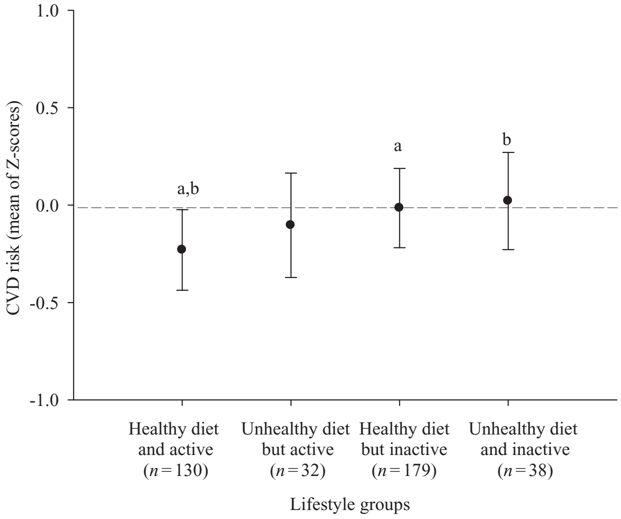

Fig. 5. Differences in the cardiovascular disease (CVD) risk score according to lifestyle groups in European adolescents ($n = 379$). CVD risk score was composed by mean of z-score from cardiorespiratory fitness, sum of four skinfolds, triglycerides, total cholesterol/high-density lipoprotein cholesterol ratio, and insulin resistance (homeostasis model assessment index) (Andersen et al., 2006). Values are shown as means and 95% CI. Z-score for CVD risk factors was adjusted by sex and age. Mixed model analyses were adjusted for sex, age, sexual maturation, and center. ^{a,b}Common superscripts indicate a significant difference (all $P \leq 0.02$).

85.3 ± 1.229) (Fig. 4). Unexpectedly, adolescents with an unhealthy diet who were inactive had borderline lower mean arterial pressure than inactive adolescents with a healthy diet (84.0 ± 1.362, $P = 0.016$ vs 85.3 ± 1.229, $P = 0.06$). Similar patterns were observed when systolic and diastolic blood pressures were studied (Fig. 4). The unhealthy diet and inactive group had markedly higher levels of HOMA index compared with the other groups (3.0 ± 0.277 vs 2.1 ± 0.192 from healthy and active group; 1.8 ± 0.311 from unhealthy but active group; and 2.3 ± 0.182 from healthy diet and inactive group) (all $P \leq 0.008$), showing active adolescents with either healthy or unhealthy diet had the lowest levels of HOMA index (Fig. 4).

The healthy diet and active group had the lowest CVD risk score and the unhealthy diet and inactive group had the highest (Fig. 5). Active adolescents with healthy diet had lower CVD risk score than inactive adolescents with either a healthy or unhealthy diet (–0.230 ± 0.94 vs –0.015 ± 0.019, $P = 0.002$ and 0.021 ± 0.122, $P = 0.019$, respectively) (Fig. 5). The same trend was observed with other metabolic risk index (Zimmet et al., 2007; Artero et al., 2011), including variables as waist circumference, TG, TC/HDL-C ratio, systolic blood pressure, and HOMA index (data not shown).

Additional analyses were performed using the 50th percentile on DQI-A to develop the lifestyle groups; overall the results did not change (data not shown). Similarly, when socioeconomic status, birth weight, or breast-feeding variables were entered as covariates in the multilevel model to assess the differences between lifestyle groups and CVD risk factors, the results remained unchanged (data not shown).

Finally, a complementary analysis was developed with dietary index and physical activity in continuous scale. The results showed that physical activity was related to most of the CVD risk factors, while dietary index was related only to a few of them, without changes when the models were mutually adjusted for both dietary index and physical activity (Supporting Information Table S2).

Discussion

Our data suggest that a healthy diet and active lifestyle have a combined influence on CVD risk factors in European adolescents, showing that the group with a healthy diet and an active lifestyle presents a healthier cardiorespiratory profile, i.e., fat mass index, TGs, and HDL-C levels and TC/HDL-C ratio. In addition, we observed that active adolescents showed a higher cardiorespiratory fitness, lower total and central adiposity, healthier blood lipid profile and blood pressure, and lower insulin resistance levels than their inactive peers, regardless of their diet quality.

Being active was associated with higher cardiorespiratory fitness profile. Although this finding was *a priori* expected, direct comparisons between the effect of diet quality and physical activity on cardiorespiratory fitness have not previously been reported in adolescents. Interestingly, when a healthy diet was combined with an active lifestyle, an additional and significantly higher cardiorespiratory fitness was observed, in comparison to only presenting an unhealthy diet but active (the magnitude of difference was 53%). This is a new finding and a major contribution of this study, supporting a combined influence of diet and physical activity on adolescents' fitness. On the other hand, the separate influence of a healthy diet (Cuenca-Garcia et al., 2012) and physical activity (Ortega et al., 2008) has been positively associated with cardiorespiratory fitness in young people.

In our study, healthy diet consumers and active participants showed lower total and central adiposity compared with those who were inactive, independent of their diet quality, thus highlighting the negative effect of inactivity in total and central adiposity in adolescents, regardless of diet quality. Several studies have reported the separate effect of diet and physical activity on total and central adiposity (Moliner-Urdiales et al., 2009; Bradlee et al., 2010). Patrick et al. (2004) showed that of the seven dietary and physical activity variables examined, insufficient physical activity was the only risk factor for higher BMI for adolescent, which is in line with our findings. In addition, they did not observe interaction between diet and physical activity when they studied the association of both with the BMI. Lioret et al. (2008) observed that overweight was inversely correlated with a varied food intake and physically active pattern and was positively associated with a snack intake and sedentary pattern in children. We have not found studies examining the combined influence of MVPA and diet quality index on more specific adiposity markers, such as waist–height ratio and fat mass index, which precludes comparison with previous studies.

Overall, inactive groups had a worse blood lipid profile than active groups, independent of diet quality. This is in agreement with the findings by Hurtig-Wennlof et al. (2007), although the diet was not used as an influencing variable. This point is important because the positive effect of a healthy diet on blood lipid profile has been suggested (Berenson et al., 1998). Based on the current literature, there is evidence for the effect of lifestyle on the lipid profile, but our findings suggest that physical activity may overcome the deleterious effects of unhealthy dietary habits, at least in adolescents. The combined influence of diet and physical activity has been frequently studied in interventional studies in adults; e.g., after a 12-week hypocaloric diet and physical activity intervention in women, greater health benefits were found from the combination of both behaviors compared with isolated interventions (Kirkwood et al., 2007). However, we have not found studies comparing the influence of both behaviors in a similar report and in young European people.

Independent of diet quality, active participants presented lower blood pressure than their inactive peers. The influence of both lifestyle behaviors has not been previously reported in adolescents because diet or physical activity has been independently studied. Lazarou et al. (2009) suggest that adherence to Mediterranean diet plays an important role in determining blood pressure in children, while no significant results were shown for self-reported physical activity, highlighting other lifestyle choices as influential. In contrast, other authors have observed favorable influences of physical activity on blood pressure (Mark & Janssen, 2008).

Adolescents from the unhealthy diet and inactive group presented the highest insulin resistance, and inactivity seems to be the major determinant of this increase. Previous studies have shown the inverse relationships of healthy diet (WHO, 2003) and physical activity (Rizzo et al., 2008) with insulin resistance level in young people. Likewise, Manios et al. (2010) developed a Healthy Lifestyle-Diet Index composed of diet, physical activity, and sedentary time that was associated with lower insulin resistance level in children. Direct comparisons are not possible because we did not measure sedentary behaviors in our study, and it is known that different sedentary patterns are associated with different food habits.

Several CVD risk indexes have been studied, taking into account different risk factors. In this study, we calculated a CVD risk score previously used by Andersen et al. (2006) in children. We observed that the healthy diet and active group had the lowest CVD risk score and the unhealthy diet but inactive group the highest. Moreover, the healthy diet and active group showed a lower CVD risk score compared with their inactive peers, independent of their diet. Moreover, we used an additional CVD risk index recommended by Zimmet et al. (2007), which excluded cardiorespiratory fitness, and the same tendency was found (data not shown). Thus, from a public health perspective, an active lifestyle may be useful for preventing risk of CVD and other noncommunicable diseases and even more, if it is combined with a healthy diet.

Some limitations of the present study need to be mentioned. Diet data were self-reported by the adolescents, while physical activity was objectively measured using accelerometers. The error of dietary assessment could have been larger than for physical activity, which could have led to an underestimation of the influence of diet on the study outcomes. Also, the cross-sectional study does not allow us to identify causal relationships. Future intervention studies should investigate the combined and single effect of lifestyle behaviors on CVD risk factors in adolescents. A major strength of the HELENA study is the highly standardized procedures used. Another strength is the use of multiple indicators of CVD risk factors, which provide valuable information about the cardiometabolic status in adolescents.

In summary, our data suggest that combination of a healthy diet and active lifestyle is associated with healthier levels of key CVD risk factors, such as cardiorespiratory fitness, adiposity, and blood lipid profile. In addition, we observed that being physically active may reduce the deleterious effects of an unhealthy diet, but whether a healthy diet can counteract the adverse effect of an inactive lifestyle was not supported by our data.

Perspectives

Although independent associations of diet and physical activity with CVD risk factors have been reported (WHO, 2003; Andersen et al., 2006), little is known about the combined influence of diet quality and physical activity on CVD risk factors. Moreover, it is well known that healthy behaviors do not always come together (Jago et al., 2010; Ottevaere et al., 2011). Additional studies would provide a better understanding of the interaction between lifestyle behaviors and individual health status. The results of this study demonstrate that combination of healthy diet and active lifestyle may prevent the CVD risk in adolescents. In addition, an active lifestyle may reduce the adverse consequences of an unhealthy diet, but whether a healthy diet can counteract the deleterious effects of an inactive lifestyle was not supported by our data. These results will assist in designing more effective intervention strategies in adolescents.

Key words: diet quality index, physical activity, body composition, lipid profile, blood pressure, insulin resistance, cardiovascular disease risk, HELENA study.

Acknowledgements

The HELENA study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). This work 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-2008-03806, AGL2007-29784-E/ALI, AP-2005-3827), the Spanish Ministry of Science and Innovation (RYC-2010-05957, RYC-2011-09011), the Spanish Ministry of Health, Maternal, Child Health and Development Network (No. RD08/0072) (LAM), Universidad Politécnica of Madrid (CH/018/2008), the Swedish Heart-Lung Foundation (20090635) and the Aragon's Regional Government (SBS). The content of this paper reflects only the authors' views and the rest of HELENA study members and the European Community are not liable for any use that may be made of the information contained therein. The authors gratefully acknowledge all participating children and adolescents, and their parents and teachers, for their collaboration. Many thanks to Petra Pickert and Anke Carstensen for their contribution to laboratory work, we also acknowledge the rest of the members involved in the fieldwork for their efforts and great enthusiasm.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Table S1. Descriptive characteristics of the European adolescents sample from HELENA study.
Table S2. Association between cardiovascular disease risk factors, dietary index, and physical activity in Europeanadolescents.
Appendix 1. The names of people involved in the HELENA Study Group.

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2. Clustering of multiple lifestyle behaviours and health

[Agrupación de múltiple factores ligados al estilo de vida y salud]

Study II *[Artículo II]*

Study II


20m
games
main
quality
medium
group
Active
Screen
fat
vs
gender
Healthy
body
health-related
analyses
homework
MVPA
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patterns
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findings
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characteristics
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previous
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circumference
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sedentary
skinfold
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unhealthy
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clusters
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diet
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systematic
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CLUSTERING OF MULTIPLE LIFESTYLE BEHAVIOURS AND HEALTH-RELATED FITNESS IN EUROPEAN ADOLESCENTS.

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NOTE: Accepted in **J Nutr Educ Behav** (Please, see email from the journal in the reverse).

Email from Karen Chapman-Novakofski
Editor in Chief
Journal of Nutrition Education and Behavior

Letter Purpose: Editor Decision ¬ Accept
Subject: Decision Letter from JNEB

Ms. Ref. No.: JNEB-D-12-00260R3
Title: CLUSTERING OF MULTIPLE LIFESTYLE BEHAVIOURS AND HEALTH-RELATED FITNESS IN EUROPEAN ADOLESCENTS
Journal of Nutrition Education and Behavior

Dear Mrs. Cuenca-García,
I am writing in reference to your Research Article, "CLUSTERING OF MULTIPLE LIFESTYLE BEHAVIOURS AND HEALTH-RELATED FITNESS IN EUROPEAN ADOLESCENTS," which was submitted to the Journal of Nutrition Education and Behavior (JNEB). I am pleased to inform you that it has been accepted for publication. It will be forwarded to the publisher, as is, for production. Once it is typeset, you will receive a copy from the publisher with request for corrections as needed. In addition, you will be receiving a short survey on the submission and publishing process with JNEB, we would appreciate your feedback on this we can better serve our authors.

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Sincerely,

Karen Chapman-Novakofski, PhD, RD, LD
Editor in Chief
Journal of Nutrition Education and Behavior

Abstract

Objective: To explore the clustering of different lifestyle behaviours and whether this clustering differs by gender, age and health-related fitness.

Design: HELENA cross-sectional study.

Setting: Ten European cities.

Participant: 2,084 adolescents aged 12.5–17.5 years.

Main outcome Measures: Four lifestyle behaviours were assessed by self-administered questionnaires: moderate-vigorous physical activity, two sedentary behaviours (homework and screen viewing) and diet. Health-related fitness components were assessed by the 20m shuttle run test (aerobic capacity), the handgrip strength and standing broad jump tests (muscular strength), the shuttle run 4x10m test (speed-agility) and anthropometry (body composition).

Analysis: A combination of hierarchical method and K-means cluster analysis. Chi-square and ANOVA tests.

Results: Five clusters were identified: ‘Healthy diet & Active’, ‘Healthy diet & Academic’, ‘Healthy diet & Inactive’, ‘Unhealthy diet & Screen users’, ‘Unhealthy diet & Active’. Younger adolescents were more active and followed a healthier diet than older adolescents. Older boys devoted more time to screen use, while older girls devoted more time to homework. Boys in the ‘‘Healthy diet & Active’’ cluster presented higher aerobic capacity, while girls presented higher aerobic capacity, strength and speed-agility. No differences by clusters were found in body composition

Conclusions and Implications: Clustering of different lifestyle behaviours is observed. Different healthy lifestyles do not always come together and clusters are associated with gender, age and health-related fitness, but not with body composition. These differences need to be considered when developing intervention strategies for prevention of unhealthy habits.

Keywords: Physical activity, homework time, screen time, healthy diet, HELENA Study

Introduction

The prevalence of negative behaviours (e.g., low physical activity, sedentarism and inadequate nutritional intake) among adolescents has increased over the past few decades [1,2]. While the promotion of healthy behaviours among adolescents is essential, there is a need to better understand how different lifestyle choices cluster in adolescence. In fact, unhealthy and healthy behaviours seem to coexist but this clustering differs between genders and across ages, and may affect health markers in adolescents.

It is well established that physical fitness is a health marker both during adolescence[3] and later in adulthood[4], and that higher levels of fitness are associated with many positive health-related outcomes (e.g., improved cardiovascular disease profile)[3]. A number of factors such a physical activity, sedentary behaviours and dietary habits are independently and strongly associated with physical fitness. For example, regular participation in moderate-vigorous physical activity (MVPA) is associated with higher fitness[5], while sedentary behaviour (e.g., television viewing or video playing) is positively related to adiposity and other metabolic cardiovascular disease risk factors[6-7]. The consumption of healthy food groups has been associated with higher cardiorespiratory fitness in adolescents[8] and diet indexes, as a measure of overall healthy diet, has been also related to health outcome[9].

To date, most studies in young people have focused on the importance of independent lifestyle behaviours, despite the fact that research suggests the coexistence (i.e., clustering) of different behaviours. Previous studies have focused on describing the clusters based on physical activity and sedentary time[10], physical activity and dietary behaviour[11-12] or sedentary behaviour and food habits[13]. Other studies have addressed the clustering of physical activity, sedentary behaviour and dietary intake[14] or dietary behaviours[15-16]. While there is some evidence that the clustering of lifestyle behaviours differs between genders[10, 12, 14, 16], the research on the clustering of behaviours and their combined effect on health-related fitness is inconsistent (e.g., body composition)[10-11, 15-16] or limited (e.g., aerobic capacity)[15]. Inclusion of other components of health-related fitness such as muscular strength and speed-agility has been identified as a gap in the existing research evidence. On the other hand, while the clustering of physical activity, sedentary time and dietary patterns and its relationship with gender, age and socioeconomic status in European adolescents has been studied[16], different types of sedentary behaviours (i.e., homework time vs. screen time) have not been studied separately; which is of importance because screen viewing is positively associated with unhealthy diet in adolescents[17].

The aims of the present study were to identify the clustering of four different lifestyle behaviours: 1) MVPA time, 2) homework time, 3) screen time, and 4) dietary behaviour; and to assess whether this clustering differs by gender, age and health-related fitness in European adolescents. The present study adds (i) the use of different types of sedentary behaviours separately and a diet quality index, as a measure of an overall healthy diet, to identify lifestyle patterns and (ii) the association of the identified clustering with the different health-related fitness components (i.e. aerobic capacity, muscular strength, speed-agility and body composition) in a relatively large sample of adolescents from nine European countries.

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-center study aiming to obtain reliable and comparable data on nutrition and health-related parameters. A total of 3,528 adolescents (age range 12.5-17.5) were assessed at schools between 2006-2007 in 10 European cities from nine countries, all fulfilling the general HELENA-CSS inclusion criteria[18]. Details on sampling procedures and study design have been reported elsewhere[19]. The study was approved by the Ethical Committee of each city involved[20]. Written informed consent was obtained from both the adolescents and their parents.

Measurements

Physical activity assessment

Physical activity was assessed with the self-reported International Physical Activity Questionnaire for Adolescents (IPAQ-A) for at least seven days. Data from questionnaires and accelerometers were correlated for the whole study sample and then stratified by gender and age category (r(s) ≤0.26)[21]. Activities were afterwards classified into light (i.e. walking), moderate and vigorous intensity according to the guidelines for data processing and analyses of IPAQ[22]. For the cluster analyses, the total time spent in moderate and vigorous activity were summed and truncated in order to avoid overestimations[23]. Briefly, physical activity data were truncated below 10 minutes and above 3 hours in each intensity (light, moderate and vigorous) and domain of physical activity (school-related physical activity including activity during physical education classes and breaks, transportation, housework and activities during leisure time).

Sedentary behaviour assessment

Habitual sedentary time was estimated by the self-reported HELENA sedentary behaviour questionnaire[24]. The reliability of the scores in this questionnaire has been previously evaluated in a subset of 183 adolescents from the HELENA study (Cohen's kappa reliability coefficients >0.7)[25]. HELENA sedentary behaviour questionnaire includes questions on daily minutes of the following sedentary items: television viewing, playing with computer games, playing with console games, use of internet for non-study reasons, use of internet for study, and studying/homework (lessons not included). For the cluster analyses, time devoted to screen viewing was calculated by summing the time spent in television viewing, playing computer or console games and using internet for non-study reasons. Whereas the time devoted to homework, was calculated by summing the time spent studying or doing homework and the use of internet for study reasons.

Dietary intake assessment

The dietary intake assessment was performed by a computer-based tool for self-reported 24h recalls, HELENA-DIAT (Dietary Assessment Tool), on 2 non-consecutive days. YANA-C, a former version of the HELENA-DIAT, showed good agreement with an interviewer-administered YANA-C interview (Cohen's kappa values= 0.8–0.92 and 0.38–0.90, respectively)[26]. The HELENA-DIAT tool has been indicated as a good method to collect detailed dietary information from adolescents[27]. Dietary intake applied to the day before the administration of the test and was divided in six meal occasions. Adolescents completed the program individually in the computer classroom during school time. Fieldworkers were present to give assistance if necessary[27].

The diet quality index (DQI) was developed using the data derived from the HELENA-DIAT and was calculated based on the DQI in preschool by Huybrechts et al.[28]. The index for adolescents consists of four pillars based on the principles of a healthy diet[29]; dietary equilibrium, dietary diversity, dietary quality and a meal index. *Dietary equilibrium* results from the difference between the dietary adequacy score (the percentage of the minimum recommended intake for each of the main food groups) and the dietary moderate score (expressing the percentage of intake exceeding the upper level of recommendation). *Dietary diversity* expresses the degree of variation in the diet (when at least one serving of food per day from each of the eight recommended food groups is consumed). D*ietary quality* components represent the optimal food quality choice within a food group. Finally, the *meal index* reflects the frequency of consumption of meals (which should ideally include at least three main courses, as breakfast, lunch or dinner). To compute the overall DQI for adolescents with Meal index, the score is calculated as the mean of the four above mentioned pillars and ranges from -25 to 100%, with a higher score indicating a higher quality of their diet (complying better with the food based dietary guidelines). More detailed information on the technical aspects of the DQI-concept is described elsewhere[28, 30].

Health-related fitness assessment

Health-related fitness was assessed by the following components: aerobic capacity, muscular strength, speed-agility and body composition. Briefly, aerobic capacity was assessed by the *20m shuttle run* test; upper-body muscular strength by the *handgrip strength test*; lower-body muscular strength by the *standing broad jump* test; speed-agility by the *4x10m shuttle run* test; and body composition by *percentages of body fat and fat free mass* (using skinfold thicknesses) and *waist circumference*. The inclusion of body composition as a component of health-related fitness was completed following the recommendations of Pate et al.[31].

Handgrip strength, standing broad jump and 4x10m shuttle run tests were performed twice and the best score was retained, while the 20m shuttle run test was performed only once and the final score was computed as the number of stages completed (precision of 0.5 stages). Reference values for European adolescents, based on the HELENA study, have previously been published[32]. Body composition measures were carried out under standardized conditions[33] the mean of three measurements was calculated. Briefly, skinfold thicknesses (triceps and subscapular) were measured with a Holtain calliper to the nearest 0.2mm and body fat and fat free mass were calculated using Slaughter's equations[34]. Waist circumference was also measured with a non-elastic tape (Seca 200) to the nearest 0.1 cm.

It has previously been shown that the results of these tests are valid[35] and reliable[36]. The Bland-Altman plots graphically showed the reliability patterns, in terms of systematic errors (bias) and random error (95% limits of agreement), of the 20m shuttle run, handgrip strength, standing broad jump and 4x10m shuttle run tests performed twice, 2 weeks apart, by the same researchers. The observed systematic error for these tests was nearly 0. The reliability values of skinfold and waist circumference were examined via intra- and inter-observer errors[33]. Intra- and inter-observer reliability values were greater than 95% for both skinfold and waits circumference.

Statistical analyses

Participants with complete and valid IPAQ-A and HELENA sedentary behaviour questionnaires and HELENA-DIAT information for at least two days were included. Heraklion and Pecs study centers were not included in the present study because incomplete information was obtained from the 24h dietary recalls. The final sample for the present study was 2,084 cases (54% girls) and the younger age category (12.5-14.9 years of age) included 57% of the cases. Cluster analyses were performed on this sample of 2,084 participants, while analyses on the associations between clusters and health-related fitness were performed on 83% of this sample, since physical fitness tests were not performed in the entire HELENA study sample due to different reasons (Table 1)[32].

Four lifestyle behaviours were used in cluster analysis: 1) MVPA time; two sedentary behaviours: 2) homework time and 3) screen time and 4) dietary behaviour (assessed by the DQI). Before clustering, the correlations among the different lifestyle behaviours were studied by Pearson's correlation. Then, the variables used in cluster analysis were transformed into standardized scores (z-scores) to provide a common range since they had different units and arithmetic scales; thus all variables were entered into the cluster model as continuous comparable variables. A combination of hierarchical method and k-means cluster analysis was used to identify clusters with similar lifestyle behaviours[37]. Different steps were undertaken: 1) hierarchical cluster analysis based on squared Euclidian distances was used to identify cluster numbers and to provide this necessary information for the next analysis (K-means cluster analysis). 2) k-means cluster analysis was used to obtain the final cluster solution, including the number of clusters obtained by the hierarchical cluster analysis. 3) Possible instability of the cluster solution was tested, the solution was re-examined on a random sample of 50% of the total sample. Additionally, Cohen's kappa was used to measure the degree of agreement (i.e., stability) of the classification of subjects using data from the entire sample and then just from the subsamples. The different clusters were labelled based on the behaviours patterns. Differences among each cluster on all behaviour indices were estimated using ANOVA post hoc Bonferroni test.

Cluster differences according to gender and age category (younger=12.5-14.99 years vs. older=15.0-17.5 years) were analysed by chi-square tests. After stratifying the study population for gender, associations between the identified clusters and the main components of health-related fitness were investigated by ANOVA and a post hoc Bonferroni test. Partial η^2 were calculated as a measure of effect size. Data of 20m shuttle run, handgrip strength, standing broad jump and 4x10m shuttle run tests were transformed into standardized z-score, after splitting for gender and 1year age groups. For percentages of body fat and fat free mass and waist circumference, analyses were controlled by age and height[38]. All analyses were performed using the statistical soft-ware PASW for Windows version 18 (PASW Inc., Chicago, IL, USA) and significance was set at $P<0.05$.

Results

Participant characteristics

Characteristics of the study population are presented in Table 1. The mean age of the participants was 14.8 (1.2) years. Boys spent more time on MVPA and screen viewing but less time on educational sedentary activities (homework) than girls. Girls showed higher DQI scores, which means healthier diet, compared with boys. Boys presented higher values in all health-related fitness tests than girls, except for percentage of body fat (Table1).

Description of the clusters

Pearson's correlations among the four behaviour patterns were low (all r <0.27; see Table 2). A higher correlation was found between DQI and sedentary time devoted to screen viewing. Based on the four behaviours (MVPA time, homework time, screen time and dietary behaviour) a five-cluster solution was reported because it seemed the most adequate and reliable representation of this study population. The stability of this cluster solution was tested by repeating the procedure on a random sample of 50% of the total sample and excellent concordance was found (Cohen's kappa values=0.96 for one subsample and kappa values=0.99 for the second subsample). The different clusters were labelled based on their characteristics and were identified by low, medium and high z-score values. According to these criteria each cluster was described based on the z-score values, in which z-score values < -0.5 are considered low, between -0.5 and 0.5 medium, and >0.5 high. Participants were considered as: low, medium or high MVPA time, homework time and screen time and DQI. Figure 1 presents the five clusters derived from the analysis of behaviour patterns (z-score means). Five subgroups emerged from the cluster analysis. Cluster 1 (n=313) was labelled 'Healthy diet & Active' because of the high z-score on DQI and MVPA, but also presenting medium and low z-scores on sedentary behaviours, homework and screen viewing, respectively. Cluster 2 (n=384, labelled 'Healthy diet & Academic') presented high z-scores on DQI and sedentary time devoted to homework, but medium z-score on sedentary time devoted to screen viewing and MVPA. Cluster 3 (n=801) was labelled 'Healthy diet & Inactive' because of the medium z-score on DQI, but with medium z-score on both sedentary behaviours and low in MVPA. Cluster 4 (n=350, 'Unhealthy diet & Screen users') was characterised by a low z-score on DQI, but also presenting high z-score on the sedentary time devoted to screen viewing plus medium z-score on MVPA and sedentary time devoted to homework. Finally, cluster 5 (n=236) was labelled 'Unhealthy diet & Active' because of the low z-score on DQI, but with high z-score on time spent in MVPA and medium on both sedentary behaviours. The 'Healthy diet & Active' cluster included 15% of the adolescents, while 17% of the adolescents were clustering in 'Unhealthy diet & Screen user'. Mean absolute values of the lifestyle behaviours by cluster solution are presented in Table 3. Mean absolute values for MVPA, homework time, screen time and DQI score were statistically different among clusters (P-values <0.001; Partial η^2-values ≥0.38). Skewness and kurtosis values for each variable for each cluster were deviated little from normality (data not shown).

Cluster group characteristics

Table 4 shows the relations between the clusters and gender, age category and health-related fitness. Boys were more active than girls (cluster 1 and 5 vs. 2, 3 and 4; $P < 0.001$). Younger adolescents were more active and followed healthier diet than older adolescents (cluster 1 and 5; $P < 0.001$). Older boys devoted more time to screen use (cluster 4), while older girls devoted more time to homework (cluster 2) ($P < 0.001$). A relatively equal distribution of gender or age groups of adolescents was found in the other groups.

Relationships between clusters and health-related fitness were observed in both boys and girls (Table 4). Boys in the 'Healthy diet & Active' group had higher aerobic capacity and speed-agility ($P \leq 0.001$, Partial $\eta^2 = 0.055$ and $P = 0.012$, Partial $\eta^2 = 0.012$; respectively) but no differences by clusters were found in muscular strength and body composition. While the girls in the same group had a higher aerobic capacity, muscular strength and speed-agility (P-values < 0.001; Partial η^2-values ≤ 0.33) no differences by clusters were observed in body composition.

Post hoc tests revealed that boys in the 'Healthy diet & Active' group presented better aerobic capacity than their peers in the rest of the clusters (clusters 2-5) and better speed-agility than boys in the 'Unhealthy & Screen users' group (P-values < 0.05). In addition, boys in the 'Unhealthy & Screen users' group showed the worst aerobic capacity compared with the rest of the groups (P-values < 0.05) (Table 4). On the other hand, girls in the 'Healthy diet & Active' group presented better aerobic capacity, muscular strength and speed-agility than their peers in the 'Healthy diet & Academic', 'Healthy diet & Inactive' and 'Unhealthy & Screen user' groups (P-values < 0.05). Also, girls from 'Unhealthy & Screen user' group showed worse lower-body muscular strength and speed-agility than their peers from the 'Unhealthy diet & Active' group (P-values < 0.05). Statistically significant differences on aerobic capacity were found between more active adolescents (cluster 1 and 5), despite of equal z-score on MVPA (the higher) and unequal z-score on DQI (high vs. low z-score; cluster 1 and 5, respectively) (Table 4) ($P < 0.05$). Additional analysis to study the difference by clusters of lifestyle behaviours and socioeconomic status was performed and no differences were observed (data not shown).

Discussion

The main aim of the present study was to examine clustering of lifestyle behaviours in adolescents. Results showed that healthy lifestyles do not always come together and differ by genders and age groups. In addition, clusters are associated with fitness related health markers in young people[3-4], like aerobic capacity in both genders and muscular strength and speed-agility in females. This finding is informative and should be taken into account when designing health promotion strategies in adolescents.

The 'Healthy diet & Active' and 'Healthy diet & Academic' groups were representing 15% and 19% of the adolescents, respectively. Both clusters may represent the most appropriate behaviour patterns, that is, better dietary pattern, lower time devoted to unfavorable sedentary activities and medium-to-high physical activity level[39]. On the other hand, 17% of the adolescents were clustering in the group 'Unhealthy diet & Screen user', which presented the least healthy dietary patterns and the lowest physical activity. This clustering of behaviours revealed that multiple lifestyle factors often coexist, which is in line with previous studies among young people[11, 15], and can be useful in designing intervention strategies to change unhealthy behaviours, as well as prevention of diseases associated with unhealthy lifestyles in adolescents[6, 9, 40].

Screen viewing (television, videos and computers) and homework have been identified as the most prevalent sedentary behaviours after school hours[41]. In addition, engagement in physical activity does not appear to displace time spent doing homework in adolescents[41]. On the other hand, it has been shown that subjects who spend more time in watching television are less likely to follow a healthy diet[13, 17]; while those adolescents who devote more time on educational sedentary activities have a healthier diet[15]. Thus, in the present study, sedentary behaviours were studied separately and the findings confirm those previously observed[13, 15, 17, 41]. The present findings confirm, first, that not all sedentary behaviours are associated with unhealthy diet and, second, that time devoted to homework was also compatible with the practice of physical activity.

Unequal distributions of boys and girls in clustering were observed. Boys seemed to be more active but girls had a better dietary pattern, which is in agreement with a previous study performed in children aged 10[11] and in adolescents aged 11 to 12[10, 15]. In addition, boys devoted more time to screen viewing, while girls devoted more time to homework, which is comparable to previous findings[24, 41]. For example, Atkin et al.[41] showed that boys spent more time watching television and playing computer and console games; while girls spent more time studying and in non-study internet use. On the other hand, a statistically significant association was also observed between cluster and age category. Younger adolescents were more active and followed the healthiest diet; which has also been observed in other studies among European adolescents[12, 42-43]. Adolescence is a crucial period in life, because the adolescents begin to take decisions regarding their lifestyle while at younger ages they are more influenced by their parents' decisions. Therefore, these different lifestyle behaviours might be explained by differences in independency between children and adolescents[18]. Thus, intervention strategies should mainly focus on the older adolescents due to the higher tendency of unhealthy lifestyle.

More active boys and girls with better dietary patterns (Cluster 1) had a better aerobic capacity, which confirms findings previously observed by Sabbe et al.[15]. Consistent with previous research, physical activity[3] and more especially MVPA[5], seems to be an important factor in improving physical fitness. On the other hand, more active adolescents but with unfavorable DQI showed lower fitness than those with equal activity level but favorable DQI (cluster 1 vs. 5). This finding supports the hypothesis that the combined effect of MVPA and healthy diet can improve the health-related fitness rather than each factor individually.

The present study has some limitations. Recording data for physical activity, sedentary behaviours and dietary intake were derived from self-reported questionnaires. Despite of the disadvantages of subjective methods, all aforementioned measurement questionnaires have previously been pilot tested and validated[21, 25, 27]. An important strength of this study is the availability of different sedentary behaviours, which is still underexplored in European adolescents. Other important strengths are the large sample size of the HELENA study and the highly standardized procedures that were used, particularly for physical fitness assessment, which is a major outcome in this study. The HELENA-CSS group has recently carried out a number of systematic reviews and methodological studies in order to evaluate the validity and reliability score of the fitness tests in young people[4, 33, 35-36, 44]. As a result of these investigations the tests used in this study provide a good measure of physical fitness in adolescents.

In conclusion, clustering of different lifestyle behaviours is observed in European adolescents. Healthy lifestyles do not always come together and the behaviour patterns are associated with gender, age and health-related fitness.

Implication for research and practice

It seemed that healthy lifestyles do not always come together and that behaviour patterns differ among age and genders. This finding is of interest because it will assist in designing more effective health promotion strategies in adolescents. In addition, this study allows health professionals to understand how the clustering of behaviours affects health indicators and outcomes as this study has shown (1) that the combined effect of physical activity and a healthy diet can improve the physical fitness (which is a physiological health indicator) and (2) that healthy behaviours may reduce the adverse consequences of another unhealthy behaviour when they are grouped together.

Acknowledgements

The HELENA-study was supported by the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). This work 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-2008-03806, EX-2007-1124, AGL2007-29784-E/ALI, AP-2005-3827), the Spanish Ministry of Economy and Competitiveness (RYC-2010-05957, RYC-2011-09011), the Spanish Ministry of Health, Maternal, Child Health and Development Network (number RD08/0072) (LAM), Universidad Politécnica of Madrid (CH/018/2008), and the Swedish Heart-Lung Foundation (20090635). The content of this paper reflect only the authors' views and the rest of HELENA-study members and the European Community is not liable for any use that may be made of the information contained therein. 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 field work for their efforts and great enthusiasm.

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Table 1. Descriptive characteristics of the HELENA study sample and stratified by sex

	All			Boys			Girls		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age (years)	2084	14.8	1.2	951	14.8	1.3	1133	14.7	1.2
Moderate-vigorous physical activity (min/day)	2084	102.0	81.1	951	116.1	87.3	1133	90.2	73.5
Sedentary time devoted to homework (min/day)	2084	95.2	77.2	951	83.2	73.2	1133	105.2	79.1
Sedentary time devoted to screen use (min/day)	2084	255.3	161.8	951	285.2	168.0	1143	230.1	152.1
Diet Quality Index (%)	2084	62.9	13.8	961	60.7	14.5	1143	64.8	12.9
20m Shuttle run (stage)	1734	5.2	2.6	810	6.6	2.6	924	3.9	1.9
Handgrip strength (kg) [‡]	1996	30.9	8.7	920	36.2	9.2	1076	26.4	4.8
Handgrip strength (kg/w) [‡]	1996	0.5	0.1	920	0.6	0.1	1076	0.5	0.1
Standing broad jump (cm)	1974	163.9	34.2	909	184.7	30.5	1065	146.2	26.3
Shuttle run 4×10m (seg)	1734	11.0	1.3	810	11.3	1.3	924	10.0	0.9
Body fat (%)	2057	23.4	9.1	921	20.2	10.4	1136	26.0	7.0
Fat free mass (%)	2057	76.6	9.1	921	79.8	10.4	1136	74.0	7.0
Waist circumference (cm)	2083	72.0	8.9	946	74.2	9.7	1137	70.2	7.8

[‡] Mean handgrip right and left. SD, standard deviation

Table 2: Pearson’s correlations (r) among four lifestyle behaviours, namely diet quality, sedentary time devoted to homework, sedentary time devoted to screen use and physical activity in European adolescents

	Sedentary time devoted to homework		Sedentary time devoted to screen use		Moderate-vigorous physical activity	
	r	P	*r*	P	*r*	P
Diet Quality Index	0.141	<0.001	-0.265	<0.001	-0.064	0.003
Sedentary time devoted to homework			0.012	0.137	0.000	0.996
Sedentary time devoted to screen use					-0.037	0.087

Table 3: Mean absolute values of behaviour patterns included in the cluster analysis in European adolescents

Cluster	Cluster 1 Healthy diet & Active	Cluster 2 Healthy diet & Academic	Cluster 3 Healthy diet & Inactive	Cluster 4 Unhealthy diet & Screen user	Cluster 5 Unhealthy diet & Active	F	P*	Partial η^2-value
% (n)	15 (313)	19 (384)	38(801)	17 (350)	11 (236)			
Moderate-Vigorous Physical Activity (min/day)	196.1 (58.2) ^{a,b}	83.3(64.0) ^{a,c}	55.9 (32.5) ^{a}	63.3 (47.5) ^{b,c,d}	219.8 (65.6) ^{a,d}	837.4	<0.001	0.615
Sedentary time devoted to homework (min/day)	72.3 (51.9) ^{a}	216.7 (60.2) ^{a,b,c}	62.5 (39.7) ^{a,d}	70.9 (58.8) ^{b}	74.1 (55.3) ^{c,d}	677.7	<0.001	0.564
Sedentary time devoted to screen use (min/day)	152.8 (86.5) ^{a}	242.6 (132.2) ^{a}	189.1 (89.6) ^{a}	480.0 (159.0) ^{a}	301.7 (148.3) ^{a}	446.1	<0.001	0.460
Diet Quality Index (%)	71.0 (7.4) ^{a,b}	68.9 (10.2) ^{c,d}	66.7 (10.3) ^{a,b,c}	50.4 (14.6) ^{a,c}	48.6 (11.4) ^{b,d}	318.2	<0.001	0.377

Data are means and standard deviations (SD). *Analysis of variance (ANOVA). $^{a, b, c, d}$ Common superscripts in the same row indicate a significant difference (P<0.05). Pairwise comparisons were performed with Bonferroni's adjustment.

Table 4: Association between lifestyle clusters identified and gender, age and health-related fitness in European adolescents

	Cluster 1 Healthy diet & Active	Cluster 2 Healthy diet & Academic	Cluster 3 Healthy diet & Inactive	Cluster 4 Unhealthy diet & Screen user	Cluster 5 Unhealthy diet & Active	X^2/ F	P*	Partial η^2-value
Gender (%(n))								
Boys	17 (161)	13 (124)	33 (316)	21 (204)	15 (146)	88.6	<0.001	-
Girls	13 (152)	23 (259)	43 (485)	13 (146)	8 (91)			
Boys								
Age (%(n))								
Younger (12.5-14.9 years)	21 (117)	14 (74)	30 (163)	19 (104)	16 (86)	23.2	<0.001	-
Older (15-17.5 years)	11 (44)	13 (50)	27 (153)	25 (100)	15 (60)			
20m Shuttle run (z-score)	0.49 (0.98) ^{a,b,c,d}	0.14 (0.93) ^{a}	0.15 (0.94) ^{b}	-0.25 (0.90) ^{a,b,c,d}	0.15 (0.94)^{d}	11.7	<0.001	0.055
Handgrip strength (z-score) ‡	0.21 (0.93)	0.00 (0.95)	0.04 (0.92)	0.06 (1.04)	0.16 (0.91)	1.3	0.268	0.006
Standing broad jump (z-score)	0.22 (0.95)	0.10 (0.96)	0.04 (0.95)	-0.06 (0.91)	0.01 (0.87)	2.1	0.080	0.009
Shuttle run 4×10m (z-score)	0.13 (1.01) ^{a}	-0.19 (0.93)	-0.07 (0.88)	-0.20 (1.00) ^{a}	-0.01 (0.95)	3.2	0.012	0.014
Body fat (%) †	19.1 (0.82)	19.6 (0.92)	20.8 (0.59)	20.7 (0.75)	19.8 (0.88)	0.9	0.457	0.002
Fat free mass (%) †	80.9 (0.82)	80.4 (0.92)	79.2 (0.59)	79.3 (0.75)	80.2 (0.88)	0.9	0.454	0.002
Waist circumference (cm) †	73.5 (0.72)	73.1 (0.80)	74.7 (0.51)	74.4 (0.64)	74.4 (0.75)	0.9	0.407	0.009
Girls								
Age (%(n))								
Younger (12.5-14.9 years)	16 (103)	20 (133)	41 (270)	12 (79)	10 (66)	19.8	<0.001	-
Older (15.0-17.5 years)	10 (49)	26 (126)	44 (215)	14 (67)	5 (25)			
20m Shuttle run (z-score)	0.52 (1.03) ^{a,b,c,d}	0.04 (0.86) ^{a}	0.03 (1.03) ^{b}	-0.12 (0.90) ^{c}	0.05 (0.92) ^{d}	8.0	<0.001	0.033
Handgrip strength (z-score) ‡	0.41 (1.06) ^{a,b,c,}	0.02 (1.01) ^{a}	0.08 (0.94) ^{b}	0.04 (0.95) ^{c}	0.23 (0.90)	4.7	<0.001	0.017
Standing broad jump (z-score)	0.45 (0.99) ^{a,b,c,}	-0.03 (1.01) ^{a}	-0.03 (0.94) ^{b}	-0.19 (0.91) ^{c,d}	0.23 (1.06)^{d}	10.2	<0.001	0.038
Shuttle run 4×10m (z-score)	0.22 (0.95) ^{a,b,c}	-0.16 (0.99) ^{a}	-0.11 (0.95) ^{b}	-0.28 (1.07) ^{c,d}	0.11 (1.02)^{d}	6.2	<0.001	0.023
Body fat (%) †	24.9 (0.56)	26.5 (0.43)	26.3 (0.32)	25.7 (0.57)	25.2 (0.72)	1.8	0.134	0.009
Fat free mass (%) †	75.1 (0.56)	73.5 (0.43)	73.7 (0.32)	74.3 (0.57)	74.8 (0.72)	1.8	0.135	0.009
Waist circumference (cm) †	68.9 (0.61)	69.9 (0.47)	70.5 (0.34)	70.6 (0.62)	71.1 (0.79)	1.9	0.106	0.008

Data are means and standard error (SE), unless otherwise indicated. *Chi-square tests and analysis of variance for category and continuous variables, respectively. ‡ Mean handgrip right and left divided by the weight. †After adjusting for age and height. $^{a, b, c, d}$Common superscripts in the same row indicate a significant difference (P<0.05). Pairwise comparisons were performed with Bonferroni's adjustment.

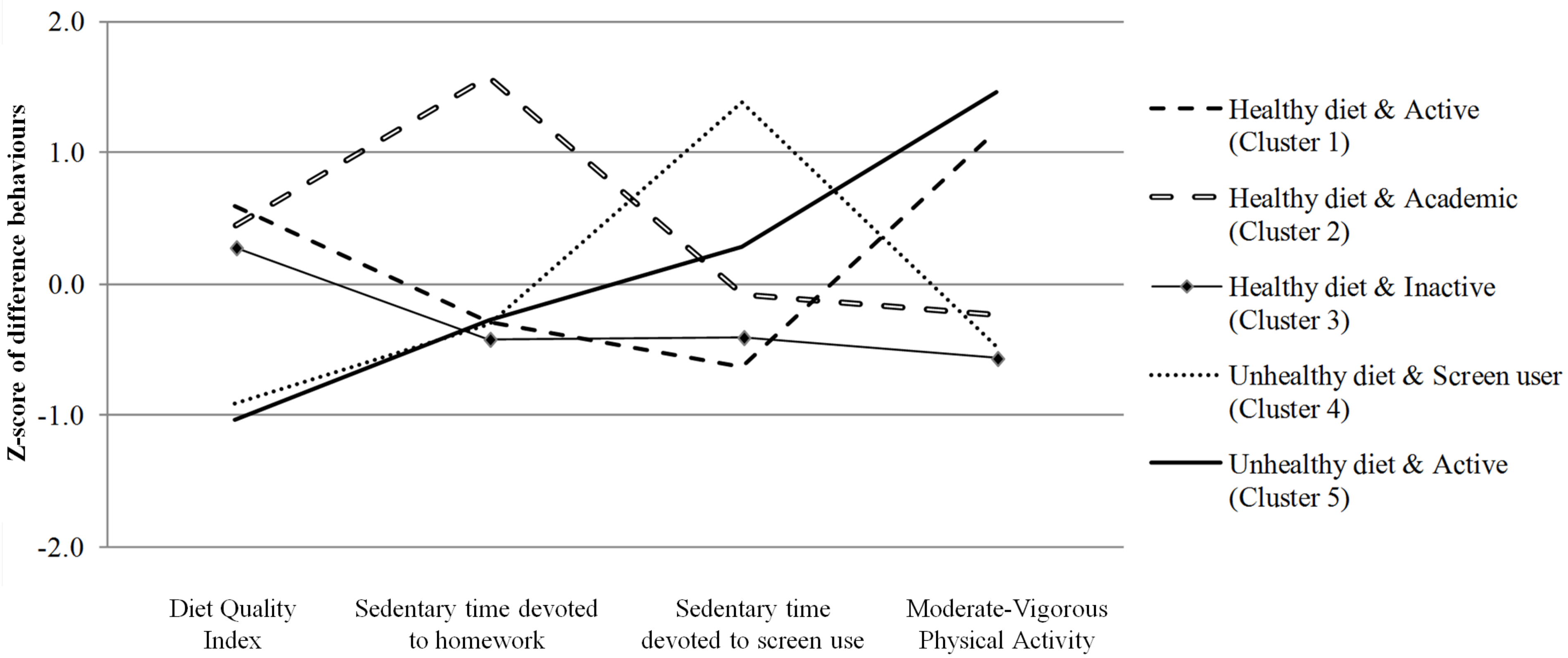


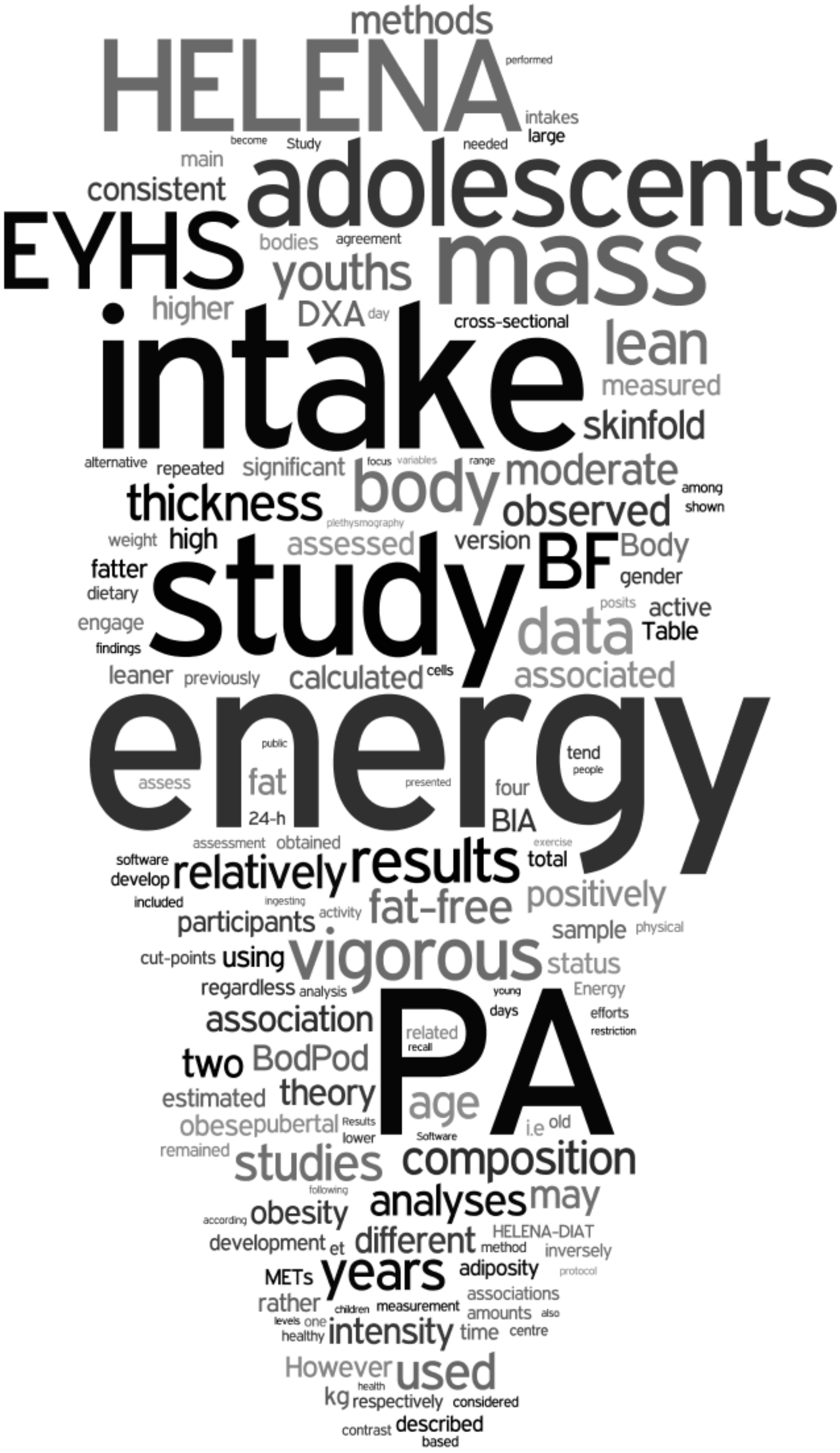
Figure 1: Standard z-scores of the final cluster solution according to the behaviour patterns in European adolescents.

3. Diet, physical activity, body composition and physical fitness

[Dieta, actividad física, composición corporal y condición física]

Studies III-IV *[Artículos III-IV]*

Study III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vigorous
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More physically active and leaner adolescents have higher energy intake: consistent results using different methods and different studies (HELENA and EYHS Studies)

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Sources of financial assistance: The HELENA study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). The EYHS was supported by grants from the Stockholm County Council. This study was also supported by grants from Spanish Ministry of Science and Innovation (AP 2008-03806: RYC-2010-05957; RYC-2011-0901). The content of this article reflects only the authors' views, and the European Community is not liable for any use that may be made of the information contained therein.

Conflicts of interest: The authors report no conflicts of interest.

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.

Keywords: Moderate and vigorous physical activity, body fat percentage, fat-free mass, energy intake, diet.

List of abbreviations: PA: physical activity; HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS: Swedish part of the European Youth Heart Study; BF%: body fat percentage; DXA: dual-energy x-ray absorptiometry; BIA: bioelectrical impedance analysis; BMI: Body mass index.

Abstract

Objective: To test the hypothesis deduced from an alternative theory, which posits that youths who engage in vigorous physical activity (PA) develop lean bodies while ingesting relatively large amounts of energy. For this purpose, we studied the association of both PA and adiposity with energy intake in adolescents.

Study desing: The study comprised adolescents who participated in one of two cross-sectional studies: HELENA study (n=1450, mean age=14.6 years) and EYHS (n=321, mean age=15.6 years). PA was measured by accelerometry and energy intake by 24-h recalls. Body composition was assessed in the HELENA study by two or more of the following methods: skinfold thickness, bioelectrical impedance analysis, plus dual-energy x-ray absorptiometry or air-displacement plethysmography in a subsample; in the EYHS, it was assessed by skinfold thickness.

Results: Body fat percentage (BF%) was inversely associated with energy intake in both studies and using four different methods (all $P \leq 0.006$). Fat-free mass was positively associated with energy intake in the EYHS ($P \leq 0.002$), whereas no significant association was found in the HELENA study. Vigorous PA was positively associated with energy intake in the HELENA study ($P<0.05$), but not in the EYHS. Overall, results remained unchanged after adjusting for potential confounding factors, after mutual adjustment among the main exposures (PA and BF%), and after elimination from the analyses obese participants who might tend to underreport energy intake.

Conclusion: Results are consistent with the hypothesis that more physically active and leaner adolescents have higher energy intakes than less active and fatter adolescents.

Introduction

The prevalence of pediatric obesity has increased for decades in much of the world; although a plateau has been observed in some countries, the prevalence is still high and is a main public health concern[1]. Thus it is important to enhance our understanding of the etiology of obesity so that we can institute effective public health preventive efforts. The classical theory of obesity posits that the main reason that some young people become fatter than others is because of an excessively positive energy balance that is mainly driven by relatively high energy intake; this theory implies that obesity prevention efforts will be most effective if they focus on restriction of energy intake[2]. However, restriction of energy intake in young people may make it difficult to meet the nutritional needs of growth and may also lead to dangerous eating disorders[3]. This may help explain why we have had so much difficulty stemming the obesity epidemic.

An alternative theory is that some youths tend to develop a leaner body composition than others because they participate in more physical activity (PA), especially vigorous PA. One potential mechanism for such a relationship is that the mechanical stimulation of vigorous PA can influence immature stem cells to differentiate into bone and muscle cells, rather than into fat cells. In this formulation, youths who engage in relatively large amounts of vigorous PA will become relatively lean, even though they may have relatively high levels of energy intake[4-5]. In thinking about the development of lean and healthy bodies, it is important that we focus on the balance of fat and lean tissue (i.e., body composition) rather than total body weight; this focus is consistent with the idea that obesity is defined as excessive fatness[4, 6].

One indirect way to cast light on these alternative theories is to determine the associations among PA, adiposity and energy intake in free-living youths. This project tested hypotheses deduced from these two competing theories: (1) the classical theory, which posits that some youths become fatter than others because they ingest relatively large amounts of energy; and (2) an alternative theory, which posits that youths who engage in vigorous PA develop lean bodies while ingesting relatively large amounts of energy. Particularly, we will explore the associations of PA and adiposity with energy intake. We report these associations in European adolescents who participated in two independent cross-sectional studies: the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study and the Swedish part of the European Youth Heart Study (EYHS).

Materials and methods

Study design

The HELENA study is a multi-centre study aiming to obtain reliable and comparable data on nutrition and health-related parameters. Altogether 3 528 adolescents (12.5–17.5 years old) were assessed at schools between 2006 and 2007 in 10 European cities[7]. All procedures involving human participants were approved by the Ethics Committee of each city involved[8].

The EYHS was designed to examine the interactions between personal, environmental, and lifestyle influences on the risk factors for future cardiovascular diseases. Altogether 1 137 children (8.5–10.5 years old) and adolescents (14.5–16.5 years old) were assessed at schools between 1998 and 1999 in two regions of Central Sweden (Orebro and southern Stockholm)[9]. The study was approved by local ethical committees (Huddinge University Hospital nº. 474/98, Örebro City Council nº. 690/98). Written informed consent was obtained from both adolescents and their parents.

For the current study, we selected adolescents from both the HELENA study and the EYHS with data on objectively measured PA (accelerometry), energy intake and information on pubertal status (Tanner staging). A total of 1 450 adolescents from the HELENA study (12.5–17.5 years old) and 321 adolescents from the EYHS (14.5–16.5 years old) met all these criteria and were therefore included in the analyses.

Energy intake assessment

The HELENA-DIAT (Dietary Assessment Tool) 24-h dietary recall software was used to obtain dietary intake data[10]. Dietary intake was divided into six meal occasions and referred to the day before the interview. Adolescents completed the program autonomously in the computer classroom during school time assisted by fieldworkers. Participants were asked to fill in the HELENA-DIAT on arbitrary days, twice in a time-span of 2 weeks. A validation study indicated that the YANA-C, a former version of the HELENA-DIAT, showed good agreement with an interviewer-administered YANA-C interview[11]. The HELENA-DIAT tool has been indicated as a good method to collect detailed dietary information from adolescents and was received well by the study participants[11].

To calculate energy intake, data from the HELENA-DIAT was linked to the German Food Code and Nutrient Date Base (BLS (Bundeslebensmittelschlüssel), version II.3.1, 2005))[12]. The usual energy intake was estimated by the Multiple Source Method (MSM) (https://nugo.dife.de/msm/). Energy intake was calculated as kcal of all food (solid and liquid) and all beverages consumed on the two days recalled. The MSM 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.

In the EHYS, information about energy intake was obtained from a single interviewer-mediated 24-h recall. A food atlas with pictures of common foods and meals in various portion sizes was available during the interview, along with standard household units to help estimate quantities accurately. Data were analysed using software (StorMats, version 4.02; Rudans Lättdata, Västeras, Sweden) based on the Swedish Food Agency’s nutritional database (version 99.1; www.slv.se). Energy intake was calculated as kcal of all food (solid and liquid) and beverages consumed on the day recalled.

Body composition and pubertal status assessment

In the HELENA study, four methods were used to assess body composition: skinfold thickness, Bioelectrical Impedance Analysis (BIA), air-displacement plethysmography (BodPod) and Dual-energy X-ray Absorptiometry (DXA). Methods and protocols used have been described elsewhere[13-14]. Inter-method agreement among these four methods has been previously reported[14]. Skinfold thickness and BIA were measured in the whole sample, while BodPod (N=218, adolescents from Stockholm and Zaragoza) and DXA (N= 200, adolescents from Zaragoza) were measured in two subsamples. In the EYHS, the skinfold thickness method was used to assess body composition. Body mass index (BMI) was calculated by dividing body weight (kg) by the square of height (m^2), and participants were categorized as obese (≥30.0 kg/m²) according to age and gender based cut-off values[15]. Pubertal status was assessed by an experienced physician in the HELENA study and by a trained researcher in the EYHS, as described elsewhere[16].

Skinfold thickness measurement

The triceps and subscapular skinfold thickness were measured three time consecutive times on the left side of the body to 0.2 mm using a Holtain Caliper (Crymmych, UK) according to Lohman's anthropometric standardization reference manual[17]. Body fat percentage (BF%) was calculated by the equation described by Slaughter *et al.*[18] and thereafter fat-free mass in kilograms (kg) was estimated by difference between body weight and fat mass in kg.

Bioelectrical impedance analysis (BIA) measurement

A tetra-polar bioelectrical impedance device (BIA 101 AKERN) was used, and body composition data were obtained using the Bodygram Software V.1.41 (Akern S.r.l. Bioresearch, Pontassieve, Italy) for Windows following the protocol described elsewhere[13]. Body fat and fat-free mass (kg) was estimated according to previously published equations[19] and thereafter BF% was calculated.

Air-displacement plethysmography (BodPod) measurement

BodPod (Body Composition System; Life Measurement, Concord, CA; Software V. 2.3) was used as previously described[20]. The procedure was repeated twice following the protocol described elsewhere[14]. Body density (g/cm^3) from the BodPod was calculated. Fat mass (kg) and

BF% were then estimated from the body density obtained through the Siri's equation[21]. Fat-free mass was calculated by difference between body weight and fat mass in kg.

Dual-energy X-ray Absorptiometry (DXA) measurement

A pediatric version of the software QDR-Explorer (Hologic, Software version 12.4, Bedford, MA) was used in DXA tests. The protocol followed is described elsewhere[22]. Body fat and lean mass in kg were obtained and BF% was calculated.

Physical activity assessment

Detailed descriptions of the PA assessment in the HELENA study and the EYHS can be found elsewhere [23-25]. Briefly, adolescents were asked to wear an accelerometer (ActiGraph®, GT1M, Pensacola, CA, USA) for 7 or 4 consecutive days (HELENA and EYHS, respectively) during all waking hours, except for water-based activities. The time sampling interval (epoch) was set at 15 or 60 s, for the HELENA study and EYHS, respectively. Accelerometer data were analyzed centrally in both studies. At least 3 days of recording with a minimum of 8 or 10 hours of registration per day (HELENA study and EYHS, respectively) were necessary to be included in the study. In both studies, bouts of ≥20 min of consecutive zero counts were deleted from the data. Total PA was expressed as total counts recorded, divided by total daily registered time (counts/min). The time spent in moderate (3–6 metabolic equivalents (METs)) and vigorous (>6 METs) PA was calculated and presented as the average time per day.

Statistical analysis

Energy intake, PA, BF%, fat-free mass and lean mass variables were logarithmically transformed because these variables were skewed. We did not find any significant interaction effect of PA or BF% by sex for energy intake (P>0.05) these analyses included boys and girls together. However, there were significant interaction effects of fat-free mass and lean mass by sex for energy intake in adolescents from the HELENA study and these results are presented separately for boys and girls. To examine the relationships between energy intake and PA, BF%, fat-free mass and lean mass we used multilevel analysis. Energy intake was considered as the dependent variable and PA, BF%, fat-free mass and lean mass as independent variables; covariates included centre (random intercept; just in the HELENA study and except in the DXA analyses because it was used only in one centre), gender, age and pubertal status. All the analyses were performed with different PA intensity levels (i.e. moderate and vigorous PA) and using different methods for assessing body composition (i.e. skinfold thickness, BIA, BodPod and DXA). Finally, analyses were repeated with mutual adjustment for main exposures, i.e.

moderate and vigorous PA were adjusted for BF% while BF%, fat-free mass and lean mass were adjusted for moderate and vigorous PA. Also**,** analyses were repeated to exclude obese participants since research shows that obese participants tend to under-report energy intakes[26]. All analyses were performed using the statistical software PASW for Windows version 18 (PASW Inc., Chicago, IL, USA) and significance was set at $P<0.05$.

Results

The descriptive characteristics of the sample both the HELENA study and the EYHS are presented in **Table I**.

BF% was inversely related to energy intake in the adolescents from the HELENA study **(Table II)** regardless of gender, age, pubertal status, centre and objectively measured PA (all $P\leq0.005$). This association was consistent across the four different methods used to assess BF%: skinfold thickness ($P<0.001$), BIA ($P<0.001$), BodPod ($P<0.001$) and DXA ($P<0.005$). In adolescents from the EYHS **(Table II)**, BF% as assessed by skinfold thickness, was also inversely associated with energy intake regardless of gender, age, pubertal status and objectively measured PA (all $P<0.001$).

We did not find any statistical significant associations between fat-free mass or lean mass and energy intake in any of the considered models in the HELENA study **(Table III).** In contrast, we observed that fat-free mass estimated by skinfold thickness was positively associated with energy intake in the adolescents from the EYHS **(Table III).**

Vigorous PA, but not moderate PA, was positively associated with energy intake in adolescents from the HELENA study, regardless of gender, age, pubertal status and centre ($P<0.001$) **(Table IV)**. Overall, the relationships were slightly attenuated but remained statistically significant after adjusting for BF% assessed by BIA ($P<0.036$), BodPod ($P<0.018$) and DXA ($P<0.050$), but not by skinfold thickness. In the EYHS, moderate PA, but not vigorous, was positively associated with energy intake regardless of gender, age, pubertal status and BF% assessed by skinfold thickness ($P\leq0.006$) **(Table IV)**. As previously reported in adolescents from both the HELENA study[23, 27] and the EYHS[28-29], higher levels of PA were related with lower adiposity (data not shown).

Analyses were repeated after excluding to the obese participants from the study sample and results remained unchanged (data not shown).

Discussion

This study tested hypotheses deduced from two competing theories dealing with the relations among PA, body composition and energy intake. Our main finding was that BF% was inversely, rather than positively, related to energy intake; i.e., the leaner youths tended ingest more energy than the fatter youths. Moreover, we found that young people who engage in PA of relatively high intensity had higher energy intakes. In addition, previous findings from the HELENA study[28-29] and EYHS[23, 27] observed that vigorous PA is inversely associated with adiposity. These results are not consistent with the theory that obesity results from excessive energy intake; rather, they are consistent with the theory that vigorous PA promotes development of leaner bodies, with the result that active youths develop lean bodies while ingesting relatively large amounts of energy and accompanying nutrients needed for healthy growth[4-5].

Our results consistently showed that fatter adolescents had lower energy intakes than leaner adolescents (HELENA study and EYHS), regardless of PA. The fact that the results were consistent in two separate populations and using four different methods to assess body composition strengthens the present study findings. In agreement with our study results, Stallmann-Jorgensen et al.[30] showed a negative association between BF% and energy intake in healthy black and white adolescents aged 14-18 years. They concluded that leaner youths are characterized by higher rather than lower energy intake. Similar results were observed by Fulton et al. in 482 youths[31]. In contrast, other studies did not observe an association between BF% and energy intake in a small sample of adults[32] or, observed a positive association between energy intake and body mass index in children until 5 years old[33].

Fat-free mass and lean mass were not related to energy intake in adolescents participating in the HELENA study, even though accurate methods were used to estimate either fat-free mass (BIA) or lean mass (DXA). However, in the adolescents from the EYHS, a positive association between fat-free mass (estimated by skinfolds thickness) and energy intake was observed. The reasons behind these discrepancies may be explained by age range, which was different between studies (12.5–17.5 years in the HELENA study and 14.5–16.5 years in the EYHS). However, we observed similar results when we performed additional analyses including only those adolescents participating in the HELENA study with age range 14.5–16.5 years. Fulton et al. observed no association between fat-free mass, as assessed by BIA, and energy intake in youths[31]; while in adults, Blundell et al. observed that fat-free mass (measured by BodPod) was positively correlated with meal size and daily energy intake[32]. Lean mass is a metabolically active tissue and it is positively related with metabolic rate. In addition, high-intensity exercise stimulates the development of lean mass and extra energy expenditure at rest, as well as during the exercise. Thus, we would expect that youths who engage in relatively high intensity PA would have higher energy intake than those who engage in PA of lower intensity.

In the HELENA study, vigorous PA was positively associated with energy intake**;** that is, more physically active adolescents were also those that had higher energy intakes. In the EYHS, similar findings were observed but for moderate PA intensity level. This discrepancy could be explained by the different cut-points used to define vigorous PA. Whereas in the HELENA study, the cut-points of 2000 and 4000 counts/min for moderate (3-6 METs) and vigorous (>6 METs) PA, respectively, were used[34]; in the EYHS, an age dependent cut-points were used instead[35]. For the average age of the adolescents from the EYHS (i.e. 15.5 years), the equivalent cut-points would be 1800 and 5100 counts/min for moderate (3-6 METs) and vigorous (>6 METs) PA, respectively. Thus, some of what was moderate PA from the EYHS was considered vigorous PA in the HELENA study. The association observed between vigorous PA and energy intake in the HELENA study was slightly attenuated but remained statistically significant after adjusting for BF%. We have observed in the adolescents participating in the HELENA study that the number of under-reporters increases with increasing body mass index categories (unpublished data). These results are in agreement with the general assumption that overweight/obese individuals tend to underreport more frequently than normal weight people[26]. However, in our study the association between PA and energy intake remained statistically significant even after excluding obese participants from the analyses (data not shown); therefore findings cannot be attributed solely to obese adolescents. Taken together, the data from both studies suggest that PA of relatively high intensity is positively associated with higher energy intake.

Although the results are from cross-sectional analyses, they are consistent with the theory that there is something about PA of relatively high intensity that promotes development of lean bodies[23, 27-29]. One possibility is that the PA increases total energy expenditure, thereby tilting the energy balance equation in a favorable direction. However, reviews of doubly-labeled water studies have been unable to show that variation in total energy expenditure underlies the development of fatness[36]. A new developmental theory is based on the idea that vigorous PA provides the mechanical stimulation needed to stimulate stem cells to differentiate into muscle and bone tissues rather into fat mass, resulting in a healthier body composition[4-5].

In light of these emerging data, obesity treatment focused on a restriction of energy intake may not be generally appropriate for growing youths because they may fail to provide the nutrients needed for optimal growth and may contribute to dangerous eating disorders[3, 37]. In contrast, more attention should be paid to PA of relative high intensity because PA helps to develop healthy bodies driving to increase muscle and bone tissues rather into fat mass[38]. However, PA of moderate intensity may be more appropriate in youths with a low physical fitness level who are starting an exercise program, building up gradually to PA of higher intensity.

Study limitations and strengths

The main one being the cross-sectional design, which precludes definitive causal attributions. Prospective and experimental studies are needed to cast further light on how diet and PA *lead* to development of body composition.

In addition, the EYHS sample, as well as the HELENA sub-samples with BodPod and DXA data, is relatively small. Nevertheless, the associations of energy intake with BF% were consistent despite sample sizes. Methodological differences between the HELENA study and EYHS existed; in the HELENA study, two 24-h recalls were collected and usual energy intake could be estimated using the MSM method; while in the EYHS just one 24-h recall was collected and it was not possible to estimate usual energy intake. Moreover, different cut-points to calculate moderate and vigorous PA were used in both studies.

The possibility of under-reporting energy intake in the fatter youths could be seen as a weakness; energy reporting is notoriously tricky and may be less accurate in overweight subjects. However, it is unclear to what degree this explanations may explain those findings. As we previously mentioned, analyses were repeated after excluding obese participants, who might tend to underreport energy intake, and results remain unchanged (data not shown). In contrast, what is clear is that it is especially difficult to examine the true relationship of energy intake and adiposity in growing children, given the dynamic nature of body size and composition during this life stage.

On the other hand, the four different methods to assess body composition (some of them considered reference methods or gold standard), the use of the objective methodology for PA and the inclusion of two different studies in a single report are strengths of this study. Because some methodological differences existed between the HELENA study and EYHS, data from both studies were analyzed separately instead of pooling them together. The fact that the results from both studies concurred suggests that the study conclusion is consistent regardless of differences in methodology, data collection year, age range (12.5–17.5 years in the HELENA study and 14.5–16.5 years in the EYHS) and geographical origin of the adolescent sample.

Conclusion

Our results support the hypothesis that more physically active and leaner adolescents have higher energy intakes than less active and fatter adolescents. If these cross-sectional results are confirmed by prospective and experimental results, they would suggest that public health efforts that promote physical activity are more likely to be effective in preventing obesity than efforts designed to restrict energy intake.

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Table I. Descriptive characteristics of the European adolescents sample from **HELENA study** and **EYHS**.

	HELENA study									**EYHS**								
	All			Boys			Girls			All			Boys			Girls		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Age (years)	1450	14.6	1.2	651	14.6	1.2	799	14.6	1.2	321	15.6	0.4	141	15.7	0.4	180	15.6	0.4
Height (cm)	1450	165.4	9	651	169.3	9.6	799	162.3	7.1	321	169.6	8.2	141	174.9	7.6	180	165.6	6.1
Weight (kg)	1450	57.6	11.6	651	60.1	13	799	55.5	9.9	320	60.3	10.5	141	63.2	11	179	58	9.6
Body Mass Index	1450	21	3.4	651	20.8	3.5	799	21	3.3	320	20.9	2.9	141	20.6	2.8	179	21.1	2.9
Energy intake (kcal)	1450	2264.6	1006.2	651	2643.5	1106	799	1955.9	793.3	321	2440.1	884.1	141	2908.2	880.3	180	2073.4	695.2
Moderate PA (min/day)	1450	39.3	14.1	651	42.9	15.4	799	36.4	12.1	321	61.4	26.9	141	66.4	31.9	180	57.4	21.6
Vigorous PA (min/day)	1450	18.8	13.5	651	24.3	14.5	799	14.3	10.6	321	13.8	12	141	16.2	12.8	180	11.8	10.9
BF by skinfold (%)*	1450	23.1	9.1	651	19.5	10	799	26	7.1	321	18.9	7.4	141	13.5	5.9	180	23.2	5.3
BF by skinfold (kg)*	1450	13.8	7.9	651	12.5	9.1	799	15	6.6	320	11.6	5.9	141	8.9	5.5	179	13.8	5.2
Fat-free mass by skinfold (kg)	1450	43.7	7.5	651	47.6	8.2	799	40.6	5	320	48.6	8.3	141	54.3	7.5	179	44.2	5.8
BF by BIA (%)	1443	19.8	8.9	647	14.5	7.4	796	24.1	7.6									
BF by BIA (kg)	1443	11.9	7	647	9.3	6.5	796	14	6.7									
Fat-free mass by BIA (kg)	1443	45.6	8	647	50.8	8.5	796	41.5	4.4									
BF by BodPod (%)	218	24.3	8.2	91	20.3	8.5	127	27.2	6.8									
BF by BodPod (kg)	218	14.7	8.2	91	13.2	9.6	127	15.8	6.8									
Fat-free mass by BodPod (kg)	218	42.2	7.1	91	45.7	8.3	127	39.7	4.9									
BF by DXA (%)	200	25.7	7.6	98	21.5	7.3	102	29.8	5.3									
BF by DXA (g)	200	14898.2	6154.3	98	13213.8	6519.1	102	16516.6	5330.2									
Lean mass by DXA (g)	200	40024.6	7601.5	98	44219.2	7906.2	102	35994.5	4510.1									

Analyses are presented as mean ± standard deviation (SD). HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS: European Youth Heart Study; PA: physical activity; BF: body fat; BIA: Bioelectrical impedance analysis; BodPod: air-displacement plethysmography; DXA: Dual energy X-ray Absorptiometry.

*Using Slaughter's equation.

Table II. Associations between energy intake (dependent variable) and body fat percentage calculated by different methods (independent variables) in adolescents from **HELENA study** and **EYHS**.

	N	β	95% CI		P
HELENA study					
Model 1					
BF % by skinfold[*]	1450	-0.224	-0.268	-0.181	<0.001
BF % by BIA	1449	-0.167	-0.202	-0.133	<0.001
BF % by BodPod	218	-0.218	-0.320	-0.116	<0.001
BF % by DXA[†]	200	-0.260	-0.401	-0.119	<0.001
Model 2					
BF % by skinfold[*]	1450	-0.224	-0.268	-0.180	<0.001
BF % by BIA	1449	-0.167	-0.202	-0.133	<0.001
BF % by BodPod	218	-0.217	-0.321	-0.114	<0.001
BF% by DXA[†]	200	-0.251	-0.394	-0.109	0.001
Model 3					
BF % by skinfold[*]	1450	-0.218	-0.262	-0.173	<0.001
BF % by BIA	1449	-0.163	-0.198	-0.128	<0.001
BF % by BodPod	218	-0.200	-0.304	-0.096	<0.001
BF% by DXA[†]	200	-0.214	-0.362	-0.066	0.005
EYHS					
Model 1[†]					
BF % skinfold[*]	321	-0.224	-0.338	-0.110	<0.001
Model 2[†]					
BF % skinfold[*]	321	-0.213	-0.326	-0.100	<0.001
Model 3[†]					
BF % skinfold[*]	321	-0.223	-0.338	-0.107	<0.001

Values were logarithmically transformed before analysis. HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS: European Youth Heart Study; BF%: body fat percentage; BIA: Bioelectrical impedance analysis; BodPod: air-displacement plethysmography; DXA: Dual energy X-ray Absorptiometry.

[*] Using Slaughter's equation.

[†] Not adjusted for centre.

Model 1: Analyses were adjusted for age, gender, pubertal status and centre.

Model 2: Model 1 was additionally adjusted for moderate physical activity.

Model 3: Model 1 was additionally adjusted for vigorous physical activity.

Table III: Associations between energy intake (dependent variable) and fat-free mass or lean mass assessed by different methods (independent variables) in adolescents from **HELENA study** and **EYHS.**

	All					Boys[‡]					Girls[‡]				
	N	β	95% CI		P	N	β	95% CI		P	N	β	95% CI		P
HELENA study															
Model 1															
FFM by skinfold (kg)[*]	1450	0.103	-0.026	0.232	0.118	651	0.120	-0.072	0.312	0.220	799	-0.091	-0.277	0.095	0.336
FFM by BIA (kg)	1449	0.043	-0.092	0.177	0.535	649	-0.048	-0.235	0.138	0.610	800	-0.058	-0.269	0.153	0.591
FFM by BodPod (kg)	218	0.194	-0.079	0.467	0.162	91	0.043	-0.304	0.391	0.804	127	0.260	-0.166	0.687	0.229
Lean mass by DXA(kg)[†]	200	-0.064	-0.356	0.228	0.667	102	0.071	-0.274	0.417	0.683	98	-0.380	-0.871	0.110	0.127
Model 2															
FFM by skinfold (kg)[*]	1450	0.104	-0.025	0.233	0.115	651	0.123	-0.069	0.315	0.208	799	-0.093	-0.279	0.093	0.329
FFM by BIA (kg)	1449	0.045	-0.090	0.180	0.511	649	-0.042	-0.229	0.144	0.657	800	-0.059	-0.270	0.152	0.586
FFM by BodPod (kg)	218	0.196	-0.077	0.470	0.159	91	0.042	-0.304	0.387	0.811	127	0.254	-0.176	0.684	0.245
Lean mass by DXA(kg)[†]	200	-0.069	-0.360	0.222	0.641	102	0.038	-0.301	0.378	0.823	98	-0.382	-0.874	0.110	0.126
Model 3															
FFM by skinfold (kg)[*]	1450	0.092	-0.037	0.221	0.163	651	0.101	-0.091	0.293	0.301	799	-0.106	-0.291	0.080	0.263
FFM by BIA (kg)	1449	0.049	-0.086	0.183	0.477	649	-0.036	-0.222	0.150	0.706	800	-0.064	-0.274	0.146	0.548
FFM by BodPod (kg)	218	0.193	-0.077	0.464	0.161	91	-0.042	-0.374	0.291	0.804	127	0.283	-0.144	0.711	0.192
Lean mass by DXA(kg)[†]	200	-0.064	-0.350	0.223	0.661	102	0.035	-0.288	0.359	0.829	98	-0.367	-0.856	0.122	0.140
EYHS															
Model 1[†]															
FFM by skinfold (kg)[*]	321	0.516	0.210	0.821	0.001										
Model 2[†]															
FFM by skinfold (kg)[*]	321	0.492	0.189	0.794	0.002										
Model 3[†]															
FFM by skinfold (kg)[*]	321	0.488	0.179	0.796	0.002										

Values were logarithmically transformed before analysis. HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS: European Youth Heart Study; FFM: fat-free mass; BIA: bioelectrical impedance analysis; BodPod: air-displacement plethysmography; DXA: Dual energy X-ray Absorptiometry.

[‡] Significant interaction effects of fat-free mass and lean mass by sex for energy intake was observed in adolescents from the HELENA study, thus results were also presented separately for boys and girls.

[*] Using Slaughter's equation.

[†] Not adjusted for centre.

Model 1: Analyses were adjusted for age, gender, pubertal status and centre;

Model 2: Model 1 was additionally adjusted for moderate physical activity;

Model 3: Model 1 was additionally adjusted for vigorous physical activity.

Table IV. Associations between energy intake (dependent variable) and objectively measured physical activity (independent variable) in adolescents from **HELENA study** and **EYHS**.

	N	β	95% CI		P
HELENA study					
Model 1					
Moderate PA	1474	0.017	-0.031	0.064	0.489
Vigorous PA	1474	0.038	0.016	0.060	0.001
Model 2					
Moderate PA	1450	0.009	-0.037	0.055	0.708
Vigorous PA	1450	0.016	-0.006	0.038	0.157
Model 3					
Moderate PA	1449	0.012	-0.034	0.059	0.596
Vigorous PA	1449	0.024	0.002	0.046	0.036
Model 4					
Moderate PA	218	0.017	-0.087	0.121	0.749
Vigorous PA	218	0.059	0.010	0.108	0.018
Model 5					
Moderate PA	200	0.050	-0.049	0.149	0.317
Vigorous PA	200	0.051	0.000	0.102	0.050
EYHS					
Model 1[†]					
Moderate PA	321	0.124	0.042	0.207	0.003
Vigorous PA	321	0.032	-0.007	0.07	0.108
Model 2[†]					
Moderate PA	321	0.114	0.034	0.195	0.006
Vigorous PA	321	0.023	-0.015	0.061	0.234

Values were logarithmically transformed before analysis. HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; EYHS: European Youth Heart Study; PA: physical activity.

[†] Not adjusted for centre.

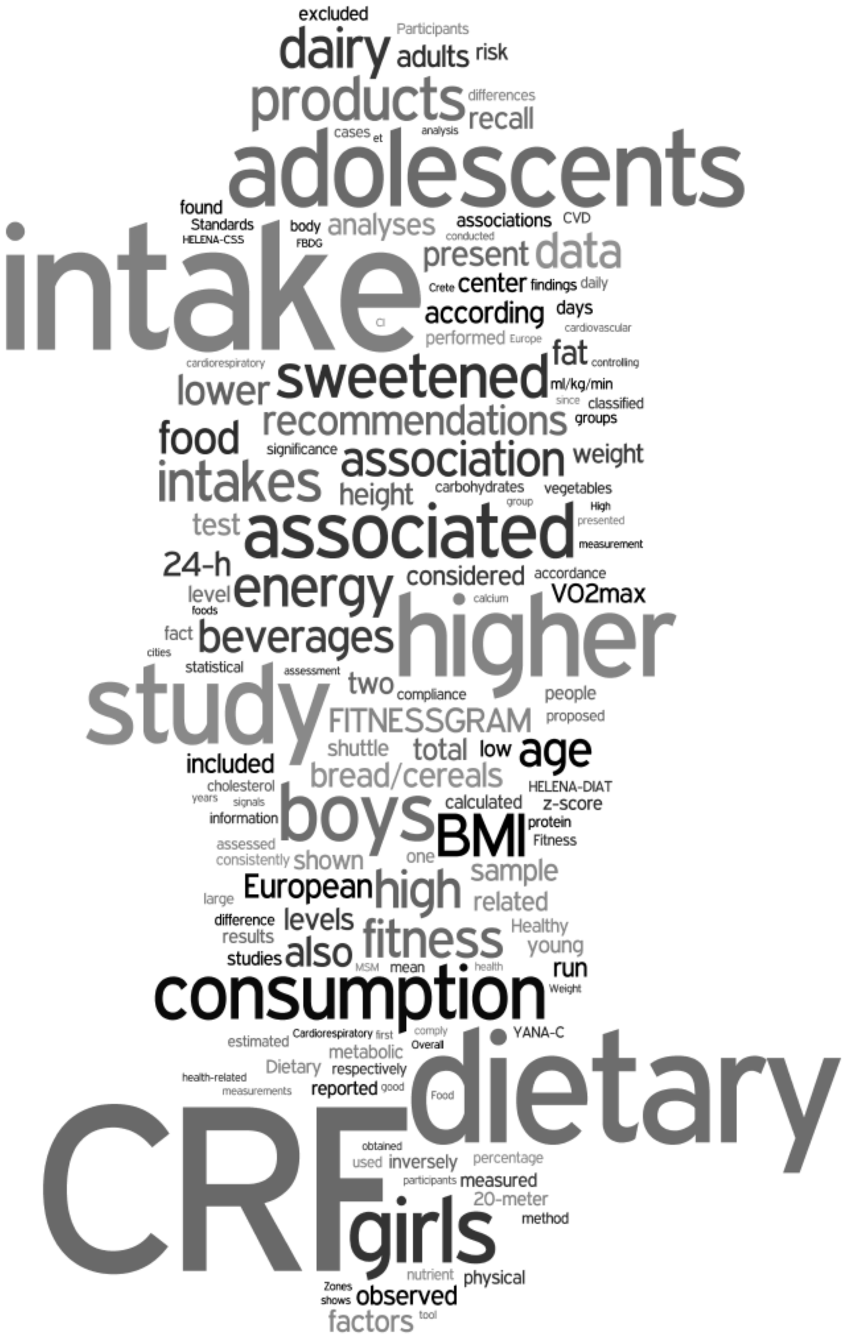
Model 1: Analyses were adjusted for age, gender, pubertal status and centre.

Model 2: Model 1 was additionally adjusted for body fat percentage calculated from skinfold thickness using Slaughter's equation.

Model 3: Model 1 was additionally adjusted for body fat percentage calculated by bioelectrical impedance analysis.

Model 4: Model 1 was additionally adjusted for body fat percentage calculated by air-displacement plethysmography.

Model 5: Model 1 was additionally adjusted for body fat percentage calculated by Dual energy X-ray Absorptiometry (DXA).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Study IV

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

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

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(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.

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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 $P > 0 \cdot 1$) 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/m^2)	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 $P\leq 0·05$. 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 ($P\leq 0·003$).
* 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

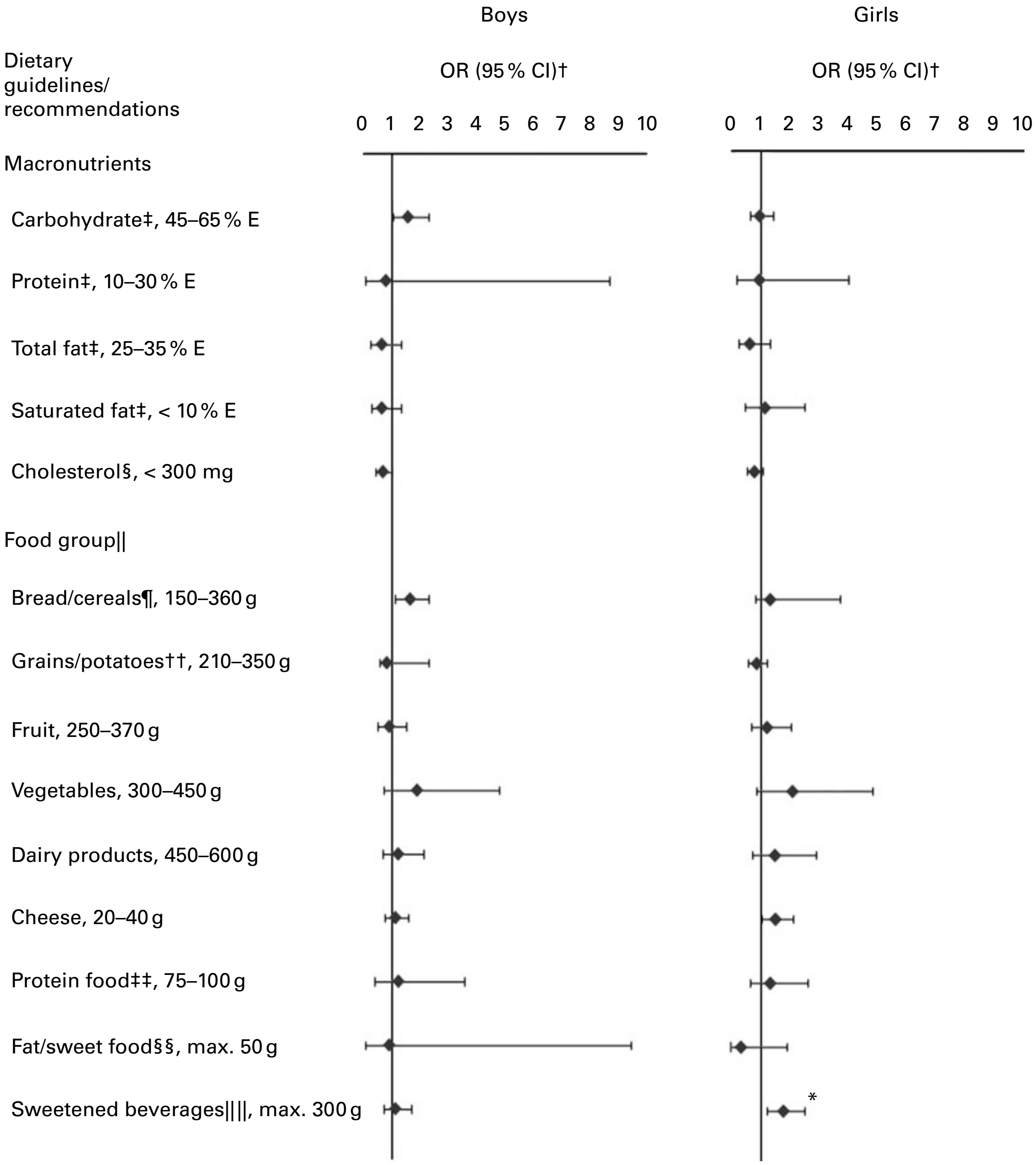

Fig. 1. OR and CI for presenting high cardiorespiratory fitness (CRF) and comply with dietary guidelines/recommendations. References present low CRF and comply with dietary recommendation (vertical lines indicate reference low CRF). † After adjusting for centre and age. ‡ Acceptable macronutrient distribution 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 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.

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4. Specific nutritional aspect, physical activity and cardiovascular profile

[Aspectos nutricionales específicos, actividad física y perfil cardiovascular]

Studies V-VII *[Artículos V-VII]*


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Study V

Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: The HELENA study*

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Running title: Breakfast, physical activity and fitness

Key word: physical activity, sedentarism, aerobic capacity, muscular strenght, speed/agility

NOTE: Submitted to **Public Health Nutr** (Please, see email from the journal in the reverse).

Email from Professor Agneta Yngve
Editor-in-Chief
Public Health Nutrition

Dear Ms. Cuenca-García,

I acknowledge receipt of your paper entitled "Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: The HELENA study," submitted to Public Health Nutrition.

Your paper has been assigned the reference number PHN-2013-006334.

Your paper is being considered for publication and you will be notified of our decision in due course.

If you have any questions, do not hesitate to contact us. Please refer to your paper by the assigned manuscript number.

Thank you for your interest in Public Health Nutrition.

Yours sincerely,

Professor Agneta Yngve
Editor-in-Chief
Public Health Nutrition

Abstract

Objective: To examine the association of breakfast consumption with objectively measured and self-reported physical activity (PA), sedentary time (ST), and physical fitness.

Design: The Healthy Lifestyle in Europe by Nutrition in Adolescence cross-sectional study. Breakfast consumption was assessed by 2 non-consecutive 24h recalls and by a 'Food Choice and Preferences' questionnaire. PA, ST and physical fitness components (cardiorespiratory fitness, muscular fitness and speed/agility) were measured and self-reported. Socioeconomic status was assessed by questionnaire.

Setting: Ten European cities.

Subjects: Adolescents (n=2,148; 12.5-17.5 years).

Results: Breakfast consumption was not associated with measured or self-reported PA. However, 24h recall breakfast consumption was related to measured ST in males and females; although results were not confirmed when using other methods to assess breakfast patterns or ST. Male breakfast consumers had higher cardiorespiratory fitness compared with occasional breakfast-consumers and -skippers, while no differences were observed in females. Overall, results were consistent using different methods (all $P \leq 0.005$). In addition, both male and female breakfast-skippers (assessed by 24h recall) were less likely to have a high measured cardiorespiratory fitness compared with breakfast consumers (OR: 0.33, 95%CI 0.18-0.59 and OR: 0.56; 95%CI 0.32-0.98, respectively). Results persisted across methods. Breakfast consumption was not related to muscular fitness and speed/agility in males and females.

Conclusion: Skipping breakfast consumption does not seem to be related to PA, ST or muscular fitness and speed-agility as physical fitness components in European adolescents; yet it is associated with both measured and self-reported cardiorespiratory fitness, which extend previous findings.

Introduction

Skipping breakfast has been associated with less healthful lifestyle behaviors, including poorer overall dietary quality or food choice and inactive lifestyle in adolescents (1-4). The amount of available energy early in the morning may have an impact on the youths' activity levels in the first part of the day, but also over the whole day (5-6). Several studies showed that adolescents who consumed breakfast regularly were more likely to be physically active compared with their skipper counterparts (6-8). In contrast, other studies did not observe a significant relationship between breakfast consumption and physical activity (2-3, 5). These contradictory findings may be in part due to the different methodology used to assess physical activity (accelerometry vs. questionnaire). The definition of breakfast consumption and the methodology used also vary across studies. In addition, there is not a consensus regarding the best tool to assess breakfast patterns. Thus, studies examining whether the observed associations persist when using different methodologies are warranted. The HEalthy Lifestyle in Europe by Nutrition in Adolescents (HELENA) study (9) includes data on two different methods to assess breakfast consumption in European adolescents: 2 non-consecutive 24h recalls and the 'Food Choice and Preferences' questionnaire, as well as data on objectively measured and self-reported physical activity and sedentary time. Therefore, we were able to examine the association of breakfast consumption with physical activity and sedentary time using two different methods to assess breakfast consumption, as well as physical activity and sedentary time.

Previous findings from the HELENA study showed that regular breakfast consumption, as assessed by the 'Food Choice and Preferences' questionnaire was associated with healthier cardiovascular profile, which included objectively measured cardiorespiratory fitness as a health marker, in European adolescents (10). However, the relation among breakfast and other health-related physical fitness components as muscular fitness and speed/agility have not previously studied. The present study aimed to add to our previous study by (i) using a different method to assess breakfast consumption, namely 24h recall, (ii) including a subjective (self-reported) measure of cardiorespiratory fitness assessed by the International FItness Scale (IFIS) (11) and (iii) analyzing other physical fitness components as muscular fitness and speed/agility.

The major contribution of this study to our previous study and the existing literature is to provide more explanatory information about the association between breakfast with physical activity and sedentary time among measure methods. Therefore, the aims of this study were: first, to examine the association of two different methods to asses breakfast consumption with objectively measured and self-reported physical activity and sedentary time and; second to study the association of breakfast consumption with physical fitness components including cardiorespiratory fitness, muscular fitness and speed/agility both objectively measured and self-reported in European adolescents participating in the HELENA study.

Subjects and Methods

Study design

Data were derived from the HELENA-Cross-Sectional Study (HELENA-CSS). HELENA-CSS is a multi-center study conducted in 10 European cities. A total of 3,528 adolescents (age range 12.5–17.5 years) were assessed at schools between 2006 and 2007 (12). All procedures involving human participants were approved by the Ethics Committee of each involved city (13). Written informed consent was obtained from both adolescents and their parents.

Assessment of self-reported breakfast habit

Breakfast habit was assessed by both a computerized tool for self-reported 24h recalls (HELENA-DIAT (Dietary Assessment Tool)), and by the "Food Choices Preferences" questionnaire.

The 24h recall was conducted on two non-consecutive days. Adolescents completed the program autonomously in the computer classroom during school time (14) assisted by fieldworkers. Dietary intake was divided into six meal occasions (i.e. breakfast, morning snacks, lunch, afternoon snacks, evening meal, and evening snacks). The first question in each meal occasion asked if they had the meal (i.e. breakfast). If they responded "no", they were prompted to an additional question 'You didn't have anything, although small, to eat or drink for breakfast? If the adolescents had breakfast, a drink or something small, they were asked 'Where and with whom did you have breakfast, yesterday?', 'Around what time was that?' and then, adolescents selected the food items consumed from a culturally adapted list; finally, they described the quantity consumed choosing among different pictures. A validation study indicated that the YANA-C, a former version of the HELENA-DIAT, showed good agreement with an interviewer-administered YANA-C interview (k = 0.8–0·92 and 0.38–0.90, respectively) (15) and, that it is a good method to collect detailed dietary information from adolescents (14). We categorized adolescents into 3 groups as follows: 'consumer' if they consumed breakfast on the two 24recall days, "occasional consumer" if they consumed breakfast on one recall day, and 'skipper' if they did not consume breakfast in either of them.

The 'Food Choice and Preferences' questionnaire was developed based on 44 focus groups which explored attitudes and issues of concern among adolescent regarding food choices, preferences, healthy eating and lifestyle (16). Breakfast consumption was assessed based on agreement with the statement: 'I often skip breakfast' with 7 answer categories from strongly disagree (1) to strongly agree (7). Then adolescents were categorized into 3 groups according with Hallstrom et al.(10): 'consumer' if they answered 1-2, 'occasional consumer' if they answered 3-5 and 'skipper' if they answered 6-7.

Assessment of objectively measured and self-reported physical activity and sedentary time

Physical activity and sedentary time were measured during seven consecutive days using accelerometers (Actigraph GT1M, Manufacturing Technology Inc. Pensacola, FL, USA). Adolescents wore the accelerometers on the lower back during the waking hours. Data were saved in 15 second intervals (epochs). Data with periods of continuous zero values for more than 20 minutes were considered 'accelerometer non-wear' periods and were therefore excluded from the analyses. Likewise, registers of more than 20,000 counts per minute were interpreted as a potential malfunction of the accelerometer and were also excluded from the analyses. Data were considered as valid if the adolescents had accelerometer counts for at least 3 days with at least 8 hours of recording time per day (17). Physical activity variables included in this study were: sedentary time and moderate-to-vigorous physical activity (MVPA) in minutes per day, and total physical activity in counts per minute (cpm). Sedentary time and MVPA were calculated according to the standardized cut-off point of <100 and ≥2000 cpm, respectively (17-18). MVPA was dichotomized into <60 (not meeting the physical activity recommendation) and ≥60 min/day (meeting the recommendation) according to the guidelines (19).

Patterns of physical activity were also self-reported using the International Physical Activity Questionnaire for Adolescents (IPAQ-A) (20). IPAQ-A covers four domains of physical activity: school-related physical activity (including activity during physical education classes and breaks), transportation, housework and activities during leisure time. In each of the four domains, the time periods per day (and the numbers of days per week) involved in activities were recorded. Data were cleaned and truncated (21) and afterwards classified into light (i.e. walking), moderate and vigorous activity according to the guidelines for data processing and analyses of IPAQ (http://www.ipaq.ki.se/ipaq.htm). Physical activity variables included in this study were: MVPA and total physical activity (walking + MVPA intensities) as minutes per day. Habitual sedentary time was estimated by the self-reported HELENA sedentary behaviour questionnaire (22-23). HELENA sedentary behaviour questionnaire include daily minutes of the following sedentary items: television viewing, playing with computer games, playing with console games, use of internet for non-study reasons, use of internet for study, and studying/homework (lessons not included). The average time spent per day in those sedentary activities was calculated.

Assessment of objectively measured and self-reported physical fitness

Physical fitness was measured by the following components: cardiorespiratory fitness, muscular fitness and speed/agility. Full description of the tests used has been previously published(24). Briefly, we assessed cardiorespiratory fitness by the *20m* shuttle *run* test; upper-body muscular strength by the *handgrip strength test*; lower-body muscular strength by the *standing broad* *jump* test; speed/agility by the *4x10m shuttle run* test(24).The equation reported by Leger et al. (25) was used to estimate the maximum oxygen consumption (VO_{2max}, ml/kg/min) from the 20m shuttle run test scores. Participants were classified in low and high cardiorespiratory fitness levels according to the FITNESSGRAM Standards for the Healthy Fitness Zones (26). Boys with a VO_{2max} of 42 ml/kg/min or higher were classified as having a high cardiorespiratory fitness level. Girls aged 12 and 13 years with a VO_{2max} of 37 and 36 ml/kg/min or higher, respectively, were classified as having a high cardiorespiratory fitness level. Girls aged 14 or older with a VO_{2max} of 35 ml/kg/min or higher were classified as having a healthy cardiorespiratory fitness level. Upper-body muscular strength was expressed as mean handgrip right and left divided by weight. All tests were performed twice and the best score was retained, while the 20m shuttle run test was performed only once.

Also, subjective physical fitness was assessed using a single-response item included in the International FItness Scale (IFIS, www.helenastudy.com/IFIS) (11). Possible answers range from 1 to 5, which correspond from "very low" to "very high", respectively. Participants were categorized into 2 groups: 'low cardiorespiratory fitness' if they answered 1-3 and 'high cardiorespiratory fitness' if they answered 4-5.

Assessment of Socioeconomic Status

Adolescents completed a self-reported questionnaire developed to collect data about socioeconomic status (27) during classroom time (3). The questionnaire contained information about the educational level of parents and family affluence. Parent's educational level was categorized into the following levels: elementary education, lower-secondary education, higher secondary education and high education or university degree. Family affluence was estimated using a modified version of the family affluence scale (FAS), a scale developed by the WHO collaborative Health Behaviour in School-aged Children (HBSC) Study (28). A sum score of the following items was used: whether the adolescent had his/her own bedroom, the number of cars in the family, the number of computers and the presence of an internet connection at home.

Data analyses

We studied the association of breakfast consumption (i.e. consumer, occasional consumer and skipper) with physical activity, sedentary time and physical fitness using multilevel analysis. Breakfast consumption was entered in the analysis as independent variable, physical activity, sedentary time and physical fitness components as dependent variables, and centre (random intercept), age, parent's education, as well as family affluence as covariates. All analyses were performed with the two different methods to assess breakfast patterns: (i) the computer-based tool for 24h recalls and (ii) the 'Food Choices and Preferences' questionnaire and; with measured and self-reported physical activity, sedentary time and physical fitness. The level of statistical significance was controlled for multiple testing (0.05/number of tests=0.05/10=0.005); therefore, results were considered statistically significant when P≤0.005.

The associations between breakfast consumers and compliance with the physical activity recommendations (at least 60 min of MVPA) and high cardiorespiratory fitness level (FITNESSGRAM Standards for the Healthy Fitness Zones), both measured and self-reported, were examined by binary logistic regression analysis, after controlling for centre, age, parent's education and family affluence. All analyses were conducted using the statistical soft-ware PASW for Windows version 18 (PASW Inc., Chicago, IL, USA).

Results

Table 1 shows breakfast consumption categories and mean estimate of measured and self-reported physical activity and sedentary time by sex in European adolescents. No differences were observed across breakfast consumption categories (assessed by 24h recall or 'Food Choice and Preferences' questionnaire) and mean estimates of measured and self-reported physical activity after adjusting for multiple comparisons (Table 1). However, there was an association between breakfast consumption and sedentary time in both males and females; results were not consistent across the different methods neither in males nor in females. Using the computer-based tool for 24h recalls to assess breakfast patterns and measured sedentary time, male breakfast consumers spent on average ~2% more time in sedentary time compared with occasional breakfast-consumers, yet they spent on average ~8% less time in sedentary time compared with breakfast-skippers (P=0.003). While using the 'Food Choices and Preferences' questionnaire to assess breakfast consumption and self-reported sedentary time, female breakfast consumers spent on average ~4% less time in sedentary time compared with occasional breakfast-consumers, however they spent on average ~13% more time in sedentary time compared with breakfast-skippers (P=0.004) (Table 1).

Tables 2 and 3 show breakfast consumption categories and mean estimates of measured and self-reported physical fitness components by sex in European adolescents. When breakfast habit was assessed by 24h recall, we observed significant associations between breakfast consumption and cardiorespiratory fitness in males, but not in females, after adjusting for multiple comparisons (0.05/10=0.005). Male breakfast consumers had on average ~5% higher measured cardiorespiratory fitness compared with occasional breakfast-consumers and -skippers (P=0.001). Similar results were observed when cardiorespiratory fitness was self-reported (with a borderline difference of P=0.006). The results persisted when breakfast consumption was assessed with the 'Food Choices and Preferences' questionnaire (Table 2). However, both males and females no differences were observed across breakfast consumption categories (assessed by 24h recall or ‘Food Choice and Preferences’ questionnaire) and mean estimates of measured and self-reported muscular fitness and speed/agility after adjusting for multiple comparisons (Table 3)

Finally, odds ratio (OR) and 95% confidence interval (CI) of breakfast consumption categories with meeting the physical activity recommendations and having high cardiorespiratory fitness are presented. Breakfast consumption was not associated with meeting the physical activity recommendations either measured or self-reported, with no difference when using both methods to assess the breakfast patterns (data not shown). However, using the 24h recall to assess breakfast patterns, male occasional breakfast-consumers and -skippers were less likely to have a high measured cardiorespiratory fitness compared with breakfast consumers (OR: 0.46, 95%CI 0.32-0.66 and OR: 0.33; 95%CI 0.18-0.59, respectively; both $P<0.001$) (Figure 1). Similarly, female breakfast-skippers had a lower OR of having high measured (OR: 0.56, 95%CI 0.32-0.98, $P=0.004$) and self-reported (OR: 0.52, 95%CI 0.31-0.89, $P=0.018$) cardiorespiratory fitness than their breakfast consumers peers. Similar results were observed when breakfast consumption was assessed with the ‘Food Choices and Preferences’ questionnaire (Figure 1).

Discussion

The present study results suggest that habitual breakfast consumption is not associated with physical activity in male and female European adolescents. These findings were consistent across the different methods used to assess breakfast consumption (24h recalls on two non-consecutive days or the ‘Food Choice and Preferences’ questionnaire) or physical activity (objectively or self-reported). However, we observed an association between breakfast consumption and measured sedentary time in both males and females; although results were not consistent across methods or gender. On the other hand, habitual breakfast consumption was related to higher cardiorespiratory fitness in males. In addition, male and female breakfast-skippers were less likely to have a high cardiorespiratory independently of the methods used to assess both breakfast consumption and cardiorespiratory fitness. These results extend previous findings observed in the HELENA study (10). Breakfast consumption was not related to muscular fitness and speed/agility in males and females.

We did not find any significant association between breakfast consumption and physical activity, which agrees with a previous study developed by Corder et al. (5). They did not find a significant relationship between eating breakfast and objectively measured physical activity (5). In contrast, other authors showed higher levels of self-reported physical activity in those youngsters who were breakfast consumers (6, 8). The different methodology used to assess physical activity may explain differences among our findings and those previously observed. Our data concur with those that assessed physical activity objectively(5). To the best of our knowledge, this study is the first to explore the association between breakfast consumption and physical activity assessed by two validated methods, accelerometry and IPAQ-A, in the same report. On the other hand, although some associations between breakfast consumption and sedentary time were detected for males and females, the present study does not provide strong evidence that breakfast consumption was related to sedentary time because the results were not consistent across methods nor gender. In addition, we have not found previous studies analyzing the association between breakfast habits and sedentary time, which hamper further comparisons.

Of note is that there is not a consensus about the best tool to assess breakfast patterns, as well as the more appropriate definition of breakfast consumption categories. Definitions of consumer, occasional consumer or skipper breakfast vary between studies. Most of the studies used three categories of breakfast pattern such as ‘always’, ‘sometimes’ and ‘never’ (5-6, 10), whereas others categorized breakfast consumption into two groups, ‘consumer’ and ‘skipper’ (2, 8). Differences in participant’s age may also contribute to explain these different findings. Likewise, there is evidence that younger adolescents were more likely to be breakfast consumer (29-30). The age range of the study sample by Cohen et al. (8 to 16 years) and Sanderdorck et al. (10 to16 years) were lower than in our study sample and they observed a significant relationship between breakfast consumption and physical activity, while we did not find that association (6, 8). On the other hand, socioeconomic status (both parental educational level and family affluence) is an important factor influencing breakfast consumption (2-3, 30); previous studies that showed relation between breakfast consumption and self reported physical activity did not control for in the analysis (6, 8).

The association between breakfast consumption and cardiorespiratory fitness has been recently examined (6, 10), although little information exist as compared with the number of studies exploring the association with physical activity. In the present study, we confirmed that male occasional consumers and breakfast skippers had lower levels of cardiorespiratory fitness than breakfast consumers. We added new data that showed similar results using a validated tool to assess self-reported cardiorespiratory fitness, the IFIS (11). Moreover, we observed that male and female breakfast-skippers were less likely to have a high cardiorespiratory fitness, both objectively measured and self-repotted, than breakfast consumers. This finding concurs with that observed by Sandercock et al.(6), although the authors failed to take into account important potential confounders such as paternal educational levels and family affluence, which are positively associated with either breakfast consumption (2, 30) or fitness (31). In addition, we were the first to study other components of physical fitness, muscular fitness and speed/agility. We observed that breakfast consumption was not related to measured and self-reported muscular fitness or speed/agility in both males and females.

Although higher physical activity is associated with higher cardiorespiratory fitness (32), in our study only cardiorespiratory fitness, not physical activity, was associated with breakfast consumption. In contrast, Sandercock et al. reported that young people aged 10-16 years who regularly ate breakfast had higher levels of both physical activity and cardiorespiratory fitness (6). Although both physical activity and cardiorespiratory fitness were objectively assessed, the measure of physical activity (which is a complex behaviour) is less accurate and valid than the measure of physical fitness, which may overestimate compared with physical activity(33). Moreover, physical fitness is not only influenced by modifiable habits as a healthy diet and physical activity; the genetic factors could also explain differences in physical fitness (34). The amount of available energy early in the morning may have an impact on the youths' activity levels in the first part of the day, but not always over the whole day (5). Thus, adolescent breakfast skippers could get energy in the rest of the meal of the day and to be more active during the afternoon. This hypothesis may explain why we did not find association between breakfast consumption and physical activity, opposite that cardiorespiratory fitness.

Some limitations of the present study need to be mentioned. Lifestyle habits could be different in weekdays and weekends, thus further studies might observe this relation from assessing physical activity and breakfast consumption during weekday and weekends separately. In addition, the cross-sectional study does not allow us to identify causal relationships. On the other hand, a major strength is that this study examines the relationship across breakfast consumption and measured and self-reported physical activity, sedentary time and physical fitness in the same report, and uses different methods to assess breakfast consumption.

Conclusion

Skipping breakfast consumption does not seem to be related to physical activity or sedentary time of European adolescent, neither of some physical fitness components as muscular fitness or speed/agility. Breakfast consumption, however, is associated with both measured and self-reported cardiorespiratory fitness, which extend previous findings.

Acknowledgements

The HELENA-study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). This work 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-2008-03806, RYC-2010-05957; RYC-2011-0901), the Spanish Ministry of Health, Maternal, Child Health and Development Network (number RD08/0072) (LAM), Universidad Politécnica of Madrid (CH/018/2008), and the Swedish Heart-Lung Foundation (20090635). The content of this paper reflect only the authors' views and the rest of HELENA-study members and the European Community is not liable for any use that may be made of the information contained therein. The authors declare that there are no competing interests. All authors have read and have approved the manuscript as submitted. MCG participated in the analysis, interpretation of the results and drafted the manuscript. JRR was involved in manuscript drafting and coordinated the statistical analysis. FBO, IL and MJC contributed to the results interpretation and editing of the manuscript. LAM coordinated the total HELENA study on international level. MGC, LAM, DM, FG, YM, WK, AK, SDH, MS and MJC were involved in the design of the HELENA study and locally coordinated the project. SGM, DC, LH and AW performed the data collection locally.

Figure Legends

Figure 1. Association of breakfast consumption categories with objectively measured and self-reported cardiorespiratory fitness by sex in European adolescents. Values are means and standard error (SE). The level of significance is considered when P≤0.005. All the analysis were adjusted for centre, age, mother's education, father's education and family affluence. †Estimated by Leger's equation. *Assessed by the International FItness Scale (IFIS, www.helenastudy.com/IFIS).

Figure 2. Odds ratios (95% confidential interval) of breakfast consumption categories (assessed by 24h recalls and 'Food Choices and Preference' questionnaire) with having a high cardiorespiratory fitness by sex in adolescents European. References are breakfast consumer and having high cardiorespiratory fitness (vertical lines are reference high cardiorespiratory fitness). All the analysis were adjusted for centre, age, mother's education, father's education and family affluence.

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Table 1. Association of breakfast consumption categories with objectively measured and self-reported physical activity by sex in European adolescents.

	Males (n=733)			Females (n=885)		
	Mean	SE	P	Mean	SE	P
24-h recalls						
Measured PA						
MVPA (min/day)						
Consumer	66.1	2.0		50.8	2.1	
Occasional	68.0	3.0	0.706	53.5	2.6	0.153
Skipper	64.7	4.3		54.7	3.3	
Total PA (cpm)						
Consumer	485.1	13.7		387.0	14.0	
Occasional	503.6	20.2	0.294	395.1	16.9	0.189
Skipper	457.6	28.5		417.6	21.9	
Sedentary time (min/day)						
Consumer	538.9	7.4		549.0	7.8	
Occasional	526.3	11.1	**0.003**	554.9	9.7	0.368
Skipper	583.3	15.7		538.2	12.7	
Self-reported PA						
MVPA (min/day)						
Consumer	115.6	9.8		90.2	9.2	
Occasional	114.4	11.3	0.876	94.3	10.4	0.638
Skipper	110.1	14.0		86.0	12.0	
Total PA (min/day)						
Consumer	172.7	12.5		154.6	13.2	
Occasional	181.5	14.5	0.515	161.1	14.8	0.696
Skipper	166.1	17.9		150.1	17.1	
Sedentary time (min/day)						
Consumer	64.6	4.9		81.8	6.9	
Occasional	53.9	6.2	0.081	79.1	8.1	0.163
Skipper	59.7	8.3		67.6	9.8	
Food Choices and Preferences						
Measured PA						
MVPA (min/day)						
Consumer	63.8	2.2		49.6	2.3	
Occasional	67.8	2.6	0.159	48.5	2.5	0.022
Skipper	66.7	2.7		52.9	2.4	
Total PA (cpm)						
Consumer	476.5	14.8		383.1	14.2	
Occasional	498.6	17.6	0.296	368.4	15.6	0.040
Skipper	490.9	17.9		397.0	14.8	
Sedentary time (min/day)						
Consumer	536.0	9.2		547.4	9.4	
Occasional	526.9	10.6	0.416	552.5	10.1	0.698
Skipper	527.0	10.8		548.9	9.7	
Self- reported PA						
MVPA (min/day)						
Consumer	114.5	9.8		88.5	9.2	
Occasional	128.0	10.4	0.116	94.7	9.7	0.507
Skipper	115.9	10.7		89.9	9.4	
Total PA (min/day)						
Consumer	172.6	12.4		145.5	13.0	
Occasional	187.7	13.2	0.182	159.0	13.7	0.226
Skipper	181.4	13.5		155.5	13.3	
Sedentary time (min/day)						
Consumer	67.6	5.1		85.3	7.1	
Occasional	59.1	5.8	0.022	88.9	7.6	**0.004**
Skipper	56.5	5.8		74.0	7.3	

Variables are means and standard error (SE). The level of significance is considered when $P \leq 0.005$. All the analysis were adjusted for centre, age, mother's education, father's education and family affluence. PA: physical activity, MVPA: moderate and vigorous physical activity, cpm: count per minute.

Table 2. Association of breakfast consumption categories with objectively measured and self-reported muscular fitness and speed/agility by sex in European adolescents.

	Males (n=733)			Females (n=885)		
	Mean	SE	P	Mean	SE	P
24-h recalls						
Measured						
Upper-body muscular strength (kg)*						
Consumer	0.5	0.02		0.6	0.01	
Occasional	0.5	0.03	0.775	0.6	0.02	0.131
Skipper	0.5	0.03		0.6	0.03	
Lower-body muscular strength (cm)†						
Consumer	187.9	2.54		147.3	3.64	
Occasional	183.4	3.11	0.122	144.4	3.97	0.306
Skipper	185.8	4.09		147.0	4.53	
Speed/agility (seg) ‡						
Consumer	11.5	0.16		12.9	0.21	
Occasional	11.6	0.17	0.390	13.0	0.22	0.118
Skipper	11.6	0.20		12.9	0.24	
Self-reported						
Muscular fitness (score)§						
Consumer	3.7	0.04		3.3	0.07	
Occasional	3.7	0.07	0.817	3.2	0.09	0.007
Skipper	3.7	0.11		3.0	0.12	
Speed/agility (score) §						
Consumer	3.9	0.06		3.5	0.08	
Occasional	3.8	0.08	0.030	3.4	0.10	0.441
Skipper	3.7	0.12		3.3	0.13	
Food Choices and Preferences						
Measured						
Upper-body muscular strength (kg) *						
Consumer	0.5	0.02		0.6	0.01	
Occasional	0.5	0.02	0.289	0.6	0.02	0.186
Skipper	0.5	0.02		0.5	0.01	
Lower-body muscular strength (cm) †						
Consumer	185.1	3.77		146.1	4.18	
Occasional	182.3	3.94	0.257	144.7	4.29	0.075
Skipper	182.6	3.97		142.7	4.23	
Speed/agility (seg) ‡						
Consumer	11.5	0.16		12.7	0.22	
Occasional	11.6	0.17	0.053	12.8	0.23	0.062
Skipper	11.6	0.17		12.9	0.22	
Self-reported						
Muscular fitness (score) §						
Consumer	3.8	0.05		3.4	0.07	
Occasional	3.7	0.06	0.748	3.3	0.08	0.020
Skipper	3.8	0.06		3.2	0.07	
Speed/agility (score) §						
Consumer	3.9	0.06		3.5	0.08	
Occasional	3.9	0.07	0.091	3.5	0.09	0.362
Skipper	3.8	0.07		3.5	0.08	

Values are means and standard error (SE). The level of significance is considered when P≤0.005. All the analysis were adjusted for centre, age, mother's education, father's education and family affluence. *Measured by the handgrip strength test (mean handgrip right and left divided by weight). †Measured by the standing broad jump test. ‡Measured by 4×10-m shuttle run. §Assessed by the International FItness Scale (IFIS, www.helenastudy.com/IFIS).

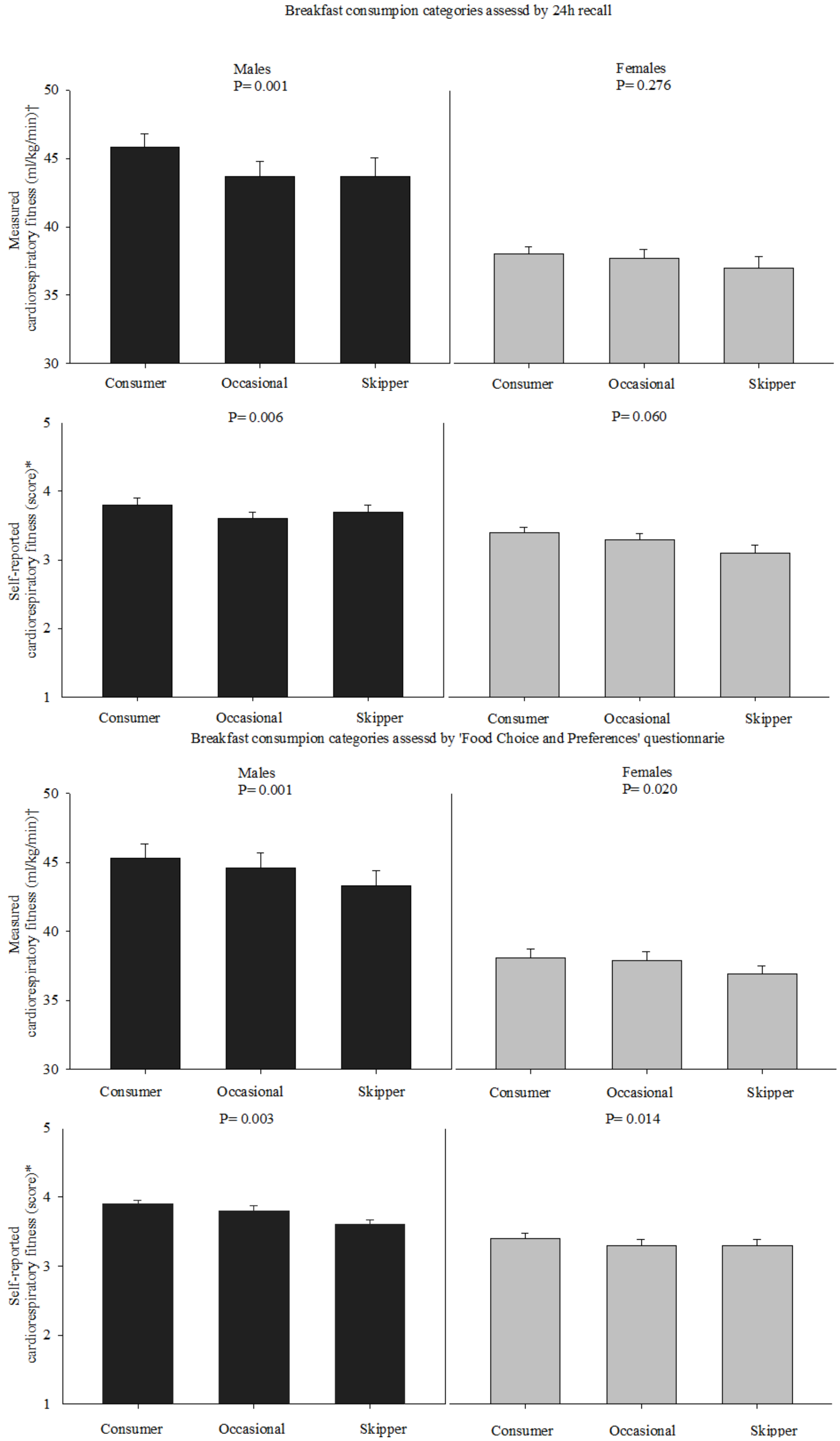


Figure 1. Association of breakfast consumption categories with objectively measured and self-reported cardiorespiratory fitness by sex in European adolescents. Variables are means and standard error (SE). The level of significance is considered when P≤0.005. All the analysis were adjusted for centre, age, mother's education, father's education and family affluence. †Estimated by Leger's equation. *Assessed by the International FItness Scale (IFIS, www.helenastudy.com/IFIS).

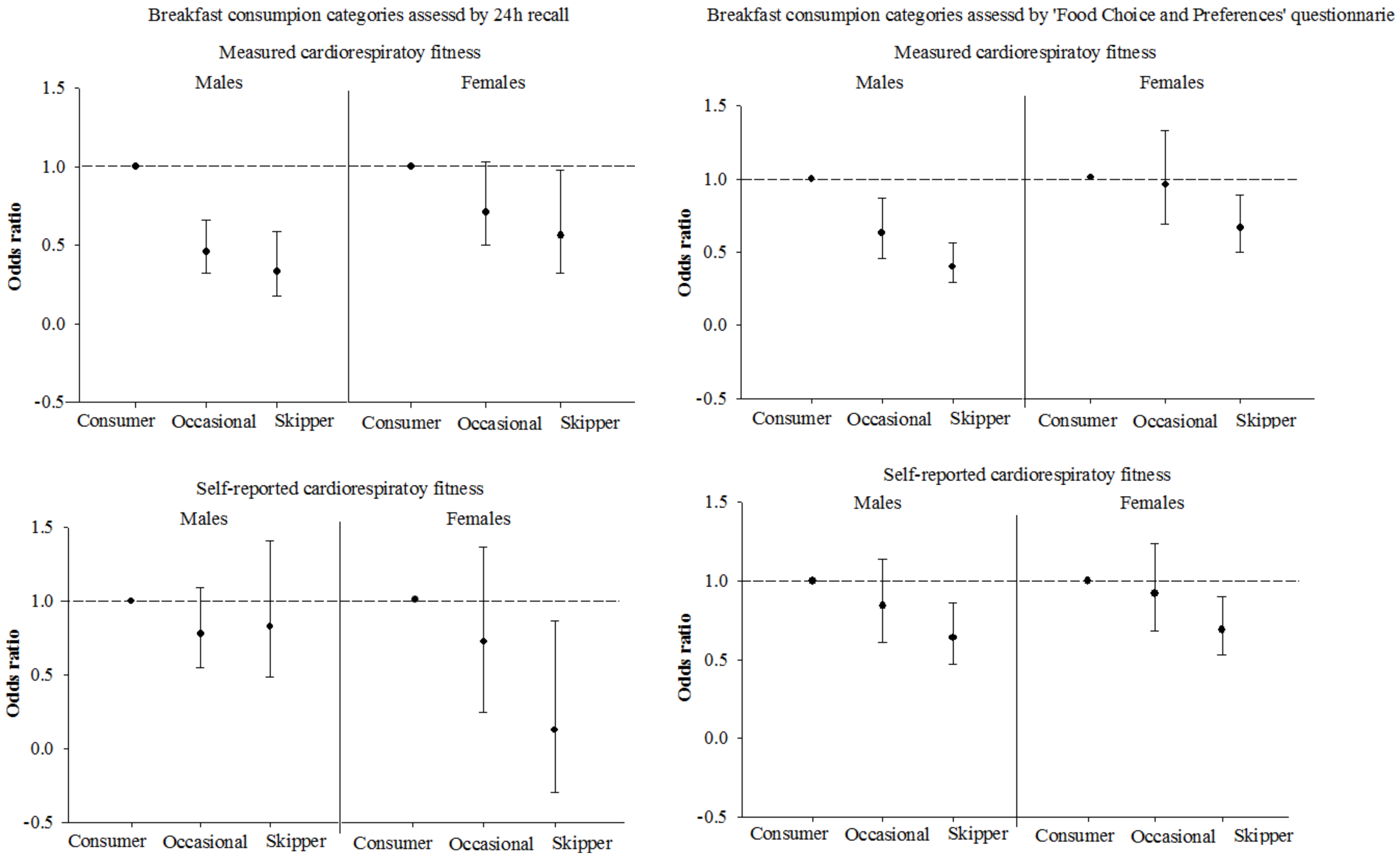
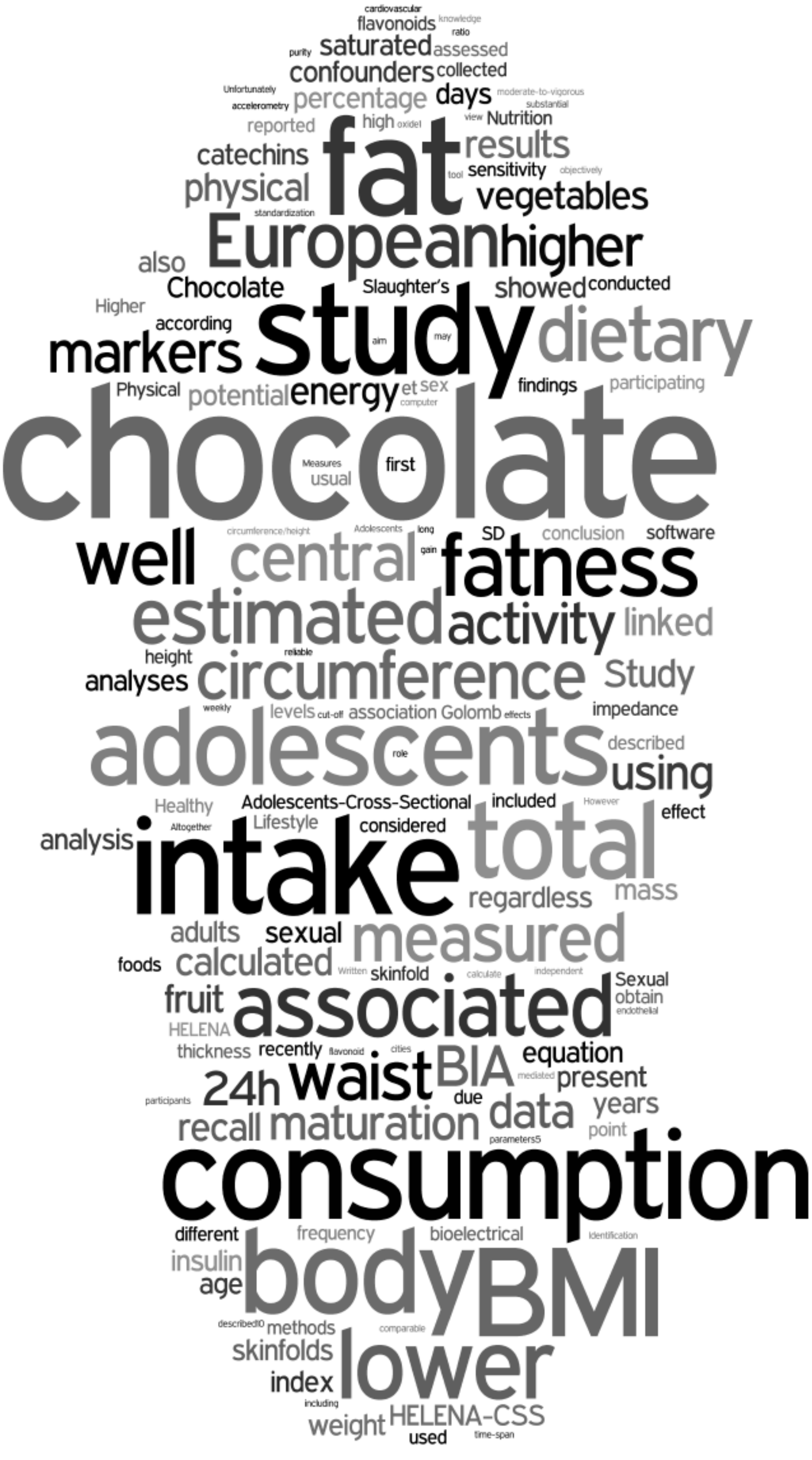


Figure 2: Odds ratios (95% confidential interval) of breakfast consumption categories (assessed by 24h recalls and 'Food Choices and Preference' questionnaire) with having a high cardiorespiratory fitness by sex in adolescents European. References are breakfast consumer and having high cardiorespiratory fitness (vertical lines are reference high cardiorespiratory fitness). All the analysis were adjusted for centre, age, mother's education, father's education and family affluence.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Study VI

Association between chocolate consumption and fatness in European adolescents

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KEYWORDS: Chocolate, body mass index, body fat percentage, waist circumference, HELENA Study

RUNNING TITLE: Chocolate and fatness in adolescents

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14-Feb-2013

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ABSTRACT

Objective: There is a substantial interest in the potential role of chocolate in prevention of cardiovascular diseases. It has been recently reported that a higher frequency of chocolate intake is linked to lower body mass index (BMI) in adults. The aim of the present study was to test if higher chocolate consumption is also associated with lower BMI, as well as other markers of total and central body fat in adolescents.

Design and Methods: This study comprised 1,458 adolescents (12.5-17.5years) participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS). Dietary intake was self-registered using a computer based tool for 24h dietary recall on 2 non-consecutive days. Weight and height were measured, and BMI was calculated. Adiposity was estimated using skinfolds (Slaughter's equation) and bioelectrical impedance analysis (BIA). Waist circumference was measured. Sexual maturation was also collected. Physical activity was measured by accelerometry.

Results: Higher chocolate consumption was associated with lower levels of total and central fatness, as estimated by BMI, body fat estimated from skinfolds and BIA, and waist circumference, regardless of potential confounders ($P \leq 0.01$).

Conclusion: Our results demonstrate that a higher chocolate consumption was associated with lower central and total fatness in European adolescents.

INTRODUCTION

Chocolate consumption has been traditionally linked with sweets, having an abundance of calories in the absence of significant nutrients, and therefore considered an unhealthy food. However, recent reports in adults suggest that chocolate consumption is associated with lower risk of cardiometabolic disorders(1). Chocolate is rich in flavonoids(2). The flavonoids from chocolate, especially catechins, may promote health due to their antioxidant, antihypertensive, anti-atherogenic, anti-thrombotic and anti-inflammatory effects, as well as due to its influence of insulin sensitivity, vascular endothelial function, and activation of nitric oxide (3). A longitudinal study concluded that dietary intake of catechins (predominant in chocolate, fruit, vegetables and tea) is inversely associated with body mass index (BMI) in adult women followed over 14 years, which suggests that flavonoid intake might have a beneficial long term effect on weight maintenance (4). This effect could be in part mediated by an improvement in insulin sensitivity and a decreased insulin levels (5) as well as a decrease in cortisol production (6). Golomb et al. recently reported that a higher frequency of chocolate intake is linked to lower BMI in adults (4).

We hypothesized that chocolate consumption could be also associated with lower BMI as well as other markers of total and central body fat in adolescents. We tested this hypothesis in adolescents from nine European countries participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS).

METHODS

Study design and subject

The HELENA-CSS is a multi-centre study aiming to obtain reliable and comparable data on nutrition and health-related parameters (7). Altogether 3 528 adolescents (12.5-17.5 years old) were assessed at schools between 2006 and 2007 in 10 European cities. All procedures involving human participants were approved by the Ethics Committee of each city involved (8). Written informed consent was obtained from both adolescents and their parents. In the study, a total of 1 458 adolescents (45% males) with valid data on BMI, body fat, waist circumference, sexual maturation and a 2 days 24h dietary recall were included. Age, body weight, height and BMI were higher in the excluded participants than in the included participants (all P<0.02).

Measures

The HELENA-DIAT (Dietary Assessment Tool) 24-h dietary recall software was used to obtain dietary intake data on 2 non-consecutive days, in a time-span of 2 weeks (9). Dietary intake was divided into six meal occasions and dietary intake was referred to the day before the interview.

Adolescents completed the program autonomously in the computer classroom during school time. Fieldworkers were present to give assistance if necessary. To calculate diet intake, data from 24h dietary recall were linked to the German Food Code and Nutrient Date Base. The usual dietary intake of energy (kcal), nutrients and foods (g) was estimated by the Multiple Source Method (10), to account for between and within person variability of the dietary intake data. Chocolate consumption was expressed in grams (g) and included all variety of chocolate (i.e.: white, milk and dark chocolate). Physical activity was measured during 7 consecutive days using accelerometers (11). Data were considered valid if the adolescents had accelerometers counts for at least 3 days with a minimum of 8-h of recording per days. Time spent in moderate-to-vigorous physical activity were calculated according with the standardized cut-off point of ≥2000 counts/min (11-12). Anthropometric measurements of weight, height, waist circumference and triceps and subscapular skinfold thickness were collected as previously described (13). BMI was calculated. Body fat percentage was calculated by the equation described by Slaughter (14) and by bioelectrical impedance analysis (BIA) (13). Sexual maturation was measured according to the methods described by Tanner and Whitehouse (15).

Statistical analyses

Descriptive statistics (mean, standard deviation (SD) and percent) were calculated. All variables were logarithmically transformed before analysis, except body fat measured by BIA (%), because these variables were skewed. There was no gender interaction between chocolate consumption and markers of fatness (all P>0.2), thus analyses were conducted with boys and girls combined. Multilevel analysis was used to examine the relationship between chocolate consumption (exposure) and markers of fatness (outcome), including potential confounders as sex, age, sexual maturation, total energy, saturated fat, fruit and vegetables intake and physical activity. The study centre was included as a random intercept. All analyses were conducted using the statistical software PASW for Windows version 18 (Chicago, IL, USA) and values of P<0.05 were considered statistically significant.

RESULTS

The mean (SD) age of the subjects was 14.6 (1.2) years, BMI was 21 (3.5) kg/m^2, waist circumference/height ratio was 0.4 (0.05) and body fat percentage was 23.2 (9.2) using the Slaughter's equation and 19.8 (8.9) measured by BIA. Adolescents consumed an average (SD) of 24.2 (27.4) g/day of chocolate (**Table 1**). Higher chocolate consumption was associated with lower levels of total and central fatness, as estimated by BMI (β:-0.011, P:0.003), body fat estimated from skinfolds (β:-0.018, P:0.033) and BIA (β:-0.406; P:0.007), and waist circumference (β:-0.006; P:0.011) (**Table 2**), regardless of sex, age, sexual maturation, total energy, saturated fat, fruit and vegetables intake, as well as physical activity. In addition, when analyses were adjusted for tea and coffee consumption, the results remained unchanged (data not shown).

DISCUSSION

Identification of lifestyle factors related to preventing weight and fat gain over the first decades of life is important from a clinical point of view. In the present study we showed that higher chocolate consumption was associated with lower total and central body fat in European adolescents, which concur with the findings showed in the study by Golomb et al. (16) in adults. The fact that the results were consistent when using different markers of fatness such BMI, body fat assessed by skinfold thickness and BIA and waist circumference further strengthens the study findings. Of note is that the observed association was independent of total energy intake and saturated fat intake as well as objectively measured physical activity. In addition, results remained unchanged after adjusting for foods with high catechins concentration as fruit, vegetables and tea; as well other product such as coffee that could influence in the observed inverse association between chocolate consumption and markers of total and central body fat. To our knowledge, this is the first study examining the association of chocolate consumption and markers of fatness in young people. Our findings should be taken with caution due to the cross-sectional nature of this study. Unfortunately, the chocolate purity could not be estimated which might be considered a limitation. The European sampling and high standardization of the measures in the HELENA study, as well as the inclusion of two different methods to assess fatness, instead of just BMI, are notable strengths of this study.

In conclusion, the results of the present study showed that a higher chocolate consumption was associated with lower levels of central and total fatness in European adolescents, regardless of a set of relevant confounders.

ACKNOWLEDGEMENTS

The HELENA study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). This study was also supported by grants from Spanish Ministry of Science and Innovation (AP 2008-03806: RYC-2010-05957; RYC-2011-0901). The content of this article reflects only the authors’ views, and the European Community is not liable for any use that may be made of the information contained therein. 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.

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Table 1. Descriptive characteristic of the study sample by sex

	All (n=1458)		Boys (n=657)		Girls (n=801)	
	Mean	SD	Mean	SD	Mean	SD
Sex (%)	100		45		55	
Age (years)	14.6	1.2	14.6	1.2	14.6	1.2
Height (cm)	165.4	9.0	169.2	9.7	162.3	7.1
Weight (kg)	57.6	11.7	60.1	13.1	55.6	10.0
Body mass index (%)	21.0	3.5	20.8	3.5	21.1	3.4
Tanner (I/II-IV/VI) (%)	(-/71/29)		(1/73/26)		(-/70/30)	
Waist circumference (cm)	71.6	8.3	73.3	8.7	70.2	7.6
Waist circumference/height ratio	0.4	0.0	0.4	0.0	0.4	0.0
Body fat by skindolf (%)	23.2	9.2	19.6	10.1	26.1	7.2
Fat mass index (kg)[1]	5.1	2.9	4.4	3.2	5.7	2.5
Body fat by BIA (%)	19.8	8.9	14.6	7.4	24.2	7.7
Body fat by BIA (kg)	12.0	7.1	9.4	6.5	14.1	6.8
MVPA (min/d)	57.9	23.5	67.0	25.3	50.4	18.8
Energy (kcal/d)	2200.6	785.7	2550.2	855.3	1913.8	584.5
Saturated fatty acids (g/d)	34.3	14.9	39.5	16.2	30.1	12.3
Fruit (g/d)	130.9	97.0	131.9	103.5	130.1	91.3
Vegetables (g/d)	91.4	54.2	91.4	58.0	91.5	50.9
Chocolate consumption (g/d)	24.2	27.4	28.5	32.0	20.6	22.3

BIA, bioelectrical impedance analysis; MVPA, moderate-to-vigorous physical activity; SD, standard deviation. [1] Fat mass index was estimated as a fat mass (kg) divided by height (m).

Table 2. Association between chocolate consumption and markers of fatness in adolescents participating in the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (n=1 458)

	Chocolate consumption				
Markers of fatness (outcome)	*B*	95% CI		P^1	P^2
Body mass index (kg/m^2) †	-0.011	-0.018	-0.004	0.003	0.003
Body fat by skinfold (%) †	-0.018	-0.035	-0.001	0.040	0.033
Fat mass by skinfold (kg) §†	-0.029	-0.052	-0.006	0.015	0.012
Body fat by BIA (%) ‡	-0.406	-0.814	-0.109	0.010	0.007
Fat mass by BIA (kg) §†	-0.042	-0.071	-0.013	0.005	0.004
Waist circumference (cm) §†	-0.006	-0.011	-0.001	0.013	0.011

β: standardized coefficients; BIA, bioelectrical impedance analysis; CI: confidence interval. Variables were logarithmically transformed before analysis, except body fat measured by BIA (%).

†The standardized coefficients are interpreted as the number of SDs that the outcome (markers of fatness) changes as a result of 1-SD change in the predictor (chocolate).

‡The standardized coefficients are interpreted as the % that the outcome (marker of fatness) changes as a result of 1-SD change in the predictors (chocolate).

[1] Model 1: Analyses were adjusted for center, sex, age, sexual maturation, total energy intake, saturated fat, fruit and vegetables.

[2] Model 2: Analyses were additionally adjusted for objectively measured moderate-to-vigorous physical activity.

§Models additionally adjusted for height.


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Study VII

Nutr Hosp Vol. 27. Suplemento 3. Diciembre 2012

Ingesta de huevo y factores de riesgo cardiovascular en adolescentes; papel de la actividad física. Estudio HELENA

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Resumen

Introducción: **Las enfermedades cardiovasculares (ECVs) suponen la principal causa de morbi-mortalidad en los países occidentales. El incremento del colesterol plasmático se ha relacionado con el desarrollo de ECV. El huevo, por su alto contenido en colesterol, ha sido indirectamente relacionado con el riesgo de desarrollar ECVs.**

Objetivo: **Examinar la asociación entre ingesta de huevo y perfil de riesgo cardiovascular en adolescentes, estudiando si dicha relación está influenciada la actividad física.**

Método: **Se estudiaron 380 adolescentes pertenecientes al estudio HELENA (HEalthyLifestyle in EuropebyNutrition in Adolescence). La ingesta de alimentos se estimó mediante anamnesis nutricional de dos días no consecutivos. Se midieron indicadores de adiposidad, perfil lipídico, glucosa, insulina, resistencia a la insulina, tensión arterial y capacidad aeróbica. Se calculó un índice integrado de riesgo cardiovascular (IRCV) como medida del perfil cardiovascular global. La actividad físicase midió mediante acelerometría. El estatus socioeconómico y consumo de tabaco se obtuvieron mediante cuestionario. La asociación entre ingesta de huevo y factores de riesgo de ECV se examinó mediante un modelo de regresión multinivel ajustado por factores de confusión.**

Resultados: **La ingesta de huevo no se asoció con perfil lipídico, nivel de adiposidad, tensión arterial, resistencia a la insulina, capacidad aeróbica o IRCV (todos P > 0,05). Esta falta de asociación no estuvo influenciada por el nivel de actividad física.**

Conclusiones: **No existe asociación entre ingesta de huevo y perfil lipídico, adiposidad, resistencia a la insulina, tensión arterial, capacidad aeróbica o el IRCV en adolescentes. La actividad física no influencia dicha falta de asociación.**

Nutr Hosp 2012; 27 (Supl. 3):3-12

Palabras clave: *Huevos. Colesterol. Enfermedades cardiovasculares. Actividad física.*

EGG INTAKE AND CARDIOVASCULAR RISK FACTORS IN ADOLESCENTS; ROLE OF PHYSICAL ACTIVITY. THE HELENA STUDY

Abstract

Introduction: **Cardiovascular diseases (CVDs) represent the main cause of morbi-mortality in occidental countries. Serum cholesterol levels have been related to cardiovascular disease (CVD). Egg intake has been indirectly related to the risk of developing CVD because of its high cholesterol content.**

Objective: **The aim of the present study was to examine the association between egg intake and CVD risk factors in adolescents, assessing the possible influence of physical activity.**

Methods: **We studied 380 adolescents enrolled in the HELENA (HEalthy Lifestyle in Europe by Nutrition in Adolescence) study. Food intake was estimated by 2 non-consecutive 24 h recalls. We measured adiposity indicators, lipid profile, blood glucose and insulin levels, insulin resistance, blood pressure and cardiorespiratory fitness. A CVD risk score was computed as a measure of the overall CVD risk profile. Physical activity (PA) was objectively measured by accelerometry. Sexual development was examined. Socioeconomic and smoking statuses were obtained by questionnaire. The association between egg intake and CVD risk factors was examined using a multilevel analysis adjusted for potential confounders.**

Results: **Egg intake was not associated with lipid profile, adiposity, insulin resistance, blood pressure, cardiorespiratory fitness or the integrated CVD risk score. This lack of association is not influenced by physical activity.**

Conclusions: **The findings of the present study suggest that egg intake is not associated with a less favorable lipid or CVD risk profile in adolescents. This lack of association is not influenced by physical activity level.**

Nutr Hosp 2012; 27 (Supl. 3):3-12

Key words: *Eggs. Cholesterol. Cardiovascular diseases. Physical activity.*

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Introducción

Las enfermedades cardiovasculares (ECVs) constituyen un problema de Salud Pública y representan la mayor causa de morbi-mortalidad en España y en la mayoría de los países occidentales[1]. La Organización Mundial de la Salud estima que más del 50% de la mortalidad total en el mundo será debida a cáncer y ECVs en 2030[2]. A pesar de que las manifestaciones clínicas de la ECV aparecen en la edad adulta, su inicio puede remontarse a etapas mucho más precoces de la vida, tales como la adolescencia o incluso la infancia[3,4]. Existen numerosos factores de riesgo para desarrollar ECV entre los que se incluyen alteraciones del perfil lipídico, resistencia a la insulina, hipertensión, sobrepeso y obesidad, parámetros inflamatorios elevados, poca actividad física o bajo nivel de condición física. Resultados de estudios longitudinales muestran que la alteración temprana de muchos de esos factores de riesgo persiste a lo largo del tiempo, llegando hasta la vida adulta[5].

El desarrollo de las ECVs está influenciado por factores no modificables tales como la edad, el sexo, o los condicionantes genéticos, y por factores modificables, como la inactividad física, el tabaco, el alcohol o una dieta poco saludable[6]. Dentro de los factores nutricionales existe un extenso debate acerca de la relación entre la ingesta de colesterol en la dieta y el incremento de colesterol plasmático, especialmente de colesterol unido a lipoproteínas de baja densidad (c-LDL)[7,8]. En este sentido, las recomendaciones nutricionales de la Asociación Americana del Corazón[9]limitan el consumo de colesterol a menos de 300 mg/d. Dado que un huevo grande contiene ~210 mg de colesterol por unidad (71% de la cantidad diaria recomendada)[6], se recomienda restringir la ingesta de huevo, a menos que la ingesta de colesterol por otras fuentes de la dieta (como carne de cerdo, aves o productos lácteos) sea limitada[9]. Sin embargo, el huevo representa un alimento de bajo coste económico y muy completo, rico en proteínas de alto valor biológico, minerales, folatos y vitaminas del grupo B, que podrían disminuir el riesgo de desarrollar ECVs. Tradicionalmente, la ingesta de huevoha tendido a asociarse indirectamente con un mayor riesgo de ECVs por su alto contenido en colesterol[10,11]. No obstante, estudios recientes han puesto de manifiesto que no hay asociación entre una ingesta de huevo inferior a 7 huevos por semana e incidencia de ECVs en adultos sanos[12-15]. Conocer la asociación entre la ingesta de huevo y los factores de riesgo de ECV en personas jóvenes tiene por tanto un interés clínico y de Salud Pública pues permitiría re-definir las recomendaciones de ingesta ya desde las primeras etapas de la vida.

Existe suficiente evidencia científica que indica que las personas que son físicamente activas tienen un menor riesgo de desarrollar ECVs[16], así como una mayor esperanza y calidad de vida. Estimaciones recientes sugieren que tanto la falta de actividad física como una dieta no saludable son dos claros factores determinantes no sólo de ECV, sino también de muchas otras enfermedades. Importantes instituciones de Salud Pública tales como el Servicio Americano de Salud y la Organización Mundial de la Salud recomiendan que los niños y adolescentes realicen 60 minutos al día de actividad física de intensidad moderada-vigorosa. Este nivel de intensidad está asociado con un mejor perfil cardiovascular así como un mejor estado de salud mental en adolescentes. Se desconoce, sin embargo, si alcanzar las recomendaciones de actividad física podría modificar el patrón de asociación entre ingesta de huevo y factores de riesgo de ECV en adolescentes.

Objetivos

Los objetivos del presente estudio fueron: 1) estudiar la asociación entre ingesta de huevo y el perfil de riesgo cardiovascular en adolescentes europeos involucrados en el estudio HELENA (HEalthyLifestyle in Europeby-Nutrition in Adolescence); y 2) determinar el papel que la actividad física ejerce en la relación entre ingesta de huevo y perfil cardiovascular en adolescentes.

Método

Diseño

El presente trabajo forma parte del estudio transversal HELENA (http://www.helenastudy.com)[17], diseñado para evaluar el estilo de vida y estado nutricional de una amplia muestra de adolescentes europeos de nueve países. La recogida de datos tuvo lugar desde 2006 a 2008 en diez ciudades europeas: Atenas y Heraklion (Grecia), Dortmund (Alemania), Ghent (Bélgica), Lille (Francia), Pecs (Hungría), Roma (Italia), Estocolmo (Suecia), Viena (Austria) y Zaragoza (España). La descripción detallada del diseño del estudio HELENA, así como los criterios generales de reclutamiento de los participantes, criterios de inclusión, proceso de estandarización de los parámetros evaluados, y control de calidad ha sido previamente publicada[17].

El estudio fue aprobado por el Comité de Ética de cada centro participante y siguió las recomendaciones de la Declaración de Helsinki 1961 (revisión de Edimburgo, 2000). Todos los participantes, así como sus responsables legales, fueron informados del propósito del estudio y firmaron su consentimiento expreso.

Participantes

De los 3.528 adolescentes (entre 12,5 y 17,5 años) inicialmente incluidos en el estudio HELENA, aproximadamente un tercio (n = 1089) fueron seleccionados aleatoriamente para la obtención de muestras de sangre.

Registro de alimentos

La ingesta de alimentos se estimó mediante un recuerdo de 24 horas realizado en 2 días no consecutivos, a través del programa informático *HELENA DIAT* (HealthyLifestylein EuropebyNutrition in Adolescence-DietaryAssessmentTool), validado para su uso en adolescentes y traducido a varios idiomas[18]. Los participantes fueron debidamente informados sobre el uso del programa, y completaron el recuerdo de forma autónoma en un aula computerizadadurante el tiempo de clase lectiva, y bajo la supervisión de investigadores con experiencia para resolver cualquier pregunta. Dicho recuerdo se dividió en seis comidas correspondientes al día previo a cada registro.

A partir de los datos derivados del programa HELENA DIAT se estimó ingesta energética total y nutrientes a partir de una base de datos de alimentos alemana (German FoodCode and NutrientDatabase; Bundeslebensmittelschlussel, version II.3.1, 2005)[19]. La ingesta alimentaria habitual se estimó mediante el 'Multiple Source Method' (http://nugo.dife.de/msm/)[20]. Este método calcula en primer lugar la ingesta diaria de los individuos, y después construye la distribución de la población, basándose en los valores individuales, y teniendo en cuenta la variabilidad intra e interindividual.

La ingesta energética total se expresó en Kcal/d, mientras que la ingesta de grasas saturadas, mono-insaturadas y poli-insaturadas, colesterol y fibra presentes en la dieta, ingesta de verduras y consumo de alcohol se expresó en g/d. La presencia de vitaminas C y E en la dieta se expresó en mg/d. Finalmente, la ingesta de huevo se expresó en g/d.

Características antropométricas

Las medidas antropométricas se tomaron con los participantes descalzos y en ropa interior, siguiendo el manual de referencia estandarizado[21]. El peso se midió utilizando una báscula electrónica (SECA 861) hacia la décima (0,1 kg) más cercana. La altura se midió en el plano de Frankfort con un tallímetro telescópico (SECA 225) hacia la décima (0,1 cm) más cercana. El índice de masa corporal (IMC) se calculó dividiendo el peso (kg) entre el cuadrado de la talla (m) (peso/talla^2) y se ajustó por edad y género para obtener un IMC estandarizado (IMC z-score). El perímetro de cintura se midió en el punto medio entre la última costilla y la cresta ilíaca utilizando una cinta antropométrica no elástica (SECA 200). El grosor de los pliegues cutáneos bíceps, tríceps, subescapular y suprailíaco, se midió con un plicómetro(Holtaincaliper). A continuación se calculó el porcentaje de grasa corporal, mediante las ecuaciones de Slaughter y cols.[22], y el índice de masa grasa, dividiendo la masa grasa (kg) entre la altura (m) al cuadrado (masa grasa/altura^2). Todas las medidas fueron tomadas por triplicado y se calculó la media para cada uno de los parámetros medidos. El desarrollo madurativo se evaluó por un médico especialista siguiendo la metodología descrita por Tanner y Whitehouse[23], basada en el desarrollo genital y vello púbico en niños, y en el desarrollo mamario y vello púbico en niñas.

Tensión arterial

La tensión arterial sistólica (TAS) y diastólica (TAD) fueron medidas mediante un dispositivo automático de tensión arterial (OMRON M6, OMROM HealthCare Co., Ltd., Kyoto, Japan) colocado en el brazo izquierdo a la altura de la arteria braquial. Se realizaron dos mediciones separadas por 10 minutos, y se utilizó la medida más baja expresada en milímetros de mercurio (mmHg). La tensión arterial media (TAM) se calculó mediante la fórmula: TAM = (TAS-TAD/3) + TAD.

Análisis bioquímico

La metodología detallada de la extracción de sangre, transporte y procesamiento de las muestras ha sido previamente publicada[24]. Brevemente, se tomaron muestras de sangre en ayuno (8:00 h) mediante punción venosa y fueron analizadas de forma centralizada en un mismo laboratorio analítico.

Se midieron triglicéridos (TG), colesterol total (CT), colesterol unido a lipoproteínas de alta densidad (c-HDL), c-LDL, y glucosa con el analizador DimensionRxL (DadeBehring, Schwalbach, Germany) mediante métodos enzimáticos, utilizando los reactivos e instrucciones del fabricante. La concentración de apolipoproteína A1 (Apo A1) y apolipoproteína B (Apo B) se midió en reacción inmunoquímica mediante analizador BN II (Dade-Behring, Schwalbach, Germany) siguiendo las instrucciones del fabricante. Se calcularon las ratios CT/c-HDL, c-HDL/c-LDL y Apo B/Apo A1. La concentración de insulina se analizó mediante ensayo inmunométricoquimioluminiscente de fase sólida, empleando el analizador Immulite 2000 (DPC BiermannGmbH, BadNauheim, Germany). La resistencia a la insulina se calculó a través del índice HOMA (del inglés, homeostasis model assessment), mediante el producto de la glucosa (mg/dL) y la insulina (µU/mL) dividido por la constante 405[25].

Capacidad aeróbica

La capacidad aeróbica se evaluó mediante el test de Course-Navette o test de 20 m de ida y vuelta[26]. Este test consistió en correr entre 2 líneas separadas por 20 m, manteniendo la intensidad marcada por una señal sonora grabada en CD. La velocidad inicial fue de 8,5 km/h, y fue incrementando en 0,5 km/h cada minuto (1 min = 1 palier). Los participantes debían correr en línea recta, pivotar sobrepasando la línea, y volver hacia la línea opuesta en el tiempo que marcaba la señal sonora. El test finalizó cuando el adolescente se detenía a causa de la fatiga o no conseguía sobrepasar la línea en el tiempo marcado en 2 ocasiones consecutivas. Se registró el último palier (o medio palier) completado por cada participante. A partir del resultado del test, y mediante las ecuaciones descritas por Lèger y cols.[26], se estimó la capacidad aeróbica (VO_{2max}; $ml/kg/min^{-1}$) de cada individuo.

Actividad física

La actividad física se evaluó objetivamente mediante acelerometría. Los adolescentes llevaron un acelerómetro (ActiGraph MTI GT1M; ActiGraph LLC, Pensacola, Florida) en la parte baja de la espalda, unido mediante una banda elástica, durante todo el día (excepto para dormir y para realizar actividades en el agua) y, durante 7 días consecutivos. El intervalo de registro de actividad fue cada 15 segundos. Se incluyeron aquellos adolescentes con al menos 3 días válidos de registro de actividad con un mínimo de 8 horas registradas por día[27].

Los datos se analizaron de forma centralizada para asegurar su estandarización. Los intervalos de 20 minutos o más de inactividad fueron excluidos del recuento total, al ser considerados como períodos de tiempo sin acelerómetro[28]. Los recuentos de más de 20.000 "counts" (o mediciones) por minuto fueron igualmente excluidos por un posible error en la lectura de datos.

Los datos sobre actividad física se presentaron como actividad física total, expresada en 'counts' por minuto (cpm), y como tiempo realizado en actividad física de moderada a vigorosa (AFMV) intensidad (definido como ≥ 3 equivalentes metabólicos en reposo (METs)), expresada en min/d. El tiempo realizado en AFMV se calculó en base a un punto de corte estandarizado de ≥ 2.000 "counts" por minuto[16]. Además, la AFMV se dicotomizó en < 60 min/d y ≥ 60 min/d, siguiendo las recomendaciones de actividad física en adolescentes[29].

Consumo de tabaco

El consumo de tabaco se registró mediante cuestionario autoadministrado[30]. A este efecto, se preguntó a los adolescentes si fumaban actualmente o no, siendo las dos las posibles respuestas (sí *vs.* no).

Estatus socioeconómico

El estatus socioeconómico se evaluó mediante cuestionario autoadministrado. El nivel educativo materno (educación primaria, educación secundaria, educación superior o universitaria) se utilizó como medida del estatus socioeconómico de los adolescentes[30].

Índice de riesgo cardiovascular

Se calculó un índice de riesgo cardiovascular (IRCV) como medida integrada del perfil de riesgo cardiovascular, siguiendo la metodología descrita por Andersen y cols.[16]. El IRCV estuvo compuesto por el promedio de los índices estandarizados (z-scores) de los siguientes factores de riesgo: suma de cuatro pliegues cutáneos, TAS, TG, CT/c-HDL, HOMA, y $VO_{2max}/(-1)$. Cada uno de estos factores fue estandarizado ajustando por sexo y edad mediante la siguiente fórmula: z-score = (valor-media) / desviación estándar. Se definió una desviación estándar por encima de la media como el punto de corte para estar en riesgo cardiovascular[16].

Análisis estadístico

El análisis estadístico de los datos se efectuó con el paquete estadístico SPSS versión 19 (SPSS, inc., IBM). El nivel de significación se estableció en $P < 0,05$ para todos los análisis. Todas las variables estudiadas, excepto IMC (z-score), TAM, Apo A1, Apo B y AFMV, fueron transformadas logarítmicamente al no seguir una distribución normal. Las diferencias entre sexos se estudiaron mediante la prueba t-Student para muestras independientes en el caso de las variables continuas, y el test Chi-2 para las variables categóricas. Los análisis de interacción por géneros entre la ingesta de huevo y los distintos factores de riesgo cardiovascular resultaron estadísticamente significativos (todos $P<0.05$), por lo que todos los análisis se realizaron por separado para niños y niñas.

La asociación entre ingesta de huevo y riesgo cardiovascular se analizó mediante un modelo de regresión multinivel[31], con lo factores de riesgo cardiovascular y el IRCV como variables dependientes, y la ingesta de huevo como variable independiente. Se efectuaron 4 modelos de ajuste: el modelo 1 se ajustó por edad, desarrollo madurativo e ingesta energética total (efectos fijos) y por centro de estudio (efecto aleatorio). En el modelo 2 se añadió, al modelo 1, la ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, vitaminas C y E, ingesta de fibra y verduras, así como el consumo de alcohol y tabaco (como efectos fijos). El modelo 3 incluyó adicionalmente estatus socioeconómico. En el modelo completo (modelo 4) se ajustó, además de todo lo anterior, por AFMV.

En un segundo análisis se estudió la asociación entre ingesta de huevo y el IRCV, así como todos los factores de riesgo que lo compusieron. En este caso, la ingesta de huevo se dicotomizó estableciendo como punto de corte las recomendaciones diarias de huevo para adolescentes (≤18 g/d *vs* >18 g/d; 18 g/d)[32].

Se estudió el efecto de la actividad física en la asociación entre ingesta de huevo y el IRCV, mediante un nuevo modelo multinivel segmentando la muestra por ingesta de huevo (≤18 g/d *vs* >18 g/d) y por cumplir o no con las recomendaciones de actividad física (≥ 60 min/d AFMV *vs* < 60 min/d de AFMV) en niños y niñas.

Por último, se examinó la asociación entre el colesterol ingerido en la dieta y el colesterol total en plasma, mediante el modelo multinivel completo ajustado previamente.

Tabla I
Características descriptivas de la muestra de adolescentes europeos procedentes del estudio HELENA

	Todos (n = 380)	*Niños (n = 188)*	*Niñas (n = 192)*	*p**
	Media ± DE	*Media ± DE*	*Media ± DE*	
Estadio de Tanner (I/II/III/IV/V) (%)	1/9/26/40/24	2/10/21/41/26	0/7/30/40/23	0,076¶
Edad (años)	14,6 ± 1,2	14,6 ± 1,3	14,5 ± 1,1	0,204
Altura (cm)	165,5 ± 9,8	169,6 ± 10,0	161,5 ± 7,7	**< 0,001**
Peso (kg)	57,4 ± 12,6	59,3 ± 13,1	55,6 ± 11,8	**0,004**
IMC (kg/m^2)	20,8 ± 3,6	20,5 ± 3,4	21,2 ± 3,7	**0,043**
IMC (z-score)	0,4 ± 1,1	0,3 ± 1,1	0,4 ± 1,1	0,836
Suma de cuatro pliegues (mm)[a]	51,4 ± 26,4	42,3 ± 24,4	60,3 ± 25,4	**< 0,001**
Grasa corporal (%)	22,6 ± 9,8	18,7 ± 10,1	26,5 ± 7,9	**< 0,001**
Índice de masa grasa (kg/m^2)	5,0 ± 3,1	4,1 ± 3,1	5,9 ± 2,8	**< 0,001**
Perímetro de cintura (cm)	71,5 ± 8,3	72,5 ± 8,0	70,5 ± 8,5	**0,010**
Ratio cintura-altura (cm)	0,43 ± 0,05	0,43 ± 0,04	0,44 ± 0,05	0,076
TAS (mmHg)	119,2 ± 12,5	122,7 ± 12,9	115,7 ± 11,0	**< 0,001**
TAD (mmHg)	67,2 ± 8,8	66,6 ± 8,7	67,8 ± 8,9	0,174
TAM (mmHg)	84,5 ± 8,9	85,3 ± 9,0	83,8 ± 8,7	0,095
TG (mg/dL)	66,6 ± 30,9	62,4 ± 28,0	70,7 ± 33,2	**0,004**
CT (mg/dL)	160,1 ± 27,6	153,0 ± 24,1	167,2 ± 29,0	**< 0,001**
c-HDL (mg/dL)	55,5 ± 10,1	53,8 ± 8,9	57,3 ± 10,9	**0,002**
c-LDL (mg/dL)	94,4 ± 24,9	90,2 ± 23,2	98,5 ± 25,9	**0,002**
Ratio CT/c-HDL	2,9 ± 0,6	2,9 ± 0,6	3,0 ± 0,6	0,163
Ratio c-HDL /c-LDL	0,6 ± 0,2	0,6 ± 0,2	0,6 ± 0,2	0,443
Apo A1 (g/L)	1,51 ± 0,22	1,47 ± 0,18	1,55 ± 0,24	**< 0,001**
Apo B (g/L)	0,65 ± 0,16	0,61 ± 0,14	0,68 ± 0,17	**< 0,001**
Ratio Apo B/Apo A1	0,44 ± 0,12	0,42 ± 0,12	0,45 ± 0,13	0,068
Glucosa (mg/dL)	90,4 ± 6,8	92,2 ± 6,9	88,7 ± 6,3	**< 0,001**
Insulina (µlU/mL)	10,3 ± 7,3	9,5 ± 7,3	11,1 ± 7,2	**0,001**
Índice HOMA	2,3 ± 1,7	2,2 ± 1,8	2,5 ± 1,7	0,160
$VO_{2\,max}$ (ml/kg/min^{-1})	45,0 ± 11,5	54,1 ± 7,4	36,0 ± 6,6	**< 0,001**
Actividad física total (cpm)	435,1 ± 158,9	499,2 ± 173,7	372,3 ± 112,1	**< 0,001**
AFMV (min/d)	58,8 ± 24,2	69,3 ± 25,6	48,5 ± 17,6	**< 0,001**
Ingesta de huevo (g/d)	11,1 ± 14,1	10,5 ± 12,8	11,8 ± 15,2	0,356
Ingesta energética total (kcal)	2.384,0 ± 1.051,5	2.743,8 ± 1.134,0	2.031,7 ± 826,2	**< 0,001**
Grasa saturada (g/d)	35,7 ± 14,9	40,9 ± 16,4	30,6 ± 11,2	**< 0,001**
Grasa monoinsaturada (g/d)	31,5 ± 12,8	36,2 ± 14,2	26,9 ± 9,3	**< 0,001**
Grasa poliinsaturada (g/d)	12,5 ± 6,6	14,2 ± 7,5	10,8 ± 5,0	**< 0,001**
Ingesta de colesterol (mg/d)	343,1 ± 130,7	373,8 ± 134,4	313,2 ± 119,9	**< 0,001**
Vitamina C (mg/d)	102,5 ± 59,2	101,4 ± 54,4	103,6 ± 63,8	**0,715**
Vitamina E (mg/d)	8,3 ± 3,8	9,0 ± 3,9	7,5 ± 3,6	**< 0,001**
Ingesta de verduras (g/d)	97,3 ± 58,1	99,9 ± 62,4	94,8 ± 53,6	0,393
Fibra (g/d)	18,9 ± 6,8	20,9 ± 7,2	16,9 ± 5,6	**< 0,001**
Alcohol (g/d)	0,9 ± 2,4	1,4 ± 3,1	0,4 ± 1,1	**< 0,001**
Consumo de tabaco (si/no) (%)	16,4/83,6	16,7/83,3	16,2/83,8	0,909

¶

Los datos se presentan como media ± desviación estándar (DE), salvo que se indique lo contrario. IMC: Índice de masa corporal; TAS: Tensión arterial sistólica; TAD: Tensión arterial diastólica; TAM: Ttensión arterial media; TG: Triglicéridos; CT: Colesterol total; c-HDL: Colesterol unido a lipoproteínas de alta densidad; c-LDL: Colesterol unido a lipoproteínas de baja densidad; Apo A1: Apolipoproteína A1; Apo B: Apolipoproteína B; HOMA: Homeostasis modelassessment; VO_{2max}: Consumo máximo de oxígeno; AFMV: Actividad física moderada a vigorosa; cpm: "Counts˝ por minuto; %E: Porcentaje de energía.

*Niños *vs.* niñas (t-student). ¶Niños *vs.* niñas (test de Chi^2).

[a] Suma de cuatro pliegues: bíceps, tríceps, subescapular, suprailíaco. El valor P corresponde a las variables transformadas logarítmicamente, excepto para edad, IMC (z-score), TAM, Apo A1, Apo B y AFMV.

Resultados

Dos centros de estudio (Heraklion y Pecs) fueron excluidos al no haber obtenido información completa de registro de alimentos. Un total de 380 adolescentes (49,5% niños) obtuvieron datos válidos de todas las variables medidas y fueron finalmente incluidos en este estudio. Se observaron diferencias entre los adolescentes incluidos y excluidos para edad, peso, e índice de masa corporal (IMC) (todos P < 0,05). No se observaron diferencias entre ambos grupos para talla, suma de cuatro pliegues, perímetro de cintura, TAS, TG, CT, c-HDL, insulina e índice HOMA (todos P > 0,05).

La tabla I muestra las características descriptivas de la muestra de estudio en conjunto y separados por sexo. Las niñas mostraron mayores niveles de TG, CT, c-HDL, c-LDL, Apo A1 y Apo B (todos P<0,05) e insulina (P = 0,001) que los niños. Los niños mostraron mayores niveles de tensión arterial sistólica, glucosa, actividad física total, AFMV, y VO_{2max} que las niñas (todos P < 0,001). La ingesta energética total, así como la ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, fibra y alcohol fue superior en niños que en niñas (todos P < 0,001), mientras que no se observaron diferencias por sexo en la ingesta media de huevo.

La tabla II muestra la asociación entre ingesta de huevo y los factores de riesgo cardiovascular estudiados en niños y niñas. El modelo inicial de ajuste mostró asociación estadísticamente significativa entre ingesta de huevo y pará-

Tabla II
Análisis multinivel examinando la asociación entre ingesta de huevo (g/d) y factores de riesgo cardiovascular en adolescentes europeos

	Niños						*Niñas*					
	β	*IC 95%*	P^a	P^b	P^c	P^d	*β*	*IC 95%*	P^a	P^b	P^c	P^d
IMC (kg/m^2)	0,020	-0,002 , 0,041	0,075	0,192	0,235	0,178	-0,014	-0,031, 0,003	0,110	0,826	0,903	0,796
IMC (z-score)	0,131	-0,025, 0,286	0,099	0,244	0,293	0,244	-0,098	-0,213, 0,017	0,094	0,779	0,912	0,806
Suma de cuatro pliegues (mm)*	0,065	0,003, 0,127	**0,040**	0,139	0,216	0,119	-0,043	-0,085, -0,001	**0,045**	0,536	0,623	0,497
Grasa corporal (%)	0,061	0,002, 0,120	**0,041**	0,120	0,175	0,092	-0,028	-0,057, 0,001	0,063	0,514	0,634	0,518
Índice de masa grasa (kg/m^2)	0,081	0,004, 0,157	**0,038**	0,120	0,172	0,096	-0,042	-0,086, 0,003	0,066	0,603	0,711	0,585
Perímetro de cintura (cm)	0,017	0,002, 0,031	**0,024**	0,052	0,062	**0,046**	-0,008	-0,021, 0,004	0,194	0,558	0,614	0,733
Ratio cintura-altura (cm)	0,015	0,002, 0,028	**0,023**	0,054	0,091	0,077	-0,015	-0,027, -0,003	**0,016**	0,083	0,081	0,110
TAS (mmHg)	0,008	-0,006, 0,023	0,248	0,202	0,109	0,105	0,004	-0,007, 0,014	0,465	0,199	0,278	0,300
TAD (mmHg)	0,013	-0,005, 0,031	0,168	0,156	0,120	0,107	-0,003	-0,018, 0,013	0,729	0,552	0,493	0,475
TAM (mmHg)	0,897	-0,341, 2,135	0,155	0,149	0,090	0,074	0,002	-0,997, 1,001	0,996	0,354	0,413	0,412
TG (mg/dL)	0,009	-0,053, 0,072	0,769	0,641	0,378	0.220	-0,011	-0,058, 0,036	0,646	0,555	0,551	0,605
CT (mg/dL)	-0,001	-0,024, 0,021	0,914	0,824	0,587	0,605	0,003	-0,016, 0,023	0,726	0,493	0,370	0,395
c-HDL (mg/dL)	0,001	-0,023, 0,025	0,925	0,541	0,609	0,344	0,015	-0,007, 0,036	0,179	0,176	0,148	0,117
c-LDL (mg/dL)	-0,007	-0,043, 0,029	0,698	0,829	0,679	0,628	-0,004	-0,033, 0,026	0,801	0,826	0,673	0,535
Ratio CT/c-HDL	-0,006	-0,033, 0,022	0,692	0,949	0,571	0,370	-0,009	-0,031, 0,014	0,446	0,584	0,670	0,730
Ratio c-HDL /c-LDL	0,011	-0,035, 0,057	0,638	0,895	0,658	0,467	0,018	-0,020, 0,056	0,342	0,521	0,600	0,786
Apo A1 (g/L)	-0,002	-0,028, 0,024	0,879	0,563	0,470	0,339	-0,001	-0,028, 0,026	0,926	0,951	0,913	0,882
Apo B (g/L)	0,000	-0,020, 0,019	0,982	0,707	0,631	0,594	0,000	-0,018, 0,019	0,963	0,936	0,861	0,736
Ratio Apo B/Apo A1	-0,005	-0,043, 0,032	0,786	0,903	0,527	0,408	-0,001	-0,033, 0,031	0,966	0,920	0,822	0,750
Glucosa (mg/dL)	-0,002	-0,012, 0,009	0,772	0,820	0,703	0,770	0,001	-0,008, 0,009	0,892	0,599	0,520	0,548
Insulina (µlU/mL)	0,048	-0,031, 0,126	0,231	0,128	0,209	0,173	-0,066	-0,123, -0,008	**0,027**	0,434	0,303	0,283
Índice HOMA	0,046	-0,037, 0,129	0,276	0,160	0,256	0,213	-0,065	-0,126, -0,005	**0,033**	0,521	0,388	0,342
VO_{2max} (ml/kg/min^{-1})	-0,011	-0,031, 0,009	0,274	0,367	0,633	0,319	0,008	-0,007, 0,023	0,303	0,763	0,660	0,599
IRCV (z-score)	0,055	0,006, 0,116	0,078	0,192	0,188	0,113	-0,054	-0,106, -0,002	**0,043**	0,372	0,252	0,210

IMC: Índice de masa corporal; TAS: Tensión arterial sistólica; TAD: Tensión arterial diastólica; TAM: Tensión arterial media; TG: Triglicéridos; CT: Colesterol total; c-HDL: Colesterol unido a lipoproteínas de alta densidad; c-LDL: Colesterol unido a lipoproteínas de baja densidad; Apo A1: Apolipoproteína A1; Apo B: Apolipoproteína B; HOMA: Homeostasis modelassessment; VO_{2max}: Consumo máximo de oxígeno; *Suma de cuatro pliegues: bíceps, tríceps, subescapular y suprailíaco; IC 95%: Intervalo de confianza al 95%. El índice de riesgo cardiovascular (IRCV) se compuso mediante la suma de los z-scores para suma de cuatro pliegues, TAS, TG, CT/HDL-c, HOMA y VO_{2max}/(-1)[16]. Todas las variables, excepto para edad, IMC (z-score), TAM, Apo A1, Apo B, actividad física de moderada a vigorosa (AFMV), e IRCV, fueron transformadas logarítmicamente.

[a] Modelo 1: ajustado por centro, edad, desarrollo madurativo e ingesta energética total.

[b] Modelo 2: modelo 1 más ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, vitamina C, vitamina E, ingesta de verduras, fibra, ingesta de alcohol y consumo de tabaco (sí/no).

[c] Modelo 3: modelo 2 más estatus socioeconómico.

[d] Modelo 4: modelo 3 más AFMV.

Tabla III
Factores de riesgo cardiovascular según la ingesta de huevo

Factores de riesgo cardiovascular	*Niños*			*Niñas*		
	≤ 18	*> 18*	*P*	*≤ 18*	*> 18*	*P*
Suma de cuatro pliegues (mm)*	43,2 ± 6,3	55,7 ± 7,8	0,098	59,3 ± 4,9	59,2 ± 5,8	0,847
TAS (mmHg)	120,4 ± 3,9	126,5 ± 4,8	0,034	114,2 ± 2.6	115,9 ± 2.9	0,403
TG (mg/dL)	63,9 ± 7,7	66,7 ± 10,0	0,574	76,7 ± 4,8	79,0 ± 6,7	0,998
Ratio CT/c-HDL	2,9 ± 0,2	3,0 ± 0,2	0,446	3,2 ± 0,1	3,1 ± 0,1	0,426
Índice HOMA	1,6 ± 0,4	2,1 ± 0,6	0,074	2,5 ± 0,3	2,8 ± 0,4	0,908
$VO_{2\,max}$ (ml/kg/min^{-1})	48,1 ± 1,8	46,2 ± 2,2	0,192	37,6 ± 0,9	38,6 ± 1,2	0,324
IRCV	0,037 ± 0,1	0,171 ± 0,1	0,046	0,067 ± 0,1	0,006 ± 0,1	0,437

Los datos se presentan como media ± error estándar. Suma de cuatro pliegues: bíceps, tríceps, subescapular y suprailíaco; TAS: Tensión arterial sistólica; TG: Triglicéridos; CT: Colesterol total; c-HDL: Colesterol unido a lipoproteínas de alta densidad; HOMA: Homeostasis modelassessment; VO_{2max}: Consumo máximo de oxígeno; IRCV: Índice integrado de riesgo cardiovascular, compuestopor la suma de los z-scores para suma de cuatro pliegues, TAS, TG, CT/HDL-c, HOMA y VO_{2max}/(-1)[16]. Todas estas variables, excepto el IRCV, fueron transformadas logarítmicamente al no seguir una distribución normal. El valor P corresponde al análisis multinivelque se ajustó por centro, edad, desarrollo madurativo, ingesta energética total, ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, vitaminas C y E, fibra, ingesta de verduras, consumo de alcohol y tabaco, estatus socioeconómico y actividad física moderada a vigorosa. Los análisis estadísticos se realizaron con las variables transformadas, pero para facilitar la comprensión, los valores presentados en la tabla corresponden a las variables sin transformar.

metros de composición corporal (suma de cuatro pliegues (P = 0,040), porcentaje de grasa corporal (P = 0,041), índice de masa grasa (P = 0,038), perímetro de cintura (P = 0,024) y ratio cintura-altura (P = 0,024) en niños y suma de 4 pliegues (P = 0,045) y ratio cintura-altura (P = 0,016) en niñas), así como con insulina (P = 0,027), el índice HOMA (P = 0,033), y el IRCV (P = 0,043) en niñas. No se observó asociación entre ingesta de huevo y los factores de riesgo de ECV estudiados al aplicar los sucesivos modelos de ajuste (Modelos 2, 3 y 4) en los adolescentes. Sin embargo, la asociación observada entre ingesta de huevo y perímetro de cintura se mantuvo (β =0,018; P = 0,046), aunque sólo en los niños. La ingesta de huevo no se asoció con el IRCV en niñas ni en niños.

La actividad física no mostró una interacción estadísticamente significativa con la ingesta de huevo para los factores de ECV estudiados (para todos P > 0,05). Tampoco para perímetro de cintura se encontró interacción entre ingesta de huevo y actividad física, a pesar de que la pendiente de regresión huevo-perímetro de cintura se atenuó ligeramente en los niños que alcanzaron las recomendaciones de actividad física (β = 0,019; P = 0,221 para los que no alcanzaron las recomendaciones *vs* β = -0,004; P = 0,771 para los que alcanzaron la recomendaciones).

La tabla III presenta los factores de riesgo cardiovascular según la ingesta de huevo (≤ 18 g/d *vs* >18 g/d) y género. No se observaron diferencias estadísticamente significativas para los factores de riesgo incluidos en el IRCV, excepto para la TAS, que fue mayor en los niños que consumieron > 18 g/d (P = 0,034). Mientras que en niñas, sin embargo, no se observó ninguna diferencia estadísticamente significativa. Aquellos niños que consumieron > 18 g de huevo/d presentaron un IRCV mayor con respecto a los que consumieron < 18 g de huevo/d (0,171 *vs* -0,037, respectivamente; P = 0,046; fig. 1). La actividad física no mostró una interacción estadísticamente significativa con la ingesta de huevo (fig. 2). No se observó asociación entre colesterol dietético y colesterol total en plasma en niños (β = 0,035; P = 0,572) ni en niñas (β = -0,101; P = 0,150).

Discusión

El presente estudio analizó la asociación entre ingesta de huevo y perfil cardiovascular en adolescentes, así como el papel de la actividad física en esta asociación. Nuestros resultados sugieren que no existe asociación entre ingesta de huevo y tensión arterial, perfil lipídico, glucosa, insulina, resistencia a la insulina o capacidad aeróbica en adolescentes. Tampoco se observó asociación entre ingesta de huevo y el IRCV o el nivel de adiposidad, al ajustar por variables de confusión. Tan solo se encontró asociación al borde estadísticamente entre ingesta de huevo y perímetro de cintura. Por tanto, estos resultados sugieren que no existe asociación entre ingesta de huevo y perfil de riesgo cardiovascular en adolescentes. Además, la actividad física no parece ejercer un papel importante en la relación entre ingesta de huevo y factores de riesgo cardiovascular en los adolescentes estudiados.

No se encontró asociación entre la ingesta de huevo y ninguna variable relacionada con el perfil lipídico, *apriori* más susceptible de verse significativamente asociado al huevo, dado su alto contenido en colesterol. Este resultado está en línea con algunos estudios prospectivos en adultos, que no encontraron asociación entre colesterol dietético y colesterol plasmático[12,33]. Además, el colesterol dietético no se asoció al colesterol plasmático total en los adolescentes estudiados. Por tanto, estos resultados apoyan las recomendaciones de no restringir la ingesta de huevo, siempre que el colesterol total ingerido en la dieta no supere los 300 mg/d[9]. En cualquier caso, la ingesta

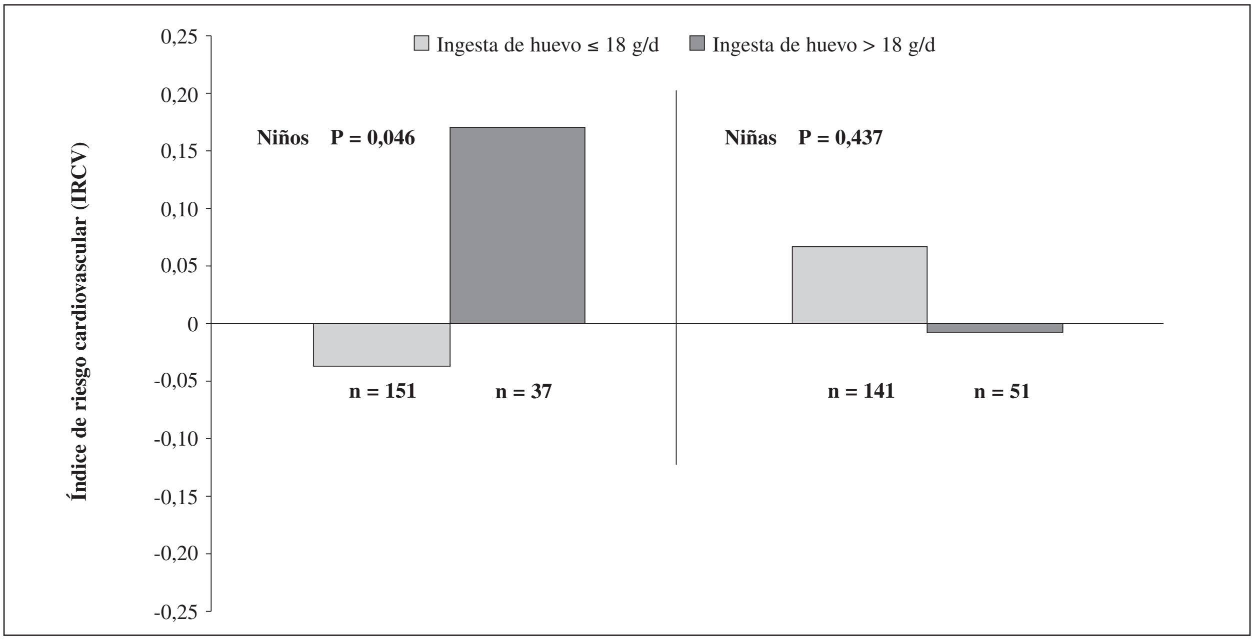

Fig. 1.—Representación gráfica del índice de riesgo cardiovascular (IRCV) en los adolescentes que ingirieron ≤ 18 g de huevo/día y los que ingirieron > 18 g de huevo/día separado por sexo. El análisis se ajustó por centro, edad, desarrollo madurativo, ingesta energética total, ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, vitamina C y E, fibra, ingesta de verduras, consumo de alcohol y tabaco, estatus socioeconómico y actividad física moderada a vigorosa. El IRCV se compuso mediante la suma de z-scores para: suma de cuatro pliegues, tensión arterial sistólica, triglicéridos, ratio colesterol total/colesterol HDL, índice HOMA y VO_{2max} *(-1)16.*

media de huevo en los adolescentes estudiados fue de 10,5 ± 12,8 g/día y 11,8 ± 15,2 g/día en niños y niñas, respectivamente. Esta cantidad es inferior a la ingesta diaria recomendada para adolescentes europeos[32].

Varios estudios epidemiológicos no han observado asociación entre ingesta de huevo (< 7 huevos por semana) y riesgo de diversas ECVs en adultos sanos[12-15]. Por ejemplo, Nakamura y cols.[12] mostraron que un consumo de huevo ‘casi a diario’ no se asociaba con mayor riesgo de cardiopatía isquémica en comparación con un consumo de 1-2 huevos/semana. Igualmente, Qureshi y cols.[13] mostraron ausencia de asociación entre consumir > 6 huevos/semana (vs consumir ≤ 1 huevo/semana) y el riesgo de padecer infarto o cardiopatía isquémica. Scrafford y cols.[14], por su parte, observaron que consumir ≥ 7 huevos/semana (*vs* < 1 huevo/semana) no se asocia con un mayor riesgo de cardiopatía isquémica en adultos. Además, estos estudios encontraron una asociación inversa entre ingesta de huevo y mortalidad por infarto en hombres estadounidenses. Zazpe y cols.[15] no observaron asociación entre ingesta de huevo e incidencia de ECVs en adultos sanos, en un estudio prospectivo en una población Mediterránea. Nuestros resultados están en línea con estos estudios en adultos, sustentando la hipótesis de que no existe asociación entre una ingesta de huevo moderada y perfil cardiovascular en adolescentes. Estos resultados son de interés para Salud Pública, dado que el origen subclínico de las ECVs aparece en edades tempranas[3,5], y este es el primer estudio que examina la asociación entre la ingesta de huevo y factores de riesgo de desarrollar ECVs en adolescentes.

Los niños que más huevo consumieron (> 18 g/día) mostraron un IRCV significativamente mayor con respecto a los que tomaron menos huevo (≤ 18 g/día). No obstante este efecto no se debe a la asociación entre consumo de huevo y perfil lipídico, sino más bien a un ligero incremento en la TAS. A pesar de ello, el valor medio del IRCV entre el grupo de mayor ingesta de huevo (IRCV: 0,171; IC: -0,124-0,466), no se correspondió con un riesgo cardiovascular considerado como clínicamente relevante. Este punto de corte fue establecido, siguiendo a Andersen y cols.[16]como el valor de la media + 1 DE (IRCV medio + 1 DE = 0,444).

Se examinó el efecto que alcanzar las recomendaciones de actividad física podía ejercer en la asociación entre ingesta de huevo y los factores de riesgo de ECV estudiados, así como con el IRCV, dado que la actividad física está asociada con un menor porcentaje de grasa corporal[28] y con un menor IRCV[16] en adolescentes. Sin embargo, el patrón de asociación observado entre la ingesta de huevo y los factores de riesgo de desarrollar ECVs, así como el IRCV, no fue significativamente diferente entre los adolescentes que alcanzaron y no alcanzaron las recomendaciones de actividad física (fig. 2). Por lo tanto, la actividad física no pareció ejercer un papel importante en la falta de relación entre ingesta de huevo y perfil de riesgo cardiovascular en adolescentes.

Algunos estudios han demostrado que una ingesta mayor a 7 huevos por semana se asocia con un mayor riesgo de insuficiencia cardíaca[34] o diabetes[35] en adultos sanos, así como con una mortalidad más elevada por

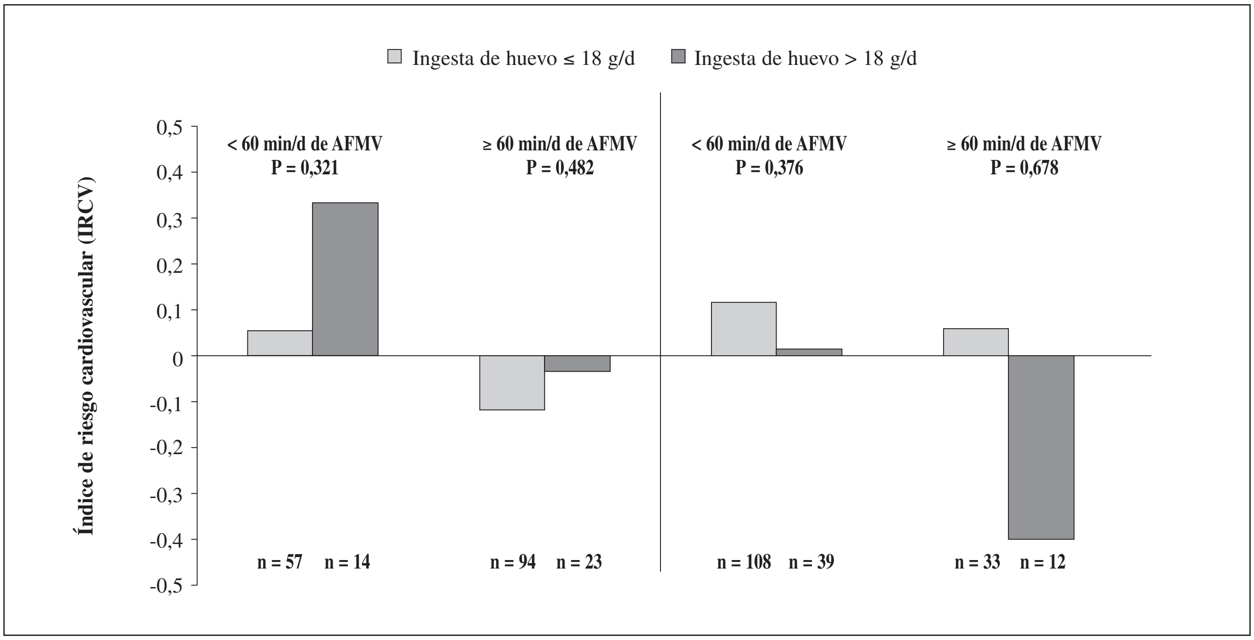

Fig. 2.—Representación gráfica del índice de riesgo cardiovascular (IRCV) en los adolescentes que ingirieron ≤ 18 g de huevo/día y los que ingirieron > 18 g de huevo/día separando por sexo y por cumplir o no con las recomendaciones de actividad física (≥ 60 min/día de actividad física moderada a vigorosa (AFMV). El modelo multinivel fue ajustado por centro, edad, desarrollo madurativo, ingesta energética total, ingesta de grasa saturada, grasa monoinsaturada, grasa poliinsaturada, colesterol, vitaminas C y E, ingesta de fibra y verduras, consumo de alcohol y tabaco y estatus socioeconómico. El IRCV se compuso mediante la suma de los z-scores para suma de cuatro pliegues, tensión arterial sistólica, triglicéridos, ratio colesterol total/colesterol HDL, índice HOMA y VO_{2max} (-1)16.

cualquier causa[36]. Sin embargo, de estos estudios, únicamente Djoussé y cols.[35] acertaron a corregir el modelo de regresión por grasa saturada, que podrían influir en los resultados obtenidos ya que la grasa saturada se asocia con un colesterol plasmático elevado[37].

Limitaciones

La metodología para obtener la ingesta nutricional supone, en cierto modo, una limitación de este estudio, ya el recordatorio de 24 h en únicamente 2 días, no nos permite obtener la frecuencia de consumo de huevo semanal. Además, los adolescentes podrían no reportar con exactitud lo que realmente comen. Sin embargo, todos los métodos utilizados, así como los cuestionarios empleados han sido ampliamente validados para su uso en adolescentes. Por otra parte, una fortaleza del presente estudio es que la actividad física se evaluó objetivamente mediante acelerometría, siendo el primer estudio examinando la asociación entre ingesta de huevo y perfil cardiovascular que utiliza la actividad física medida objetivamente como variable de ajuste.

Conclusiones

Los principales hallazgos del presente estudio sugieren que no existe asociación entre ingesta de huevo y el perfil cardiovascular en adolescentes. Además, la actividad física no parece ejercer un papel importante en la relación entre ingesta de huevo y los factores de riesgo de desarrollar ECVs en los adolescentes estudiados. Es necesaria una mayor investigación en otras poblaciones de adolescentes en las que la ingesta de huevo sea superior a la del presente estudio, y con un tamaño de muestra mayor, de cara a determinar si una elevada ingesta de huevo podría asociarse con un perfil cardiovascular menos favorable en adolescentes.

Agradecimientos

El estudio HELENA se llevó a cabo con el apoyo económico del Sexto Programa Marco de la Unión Europea (Contract FOOD-CT: 2005-007034). Este estudio también fue apoyado por becas del Ministerio de Ciencia e Innovación (AP 2008-03806: RYC-2010-05957). El contenido de este artículo refleja sólo el punto de vista de los autores, y la Comunidad Europea no es responsable del uso que pueda hacerse de la información contenida en el mismo. Los autores agradecen a todos los adolescentes participantes, así como sus padres y profesores por su colaboración. También agradecen a todos los miembros involucrados en el trabajo de campo por su gran esfuerzo y entusiasmo.

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5. Physical activity and fitness and metabolic disease (diabetes)

[Actividad física, condición física y patologías metabólicas (diabetes)]

Study VIII *[Artículo VIII]*


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DOI: 10.1111/j.1464-5491.2012.03740.x

Research: Treatment

How does physical activity and fitness influence glycaemic control in young people with Type 1 diabetes?

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Accepted 26 June 2012

Abstract

Aims To assess physical activity and fitness levels of young people with Type 1 diabetes compared with siblings without diabetes, and to investigate the association between physical activity, physical fitness and glycaemic control (HbA_{1c}) in those young people with diabetes.

Methods The study consisted of 97 young people aged 8 to 16 years (62% male) from a Paediatric Diabetes Service in South West England. Sixty participants (67% male) had Type 1 diabetes and 37 participants (54% male) were siblings without diabetes (control group). We measured weight, height and waist circumference, calculated BMI and waist–height ratio and recorded pubertal status, blood pressure and current insulin regimen information. We assessed physical activity by accelerometry, from which we calculated light and moderate-to-vigorous intensity activity. We measured physical fitness by multistage sub-maximal bicycle ergometer test. We obtained HbA_{1c} by venipuncture.

Results There were no differences between the young people with diabetes and siblings without diabetes in body composition, blood pressure, physical activity and fitness. Moderate-to-vigorous physical activity was associated with better glycaemic control, accounting for 30–37% (R^2 = 0.295–0.374) of the variance for HbA_{1c}. Physical fitness was not associated with $HbA_{1c.}$

Conclusions Moderate-to-vigorous physical activity was associated with better glycaemic control while fitness was not. Findings suggest that developing strategies to increased moderate-to-vigorous physical activity may prove an effective method of improving glycaemic control in young people with diabetes.

Diabet. Med. 29, e369–e376 (2012)

Introduction

The benefits of improved glycaemic control in childhood-onset diabetes are well documented. For every 1 mmol/mol (1%) reduction in HbA_{1c} can bring a several-fold decrease in micro- and macrovascular complications [1]. The International Federation of Clinical Chemistry (IFCC) recommends a target HbA_{1c} < 58 mmol/mol [equivalent to the National Institute for Health and Clinic Excellence (NICE) Guideline recommendation of < 7.5%], but, as the Hvidore Study Group on Childhood Diabetes reported in 22 paediatric centres internationally, this level of control is difficult to achieve [2].

Previous research has indicated that regular physical activity is safe for young people with Type 1 diabetes [3–5]. However, there is inconsistent information about the association between physical activity and physical fitness and HbA_{1c} levels among young people with Type 1 diabetes. For example, some researchers have suggested that physical activity may account for some of the variance in HbA_{1c} levels [6–8], while other research groups have reported no association between physical activity and HbA_{1c} [9–12]. The lack of correlation is likely explained by multiple confounding factors (i.e. age, gender, pubertal stage, body composition, diabetes duration, insulin dose, method of insulin administration, ethnicity and socio-economic status), which should be taken into account in both cross-sectional and intervention studies.

Higher levels of moderate-to-vigorous physical activity are required to achieve an improvement in aerobic capacity [13] and a higher aerobic capacity reduces the increase of insulin resistance risk factors in adolescents with Type 1 diabetes [4]. Others studies found that greater fitness levels predicted both better glycaemic control and total cholesterol in adolescents with Type 1 diabetes [14–16].

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The American Diabetes Association (ADA) recommends improving lifestyle strategies, such as healthy diet and regular physical activity, to optimize glycaemic control and the International Society for Pediatric and Adolescent Diabetes (ISPAD) encourages physical activity [17,18]; although there are not specific quantitative physical activity guidelines for young people with Type 1 diabetes. However, there are quantity recommendations for children in general, such as the UK's 60 min of moderate-to-vigorous physical activity on most days of the week [19]. In addition, some studies have suggested that a large proportion of young people with Type 1 diabetes fail to meet these recommendations for physical activity [20] and report less time spent in physical activity than their peers without diabetes [20,21]. In order to better educate our families living with diabetes, we require more evidence on how moderate-to-vigorous physical activity and fitness influence medium- to long-term glycaemic control.

The present study assessed the physical activity and fitness levels of young people with Type 1 diabetes compared with siblings without diabetes (control subjects), and investigated the association between physical activity, physical fitness and glucose control (HbA_{1c}) in those young people with Type 1 diabetes, controlling for confounding factors such as gender, age, puberty, body composition, insulin dose and insulin regimen.

Patients and methods

Research design

This is a case–control cross-sectional study. Participants with Type 1 diabetes were recruited from the three clinics in the Bristol and Weston Paediatric Diabetes Service at Bristol Royal Hospital for Children, Southmead Hospital, and Weston General Hospital. Patients and families were approached if the index child was aged 8–16 years and did not manifest any of the exclusion criteria such as current hypoglycaemia unawareness, co-morbidities such a severe asthma or physical disability. Control group participants were siblings of the participants with diabetes, who were aged 8–16 years without diabetes. Of a total of 422 patients in the diabetes service, 240 patients were aged 8–16 years with Type 1 diabetes, 25 of whom had one or more exclusion criteria, leaving 215 eligible patients [mean HbA_{1c} of eligible group 65 mmol/mol (8.1%)]. The 60 patients who were then recruited (i.e. 28% of 215) were in the numbers who then agreed to participate. Recruited patients with Type 1 diabetes were asked if they had a sibling, aged 8–16 years without diabetes, who could be invited to participate in the study. In total, 97 participants were recruited, of which 60 participants (40 male, 20 female) had Type 1 diabetes and 37 participants (20 male, 17 female) were siblings without diabetes (control subjects). Figure 1 shows a flow chart of sample study selection.

The study was approved by Southmead Ethics Committee (REC ref. 07/H0102/73) and informed parental consent was obtained for all participants (those with diabetes and control subjects).

Measures

Physical examination and anthropometry

Blood pressure was measured with an automated monitor (using an Omron 705PC-II). Two readings of systolic and diastolic blood pressure were taken and the mean of each calculated. Height was measured in bare feet to the nearest 0.1 cm with a Harpenden stadiometer (Holtain Ltd, Crymych,

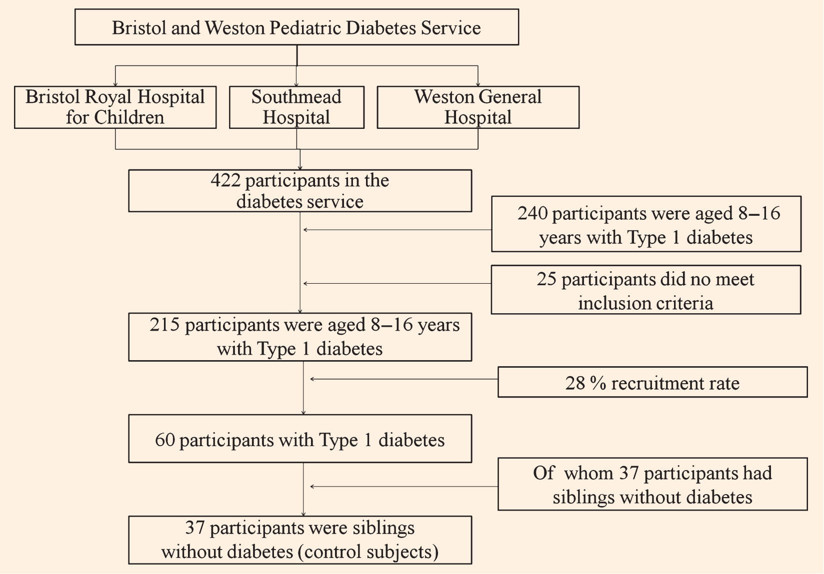

FIGURE 1 Flow chart of sample study selection.

UK). Body weight was determined to the nearest 0.1 kg using an electronic scale (SECA scales), with the participants in bare feet and wearing a T-shirt and shorts. BMI was calculated as weight (kg) divided by height squared (m) and adjusted for age and sex to give a BMI standard deviation score (BMI Z-score) [22]. Waist circumference was measured to the nearest 0.1 cm with a non-elastic tape (Seca 200). Waist–height ratio was computed as dividing waist circumference (cm) by height (cm), to provide a surrogate measure of central body fat [23]. All measurements were carried out under standardized conditions and were collected by a trained, research nurse [24]. Pubertal status was assessed by Tanner and Whitehouse staging by experienced paediatric endocrinologists [25]. Briefly, degree of pubertal development ranged from 1 to 5 (stages), and classification was based on the development of the testes, scrotum and penis size in the boys, and on breast development and pubic hair in the girls. Information was available for 100% of the participants with diabetes. Pubertal status was also assessed in the control group by a self-estimation questionnaire [26]. HbA_{1c} was obtained by venipuncture just before the physical fitness test in the participants with diabetes.

Parental education

Parental education was provided by participants using a basic questionnaire with the following answers to choose: (1) none; (2) secondary school up to 16 years of age (GCSE, O-level or equivalent); (3) completed secondary school education (A-level or equivalent); (4) post-school vocational qualification [National Vocational Qualifications (NVQ) level 1 or equivalent]; (5) degree or equivalent; and (6) higher degree (Masters or PhD).

Diabetes assessment

The research nurse collected the following details from each participant: age at diagnosis and duration of diabetes, insulin dose requirements and insulin regimen (type and number of injections).

Physical activity

Participants wore an Actigraph accelerometer model GT1M (Actigraph Model GT3X; Manufacturing Technology Inc., Pensacola, FL, USA), for 7 days. This small uni-axial accelerometer measures and records time-varying accelerations ranging in magnitude from approximately 0.05 to 2.5 gravitational acceleration units. It provides minute-by-minute assessments of participants' habitual physical activity and has been shown to be a reliable measure of physical activity in young people [27]. The participants were also advised not to wear the monitor during aquatic activities. Each participant was monitored for seven consecutive days (5 weekdays). Data were considered as valid if the participants had accelerometer counts for at least 3 days. Data with periods of zero for more than 20 min values were considered 'accelerometer non-wear' periods and were excluded from the analyses. Likewise, registers of more than 20 000 counts/min were interpreted as a potential malfunction of the accelerometer and were also excluded from the analyses. Finally, a total of 87 participants (54 patients with Type 1 diabetes and 33 siblings without diabetes) had complete data. Data were analysed to provide the mean number of counts/h and, in addition, the total volume of physical activity in which the participant engaged. Young people-specific cut points [28] were used to determine the minutes per day spent in light and moderate-to-vigorous intensity physical activity. Threshold counts were: between 800 and 3200 counts/min for light physical activity and ≥ 3200 counts/min for moderate-to-vigorous physical activity. Objective assessments of physical activity, such as accelerometry, are now widely being used for assessing physical activity in young people. Accelerometer data have been positively related with an objective measure for cardiorespiratory fitness, to investigate if they are able to identify young people with high physical activity intensity levels, using maximum oxygen uptake as a surrogate marker for high physical activity intensity [29].

Physical fitness

Physical work capacity (watts) at a heart rate of 170 beats/min (PWC_{170}) was predicted from a multistage sub-maximal bicycle ergometer test [30] to estimate aerobic capacity. Briefly, fitness was assessed using an electronically braked cycle ergometer adjustable in a range of 7–1000 watts (Corival). The ergometer saddle and handlebar height were adjusted for each participant, and after a 1-min warm-up, participants pedalled at a rate of 60 revolutions/min (rpm) for 3 min (each of three workloads). The initial workload (either 30 or 60 watts) was based on the participant's weight. The resistance during the next two stages was increased by 30–60 watts, depending upon the participant's heart rate response at the end of the first stage. Heart rate was recorded the last 10 s of each minute using a heart rate monitor with a chest strap (Polar FS2c). The protocol was designed to obtain the heart rate in the range of 160 beats/min during the third stage. The mean heart rate during the last minute of each stage was used to extrapolate a physical work capacity, expressed in watts, at a heart rate of 170 beats/min. The PWC_{170} was computed in absolute terms of watts, and relative to weight in watts/kg. Subjects, but not controls, provided a fingerprick blood glucose measurement just before commencing the fitness test, and the test that proceeded provided the blood glucose > 4 mmol/l. We made arrangements to defer the test if participants were hypoglycaemic for safety reasons, but not to defer for hyperglycaemia so as not to distort the real-life patient group. If the blood glucose was lower than 4 mmol/l, the participant had the usual treatment for low blood glucose, i.e. a drink and snack, and then the test would have been scheduled for another day (in practice this did not happen with any patient). The blood glucose levels prior to commencing the exercise test were 10.2 mmol/l (4.1–24.0) [mean (minimum–maximum)]. A further fingerprick blood glucose measurement was performed at the conclusion of the fitness test [9.5 mmol/l (2.2–22.0); mean (minimum–maximum)], and also during the test only if they developed symp-

Table 1 Comparison of descriptive data between young people with Type 1 diabetes and those without diabetes

	With diabetes (n = 60)		Without diabetes (n = 37)		
	Mean	SD	Mean	SD	P*
Gender (male/female) (%)	(67/33)		(54/46)		0.152
Pubertal self-assessment (%)					
Not started	20		30		0.209
Barely started	27		10		
Definitely underway	22		22		
Seems completed	23		24		
Completed	8		14		
Parental education (%)					
None	3		5		0.968
Secondary school up to 16 years	23		19		
Completed secondary education	18		22		
Vocational qualification	12		3		
Degree or equivalent	27		22		
Higher degree	17		19		
Age (years)	12.5	2.3	12.0	2.5	0.391
BMI (kg/m^2)	19.9	3.9	19.6	3.1	0.713
BMI Z-score	0.3	0.9	0.3	0.9	0.846
Waist circumference	70.7	7.9	69.0	7.7	0.318
Waist–height ratio	0.5	0.0	0.4	0.0	0.572
Systolic blood pressure (mmHg)	120.4	13.7	117.5	14.1	0.322
Diastolic blood pressure (mmHg)	67.1	7.6	65.2	8.2	0.249
Accelerometry (counts/h)	26 995.1	11 668.6	26 477.1	10 157.6	0.417
Light physical activity (min/day)	116.9	41.5	112.6	43.1	0.648
Moderate-to-vigorous physical activity (min/day)	27.6	21.4	20.1	11.4	0.067
PWC_{170} (watts)	90.7	34.3	99.5	45.9	0.467
PWC_{170} (watts/kg)	1.8	0.6	2.0	0.5	0.467

Data are presented as means and standard deviation (SD) unless otherwise specified.
*With vs. without diabetes.
PWC_{170}, physical work capacity at a heart rate of 170 beats/min.

toms of hypoglycaemia (although this did not happen in any patient).

Statistical analysis

Descriptive statistics (mean ± SD, per cent) were calculated for all variables. As preliminary analyses indicated that physical activity and fitness variables were skewed, these variables were transformed to the natural logarithm. Chi-square and independent sample t-tests were used to assess whether there were differences in the pubertal stage, parental education, body composition, blood pressure, physical activity and fitness of the young people who had Type 1 diabetes and the control group.

Five different linear regression models were run with: (1) physical activity mean count/h of total physical activity; (2) mean min/day of light physical activity; (3) mean min/day of moderate-to-vigorous physical activity; (4) physical fitness through aerobic capacity estimated using PWC_{170} tests (watts); and (5) fitness adjusted for body mass (watts/kg) as the independent variables predicting HbA_{1c}. Models were built in three steps. Step 1 was the unadjusted model, which just included just the independent variable. In step 2, the model was adjusted for gender, age, pubertal staging, insulin dose (units kg^{-1} day^{-1}), insulin regimen (type and number of injections/day) and BMI Z-score. Finally, to assess whether associations were different when waist–height ratio was included in the model instead of BMI Z-score, a third step was run in which BMI Z-score was replaced by waist–height ratio. All analyses were performed using the statistical software PASW for Windows version 18 (PASW Inc., Chicago, IL, USA) and alpha was set at 0.05.

Results

Physical characteristics of the participants are presented in Table 1. There were no differences between the young people with and without diabetes in terms of pubertal status, body composition, blood pressure, physical activity and physical fitness using PWC_{170} to estimate aerobic capacity. BMI, age and gender between groups were also similar (all $P > 0.05$).

Specific descriptive data in young people with Type 1 diabetes are presented in Table 2. Mean glycaemic control measured by HbA_{1c} was 68 ± 12 mmol/mol (8.4 ± 1.1%) and the insulin dose was 0.9 ± 0.3 units kg^{-1} day^{-1}. Mean duration of diabetes was 5 ± 3.7 years, the majority of the participants (66%) were either in mid-puberty or post-pubertal. Eighteen per cent (n = 11) of those with diabetes gave less than four injections per day, whilst the majority (n = 35, 58%) gave

Table 2 Specific descriptive data in young people with Type 1 diabetes

	Type 1 diabetes (n = 60)	
	Mean	SD
HbA_{1c} (mmol/mol)	68	12
HbA_{1c} (%)	8.4	1.1
Insulin dose (units kg^{-1} day^{-1})	0.9	0.3
Diabetes duration	n	%
≤ 5 years	33	55
> 5 years	27	45
Pubertal status		
Prepubertal (Tanner I)	12	20
Early puberty (Tanner II)	8	14
Mid-puberty (Tanner III or IV)	20	33
Post-pubertal (Tanner V)	20	33
Insulin regimen		
≤ 3 injections/day*	11	18
≥ 4 injections/day (basal bolus)†	35	58
Insulin pump	14	24

SD, standard deviation.
*Twice daily Mixtard 30, Novomix 30 (Novo Nordisk Ltd, Crawley, UK) or Humalog Mix25 (Lilly, Speke, UK); or Novomix 30 (Novo Nordisk) or Humalog Mix25 (Lilly) with Novorapid and Insulatard or Levemir (Novo Nordisk).
†NovoRapid (Novo Nordisk) or Humalog (Lilly) with Levemir (NovoNordisk) or Lantus (Sanofi-Aventis, Guildford, UK).

four or more injections depending on the basal–bolus system. Twenty-four per cent (n = 14) utilized pump therapy.

The linear regression models are presented in Tables 3, 4, 5 and 6. Inverse relations were observed between total and light physical activity with HbA_{1c} (all $P \leq 0.04$ in step 1, unadjusted), but the results changed in steps 2 and 3, i.e. after adjusting for gender, age, pubertal status, body composition, insulin dose and insulin regimen (Tables 3 and 4, respectively). The following regression model analysis revealed moderate-to-vigorous physical activity (β = −0.544, 95% CI −0.888 to −0.199, P = 0.003 in step 2; and β = −0.493, 95% CI −0.857 to −0.128, P = 0.009 in step 3) predicted 30–37% (R^2 = 0.295–0.374) of the variance for HbA_{1c}, regardless of gender, age, pubertal status, body composition, insulin dose and insulin regimen (Table 5). In other words, the physical activity intensity was associated with better glycaemic control. In addition, total, light and moderate-to-vigorous physical activity were adjusted for physical fitness [PWC_{170} (watts/kg)] and an inverse association between total physical activity and HbA_{1c} was found (data not shown). In the last two regression model analyses presented, physical fitness was not associated with HbA_{1c}, in any of the steps (Table 6). The results remained unchanged when diabetes duration and parental education levels were included as confounders (data not shown).

Discussion

In this study we found no differences between young people with diabetes and their siblings in body composition, blood pressure, physical activity and fitness. Importantly, our study reveals moderate-to-vigorous physical activity is associated with better glycaemic control, regardless of gender, age, pubertal status, body composition, insulin dose and insulin regimen.

Lower HbA_{1c} was associated with increased levels of moderate-to-vigorous physical activity, regardless of gender, age, pubertal status, body composition, insulin dose and insulin regimen, suggesting that the intensity of physical activity influences medium- to long-term glycaemic control. These results are in agreement with previous intervention studies in young people with Type 1 diabetes that resulted in better glucose control. For example, Michaliszyn and Faulkner [16] support the beneficial effects of increased moderate activity and decreased sedentary behaviour to reduce cardiovascular risks and improve glucose control in adolescents with Type 1 diabetes. Valerio *et al.* [6] demonstrated that regular physical activity (moderate and vigorous physical activity and sporting activity) was associated with better metabolic control and lipid profiles. The study by Herbst *et al.* [7] found that HbA_{1c} level was higher in the groups with less frequent physical activity than their more actives peers, and

Table 3 Linear regression model examining the association between HbA_{1c} and physical activity mean count/h of total physical activity after adjusting by potential confounders in young people with Type 1 diabetes (estimated values and 95% confidence interval)

	Dependent variable: HbA_{1c}*				
	β	95% CI		P	R^2
Independent variables					
Accelerometry					
Step 1 (unadjusted)	−0.802	−1.425	−0.180	0.013	0.118
Step 2 (adjusted†)	−0.633	−1.332	0.067	0.075	0.282
Step 3 (adjusted plus waist–height ratio‡)	−0.643	−1.396	0.109	0.092	0.279

*β, estimated value; CI, confidence interval; R^2, coefficient of determinations.
†Adjusted for gender, age, pubertal status, insulin dose (units kg^{-1} day^{-1}), insulin regimen (type and number of injections/day) and BMI Z-score.
‡BMI Z-score was replaced by waist–height ratio.

Table 4 Linear regression model examining the association between HbA_{1c} and mean min/day of light physical activity after adjusting by potential confounders in young people with Type 1 diabetes (estimated values and 95% confidence interval)

	Dependent variable: HbA_{1c}*				
	β	95% CI		P	R^2
Independent variables					
Light physical activity					
Step 1 (unadjusted)	−0.802	−1.555	−0.050	0.037	0.084
Step 2 (adjusted†)	−0.629	−1.685	0.427	0.236	0.251
Step 3 (adjusted plus waist–height ratio‡)	−0.598	−1.648	0.453	0.257	0.252

*β, estimated value; CI, confidence interval; R^2, coefficient of determinations.
†Adjusted for gender, age, pubertal status, insulin dose (units kg^{-1} day^{-1}), insulin regimen (type and number of injections/day) and BMI Z-score.
‡BMI Z-score was replaced by waist–height ratio.

Table 5 Linear regression model examining the association between HbA_{1c} and mean min/day of moderate-to-vigorous physical activity after adjusting by potential confounders in young people with Type 1 diabetes (estimated values and 95% confidence interval)

	Dependent variable: HbA_{1c}*				
	β	95% CI		P	R^2
Independent variables					
Moderate-to-vigorous physical activity					
Step 1 (unadjusted)	−0.381	−0.724	−0.039	0.030	0.019
Step 2 (adjusted†)	−0.544	−0.888	−0.199	0.003	0.374
Step 3 (adjusted plus waist-to-height ratio‡)	−0.493	−0.857	−0.128	0.009	0.344

*β, estimated value; CI, confidence interval; R^2, coefficient of determinations.
†Adjusted for gender, age, pubertal status, insulin dose (units kg^{-1} day^{-1}), insulin regimen (type and number of injections/day) and BMI Z-score.
‡BMI Z-score was replaced by waist-to-height ratio.

Table 6 Linear regression model examining the association between HbA_{1c} and physical fitness through aerobic capacity estimated using PWC_{170} tests (watts and watts/kg) after adjusting by potential confounders in young people with Type 1 diabetes (estimated values and 95% confidence interval)

	Dependent variable: HbA_{1c}*				
	β	95% CI		P	R^2
Independent variables					
PWC_{170} (watts)					
Step 1 (unadjusted)	0.512	−0.239	1.263	0.178	0.033
Step 2 (adjusted†)	−0.326	−1.295	0.643	0.502	0.226
Step 3 (adjusted plus waist–height ratio‡)	−0.154	−1.106	0.798	0.746	0.217
PWC_{170} (watts/kg)					
Step 1 (unadjusted)	−0.206	−0.748	0.336	0.450	0.010
Step 2 (adjusted†)	−0.122	−0.631	0.386	0.631	0.222
Step 3 (adjusted plus waist–height ratio‡)	−0.126	−0.716	0.465	0.670	0.218

*β, estimated value; CI, confidence interval; R^2, coefficient of determinations.
†Adjusted for gender, age, pubertal status, insulin dose (units kg^{-1} day^{-1}), insulin regimen (type and number of injections/day) and BMI Z-score.
‡BMI Z-score was replaced by waist–height ratio.
PWC_{170}, physical work capacity at a heart rate of 170 beats/min.

revealed that regular physical activity was one of the most important factors influencing the HbA_{1c} level without increasing the risk for severe hypoglycaemia. Bernardini *et al.* [31] studied the adherence to physical activity in children and showed that those who participated in competitive sport (at least 360 min/-week) had better glycaemic control than other active peers [31]. In contrast with our findings, no decrease in HbA_{1c} levels was reported by Laaksonen *et al.* [12] after a 12-week training programme in 20 patients with Type 1 diabetes compared with a control group. As other authors have shown, resistance/aerobic training did not improve HbA_{1c} in patients with Type 1 diabetes [11]. These findings are of particular interest, because physical activity should play a pivotal role in the management of this condition, as improving glycaemic control would reduce the risk of cardio-metabolic complications. Our study adds to current literature sharing findings that moderate-to-vigorous physical activity is associated with better glycaemic control in young people with Type 1 diabetes. The data suggested that increased physical activity is associated with lower $HbA_{1c,}$ thereby suggesting that an active lifestyle is helpful in maintaining long-term glucose control.

Peak work capacity was not associated with HbA_{1c} levels among young people with Type 1 diabetes. Similar results have been previously demonstrated. For example, Roberts *et al*. [10] showed improvements in maximal oxygen uptake with no associated changes in HbA_{1c} levels after 12 weeks of exercise. However, contradictory data have been reported regarding the benefits of aerobic capacity on metabolic control in patients with diabetes. Michaliszyn *et al*. [15] and Austin *et al*. [14] have reported that aerobic capacity was inversely associated with HbA_{1c} in young people with Type 1 diabetes. This is consistent with a previous study that showed aerobic capacity has been positively associated with insulin sensitivity in adolescents with Type 1 diabetes [4]. These studies provide evidence of the potential impact of fitness on glucose control, although our results were not found to be statistically significant. While it has been shown that moderate-to-vigorous activity improves aerobic capacity, the relationship found between HbA_{1c} and physical activity, was not found with fitness as a marker of aerobic capacity, despite the fact that a positive correlation was observed between both physical activity and aerobic capacity ($r = 0.380$, $P = 0.005$). This could be explained because physical fitness is also determined by constitutional factors, and it has been suggested that up to ~40% of variation in fitness may be attributable to genetic factors [32].

Strengths and limitations

A major strength of this study is the use of an objective and reliable method to assesses the physical activity levels [27]. In addition, the physical work capacity has been found to be consistently related to peak oxygen uptake in children with diabetes and healthy young people, as well as estimating aerobic capacity [13]. Thus, PWC_{170} is an appropriate test to compare the physical fitness of participants with diabetes and those of participants without diabetes. However, this study has some limitations. It should be pointed out that recruitment to the study was only 28% of those eligible, which may have influenced the levels of moderate-to-vigorous physical activity and fitness reported, as more sedentary individuals may have been less willing to participate. We did not have access to the individual data of participants who did not consent to be in the study. We have, however, highlighted the mean HbA_{1c} levels of the two groups (8.1% for participants vs. 8.4% for non-participants). In addition, the non-independence of observations between siblings and control subjects was not studied because it was a secondary objective to provide an indication of potential differences between young people with and without diabetes only. Another limitation may be that pubertal staging was carried out by examination in the group with Type 1 diabetes while in the control group was by self-report, which is a poor way to measure the pubertal staging. Also, the cross-sectional nature of this study precludes examination of causality. Nonetheless, this study adds to the literature suggesting that longitudinal observational studies and targeted interventions examining prospective relationships between moderate-to-vigorous physical activity and medium to long-term glycaemic control are warranted.

Conclusions

In conclusion, our results indicate that moderate-to-vigorous physical activity is associated with better glycaemic control, regardless of gender, age, pubertal status, body composition, insulin dose and insulin regimen. Thus, encouraging increased moderate-to-vigorous physical activity in children with Type 1 diabetes should be incorporated as a core element of multicomponent diabetes therapy in the future.

Competing interests

Nothing to declare.

Acknowledgements

This study took place with the financial support of the Diabetes UK Research Grant (reference: 06/0003396). This work was also partially supported by the David Telling Charitable Fund and from research arising from a Career Development Fellowships (to RJ) supported by the National Institute for Healthy Research. MCG is supported by a Spanish Ministry of Education (AP-2008-03806) studentship. The views expressed in this publication are those of the authors and not necessarily those of the National Health Service, the National Institute for Health Research, Diabetes UK or the Department of Health. The authors gratefully acknowledge all participants, and their parents and tutors, for their collaboration. They also acknowledge Linda Mottram for her efforts and great enthusiasm in fieldwork.

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6. Implicación práctica. Informe de Salud Escolar

[Practical implication. Report of School Health]

Artículo IX *[Study IX]*


mediante máxima validez
CV
Course-Navette
futuro manual of ser
to test respectivamente debe
mano kg
muestra and
Además rango detectar
hacia relacionada aplicación
CFCA
adolescentes
veces capacidad et aeróbica perímetro
edad
condición según
legumbres
adecuado jóvenes P50
the física
docente fuerza
pueden nivel riesgo
referencia determinar datos E.F
bebidas participantes
sobrepeso
Physical fácil alumnos P80
hábitos base
cada Fitness
tests VO2máx obtenidos
vida años
parámetros forma presente prueba
saludables estudio
grupos
ello alimentarios
P20 niños
escolar baja
puede
carbonatadas media porcentaje
GC salud IR corporal
dos informe
cintura
in
addendum resultados
españoles
normal alimentos
medida
consumo IMC
línea alimentación
información

Study IX

Revista de Investigación en Educación, nº 9 (2), 2011, pp. 35-50
http://webs.uvigo.es/reined/
ISSN: 1697-5200
eISSN: 2172-3427

ARTÍCULO ORIGINAL

Condición física relacionada con la salud y hábitos de alimentación en niños y adolescentes: propuesta de addendum al informe de salud escolar

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RESUMEN. **Objetivo:** Aplicar, en el ámbito escolar, la batería de test ALPHA-fitness (desarrollada y estandarizada en el proyecto europeo: ALPHA-Assessing Levels of Physical Activity and Fitness) para evaluar la condición física, complementándola con un estudio de hábitos alimentarios y, así, estudiar su viabilidad en el contexto escolar. En base a ello, diseñar y proponer un addendum al Informe de Salud Escolar. **Método:** Los profesores de Educación Física, de forma autónoma y previamente instruidos, evaluaron a 138 alumnos (6-18 años). **Resultados y conclusión:** La medida de la condición física relacionada con la salud y los hábitos alimentarios es factible de ser evaluada en el ámbito escolar e incorporada al Informe de Salud Escolar. Esta información es relevante para la salud basándose en la reciente evidencia científica.

PALABRAS CLAVE. Condición física, Patrones de alimentación, Informe de Salud Escolar

Health-related fitness and eating habits in children and adolescents: proposal for an addendum to the report of school health

ABSTRACT. **Aim:** To conduct the ALPHA-fitness test battery (developed and standardized in the European project: ALPHA-Assessing Levels of Physical Activity and Fitness) in the school setting, as a complementary tool to the study of eating habits, and to study its feasibility. We also aimed to design and propose an addendum to the Report of School Health. **Method**: The teacher of Physical Education assessed a total of 138 students (age: 6-18 years) in the school setting. **Results and conclusion**: The assessment of health-related physical fitness and eating habits is feasible in the school setting and can be easily included into Report of School Health. This finding is relevant to health based on previous scientific evidence.

KEY WORDS. Physical Fitness, Eating patterns, Report of School Health

1. INTRODUCCIÓN

El desarrollo de patrones de conducta no saludables entre los más jóvenes está aumentando (Fernández-San Juan, 2006). Los avances tecnológicos fomentan un estilo de vida más sedentario y, por otro lado, la amplia y variada oferta alimentaria expone a los jóvenes consumidores hacia hábitos nutricionales inadecuados. El creciente incremento del sobrepeso en los jóvenes españoles está despertando gran interés en el ámbito de la investigación para la salud. España ha participado en diversos proyectos de gran envergadura, nacionales e internacionales, encaminados a evaluar tanto en niños (e.j.: enKid (Serra-Majem et al., 2003) o IDEFICS (Ahrens et al., 2006)) como en adolescentes (e.j.: enKid , AVENA (Gonzalez-Gross et al., 2003) o HELENA (Moreno et al., 2008)), el estado de salud, los hábitos de comportamiento, el nivel de actividad física y condición física, los patrones de alimentación y la situación metabólico-nutricional, entre otros. Además de la importante labor desempeñada con la Estrategia NAOS, desarrollada por el Ministerio de Sanidad Español (Ballesteros Arribas, Dal-Re Saavedra, Pérez-Farinós y Villar Villalba, 2007).

La infancia y la adolescencia constituyen etapas claves en la adquisición de estilos de vida. Una vida físicamente activa, en la que el sujeto pueda adquirir un nivel de condición física adecuado, y unos hábitos alimentarios saludables, son importantes determinantes de salud presente y futura (Ortega, Ruiz, Castillo y Sjostrom, 2008; Ruiz et al., 2009; WHO, 2003). Evaluar ambos parámetros desde edades tempranas puede ayudar a encauzar a los jóvenes hacia hábitos de vida saludables. En este sentido, los centros educativos pueden ayudar a desarrollar una labor esencial evaluando sistemáticamente a sus alumnos y obteniendo informes acerca del estado de salud, a lo largo del extenso periodo de escolarización. En esta línea, España-Romero et al. (2010) han comprobado la fiabilidad, viabilidad y seguridad de una batería de tests de condición física relacionada con la salud (ALPHA-fitness test battery), cuando ésta es aplicada por el docente de E.F. en los centros educativos. El citado estudio supone un paso importante, ya que tradicionalmente han sido evaluadores experimentados los encargados de desarrollar estas competencias.

Un control periódico del nivel de condición física relacionada con la salud y los hábitos alimentarios puede representar una estrategia eficaz de cara a diseñar programas de intervención sobre estilos de vida saludables en los jóvenes y detectar futuros problemas de salud. Dado que el docente de E.F. está capacitado para desarrollar estas evaluaciones (España-Romero et al., 2010), el siguiente paso es facilitarle información que aborde la interpretación de los resultados de forma fácil y sencilla, así como su

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Fecha de recepción: 16/2/2011 · Fecha de aceptación: 30/9/2011

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relación con el estado de salud (Ortega et al., 2008). Para ello, en la bibliografía encontramos diversas fórmulas validadas en niños y adolescentes mediante las cuales obtener parámetros como índice de masa corporal (IMC) (Cole, Bellizzi, Flegal y Dietz, 2000), porcentaje de grasa corporal (GC) (Rodriguez et al., 2005) o consumo máximo de oxígeno (VO2máx.) (Leger, Mercier, Gadoury y Lambert, 1988), entre otros. Además, disponemos de valores de referencia recientes en jóvenes españoles (Castro-Pinero et al., 2009; Castro-Piñero et al., en prensa; Moreno et al., 2006; Moreno et al., 2007; Ortega et al., 2005) donde se utilizaron los mismos tests que aquí se proponen. Ambos planteamientos, valoración e interpretación, son herramientas útiles y objetivas para determinar el estado de salud de la persona. Estos informes pueden ayudar a profesionales sanitarios, padres y educadores a prevenir e incluso detectar futuras patologías, lo que supone una contribución al intento de reducir el riesgo de enfermedades crónicas, con la consecuente repercusión sobre el gasto público sanitario asociado a un estilo de vida sedentario y hábitos de alimentación inadecuados.

Los objetivos de la presente investigación han sido: a) Aplicar, en el ámbito escolar y de una manera práctica, la batería de test ALPHA (ALPHA-fitness test battery), desarrollada y estandarizada en el marco del proyecto europeo ALPHA-Assessing Levels of Physical Activity and Fitness); b) complementar esta evaluación con un estudio sencillo de hábitos alimentarios; c) establecer la forma de aplicación práctica; d) basándose en los resultados obtenidos, diseñar y proponer un addendum al informe de salud escolar.

2. MÉTODO

2.1. El proyecto ALPHA

La presente investigación forma parte del Proyecto ALPHA (**A**ssesing **L**evels of **Ph**ysical **A**ctivity and Fitness) (*www.thealphaproject.eu*), cuya metodología completa ha sido publicada con anterioridad (Meusel et al., 2007). Se trata de un estudio multicéntrico que ha proporcionado una serie de instrumentos para evaluar los niveles de actividad física y de condición física de forma comparable en los países miembros de la Unión Europea (Ruiz et al., 2010). Los resultados de condición física analizados en este trabajo son de carácter descriptivo y, de forma paralela, se registró la frecuencia de consumo de alimentos.

2.2. Sujetos y diseño experimental

El estudio se realizó en condiciones de trabajo ordinario y contando con los propios docentes de E.F. de los centros implicados, de forma autónoma en las condiciones en que lo harían habitualmente. Previamente recibieron una sesión instructiva de 2-3 horas de duración por parte de evaluadores experimentados y dispusieron de un manual de evaluación específico. Se estudió una muestra de 58 niños (entre 6 y 11,9 años) y 80 adolescentes (entre 12 y 18 años) de la provincia de Granada. Capacidad aeróbica, fuerza muscular y composición corporal fueron los componentes de condición física relacionada con la salud evaluados mediante la batería de tests propuesta en el estudio ALPHA. Los hábitos de alimentación fueron analizados en una sub-muestra de 33 niños (entre 8 y 11,9 años) y 40 adolescentes (entre 12 y 18 años), mediante un Cuestionario de Frecuencia de Consumo de Alimentos (CFCA) (Gonzalez-Gross et al., 2003), simplificado y adaptado *ad hoc*.

Docentes de la especialidad de E.F., padres y alumnos fueron informados de la finalidad del estudio y se contó con su consentimiento expreso.

2.3. Condición física relacionada con la salud

La recogida de datos fue supervisada de manera externa y sin intervenir por dos evaluadoras. Los test seleccionados proporcionan una medida objetiva de la condición física (Ortega et al., 2008) y tiene una relación directa con la salud, según directrices del American College of Sport Medicine (Amstrong, Whaley, Brubaker y Otto, 2005). A su vez, la justificación científica en la que se ha basado la selección de estos tests se ha llevado a cabo a través de pruebas de validez, fiabilidad y capacidad para predecir el estado de salud presente y futuro previamente publicadas (Ruiz et al., 2010).

2.3.1. Capacidad aeróbica

Test de Course-Navette o test de 20 metros de ida y vuelta. Esta prueba evalúa la capacidad aeróbica máxima a través de un test de campo indirecto e incremental de ida y vuelta en una distancia de 20 metros hasta el agotamiento. El ritmo del test es marcado por una señal acústica, con una velocidad inicial de 8,5 km/h, incrementándose en 0,5 km/h cada minuto (1 minuto equivale a 1 palier). Mediante el resultado en este test se puede determinar el VO_2máx., variable fisiológica que mejor define la capacidad aeróbica. La fiabilidad y validez de este test para predecir el VO_2máx. en niños y adolescentes ha sido demostrada (Castro-Pinero et al., 2010; Liu, Plowman y Looney, 1992). Para calcular el VO_2máx. a partir del resultado obtenido en el Course-Navette es suficiente con introducir la edad (E) y la velocidad final (V=8+0,5 × último palier completado) en la siguiente fórmula (Leger et al., 1988):

$$\mathbf{VO_2\ máx.}=31{,}025+3{,}238\mathbf{V}-3{,}248\mathbf{E}+0{,}1536\mathbf{VE}$$

2.3.2. Fuerza muscular del tren superior

Test de dinamometría manual. Esta prueba evalúa la fuerza máxima isométrica de prensión manual, utilizando para ello un dinamómetro digital Takei TKK5101 (rango de 5 a 100 kg; precisión de 0,1 kg). El participante debe aplicar la máxima prensión manual en dos intentos alternativos con cada mano en una posición estandarizada, de pie, con los brazos paralelos al cuerpo y sin contacto alguno con el dinamómetro salvo la mano que está siendo evaluada. El resultado final es consecuencia de la media de los dos intentos de cada mano y la suma de ambas medias. Es preciso graduar el agarre del dinamómetro al tamaño de la mano de cada participante. Para ello existen ecuaciones específicas tanto en niños (España-Romero et al., 2008) como en adolescentes (Ruiz et al., 2006). Tan sólo se necesita medir la longitud de la mano desde el meñique al pulgar e introducir la medida obtenida (X) en una de las siguientes fórmulas, en función de la edad y el género del participante, obteniéndose finalmente la longitud idónea del agarre (Y):

Niños: Chicos: $Y= \mathbf{X}/4+0{,}44$ Chicas: $Y=0{,}3\mathbf{X}-0{,}52$

Adolescentes: Chicos: $Y= \mathbf{X}/7{,}2+3{,}1$ Chicas: $Y=\mathbf{X}/4+1{,}1$

2.3.3. Fuerza muscular del tren inferior

Test de salto horizontal sin impulso. Esta prueba evalúa la fuerza explosiva del tren inferior mediante la máxima distancia alcanzada en dos intentos, tomando como referencia el talón más atrasado. Tan sólo precisa una cinta métrica y una superficie no resbaladiza sobre la que realizar el test.

2.3.4. Composición corporal

La inclusión de la composición corporal como un componente de salud relacionada con la condición física sigue los principios establecidos por el American College of Sport Medicine (Amstrong et al., 2005). Las mediciones antropométricas se realizaron de acuerdo con el manual de referencia de estandarización de Lohman et al. (1988).

Para determinar la composición corporal se midieron (dos veces, no inmediatamente consecutivas) los siguientes parámetros: peso, talla, pliegues tricipital y subescapular, y perímetro de cintura. A continuación se calculó la media para cada uno de los parámetros medidos. Estos datos permiten determinar índices antropométricos tales como, el IMC (*IMC = Peso (kg)/Talla (m)*^{2}) o el porcentaje de grasa corporal (GC) según diferentes ecuaciones en función de las medidas empleadas: pliegues cutáneos (tríceps y subescapular) o perímetro de cintura. Siguiendo las recomendaciones de validez publicadas en adolescentes (Rodriguez et al., 2005), nosotros hemos utilizado las ecuaciones de Slaughter et al. (1988) para determinar el porcentaje de GC. Los instrumentos de medida utilizados fueron: a) una báscula electrónica SECA 861 (rango de 0,05 a 130 kg; precisión de 0,05 kg), para el peso; b) un tallímetro telescópico SECA 225 incorporado en la báscula(rango de 60 a 200 cm; precisión de 1 mm), para la talla; c) un plicómetro modelo Holtain (rango de 0 a 40 mm; precisión de 0,2 mm), con una presión constante de 10 g/mm^2 en la superficie de contacto, para los pliegues cutáneos tricipital y subescapular; y d) una cinta no elástica Seca Tipo 200 (rango de 0 a 150 cm; precisión de 1 mm), para el perímetro de cintura.

Para medir el peso, basta con colocar al individuo sobre la báscula, sin ningún apoyo externo y en una posición centrada. La talla debe medirse teniendo en cuenta el plano de Frankfurt, consistente en colocar la cabeza de forma que la línea imaginaria que una el borde inferior de la órbita de los ojos y el superior del meato auditivo externo sea horizontal; con los pies juntos, rodillas extendidas, talones, nalgas y espalda en contacto con la pieza vertical del aparato medidor. El pliegue tricipital se encuentra en el punto medio entre el borde superior del acromion en su aspecto más lateral y el borde más próximo y lateral de la cabeza del radio, el panículo debe correr paralelo al eje longitudinal del brazo. El pliegue subescapular se localiza a 2 cm en una línea que corre hacia abajo en forma lateral desde el punto más inferior de la escápula, el panículo debe correr paralelo al eje oblicuo (45º) de la escápula. Por último, para medir el perímetro de cintura se requiere colocar al individuo en una posición erguida, con brazos en posición relajada y abducida. La medida debe ser tomada en el nivel más estrecho, al final de una espiración normal y sin presionar la piel.

2.4. Hábitos alimentarios

El CFCA es un modelo de encuesta que registra la frecuencia media de consumo de alimentos por un tiempo determinado y su validez ha sido publicada con anterioridad (Martin-Moreno et al., 1993). En el presente estudio se eligió un CFCA previamente utilizado en el estudio AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes Españoles) (Gonzalez-Gross et al., 2003). La simplificación consistió en seleccionar la parte del cuestionario que registra el consumo medio de alimentos durante el año y descartar la sección de preguntas cualitativas. Se seleccionaron 18 ítems, siendo el criterio de dicha selección la relación de cada uno de ellos con un determinado alimento o un grupo de alimentos con similar composición, basándose en la pirámide nutricional propuesta en la Guía de alimentación saludable de la Sociedad Española de Nutrición Comunitaria (SENC) (2004). La formulación de la pregunta y las posibles respuestas siguieron la estructura del cuestionario original resultando en una versión simplificada de éste. Frutas, verduras, legumbres, cereales, dulces, aceite de oliva, otros ácidos grasos, salsas, bebidas carbonatadas, bebidas no carbonatadas, agua, lácteos, huevos, carnes magras, carnes grasas, embutidos, pescado y misceláneas fueron los ítems registrados. Nueve fueron las diferentes opciones de respuesta: Nunca/casi nunca; 1-3 veces al mes; 1, 2-4, 5-6 veces a la semana y 1, 2-3, 4-6, +6veces al día. Durante dicha administración estuvo presente el docente de E.F. y se permitió resolver cualquier pregunta.

2.5. Análisis estadístico

Los resultados desprendidos de la valoración de la condición física relacionada con la salud (media ± DT) siguen una distribución normal. La comparación de medias en los diferentes grupos de estudio (sexo y grupos de edad, niños y adolescentes) se llevó a cabo mediante la prueba estadística T-Student para muestras independientes. En la segunda fase del análisis, la muestra fue clasificada en normopeso y sobrepeso (incluido obesidad), de acuerdo con los puntos de corte para el IMC propuestos en la bibliografía (Cole, Bellizzi, Flegal y Dietz, 2000). Se utilizó una escala tipo Likert (muy baja ($X < P_{20}$), baja ($P_{20} \leq X > P_{50}$), normal ($P_{50} \leq X > P_{80}$) o buena ($X \geq P_{80}$)) para interpretar el nivel de capacidad aeróbica y fuerza muscular de los participantes, basándose en los valores de referencia normales en niños y adolescentes españoles (Castro-Pinero et al., 2009; Castro-Piñero et al., en prensa; Ortega et al., 2005). En ambos casos, se consideró el género y la edad de los participantes. El índice de riesgo cardiovascular (CV) se estableció de acuerdo a la propuesta del Grupo FITNESSGRAM del Cooper Institute (2007), validada en niños y adolescentes (Lobelo, Pate, Dowda, Liese y Ruiz, 2009). El umbral de riesgo CV para los chicos se corresponde a un VO_2máx. de 42 ml/kg/min y para las chicas de 14 años en adelante a un VO_2máx. de 35 ml/kg/min, mientras que para aquéllas con 13, 12, 11 y 10 años se corresponde con un VO_2máx. de 36, 37, 38 y 39 ml/kg/min, respectivamente .

Los datos desprendidos del CFCA fueron re-categorizados en dos niveles: consumo adecuado frente a consumo no adecuado, basándose en las ingestas recomendadas (IR) por la SENC (2004). En el siguiente paso, el análisis inferencial, destinado a detectar diferencias entre grupos, se empleó la prueba de Chi-cuadrado (χ^2). El análisis estadístico de los datos fue efectuado con el programa SPSS v. 15,0 para Windows XP (SPPS Inc. Chicago Il. USA). El nivel de significación se fijó en 0,05.

3. RESULTADOS

La operativa resultó de fácil aplicación siendo bien aceptada y desarrollada por todas las partes implicadas. No se registró incidencia digna de interés y todo el desarrollo de las pruebas se produjo dentro del tiempo esperado que era el correspondiente a la clase de E.F.. La Tabla 1 muestra los resultados obtenidos en la evaluación de la condición física relacionada con la salud. Además se presentan otros parámetros calculados a partir de los mismos: IMC, porcentaje de GC y riesgos CV futuro. Los datos se presentan diferenciando entre grupos de edad y sexo. No se observaron diferencias significativas entre sexos para el grupo de los niños en ninguna de las medidas analizadas, con excepción del VO_2máx., siendo éste mayor en los chicos. Entre los adolescentes, chicos y chicas mostraron diferencias significativas en todas las medidas antropométricas excepto en el IMC. Las chicas obtuvieron mayores resultados en pliegues, perímetro de cintura y porcentaje de GC. Los resultados en los tests Course-Navette, dinamometría manual y salto horizontal sin impulso fueron significativamente mayores en chicos. La prevalencia de sobrepeso observada fue mayor en niños que en adolescentes (37,5% vs. 30,3%). El riesgo CV futuro según la capacidad aeróbica actual de los participantes, no supera el 4% y 14 % en niños y adolescentes, respectivamente.

	Niños (n=58)			Adolescentes (n=80)		
	Todos	Chicos	Chicas	Todos	Chicos	Chicas
Peso (kg)	37 ± 10,4	36,4 ± 10,7	37,4 ± 10,2	57,9 ± 12,2	61,1 ± 14,6	54,9 ± 14,6*
Talla (cm)	138,9 ± 12,6	138 ± 12	140 ± 13	163,6 ± 8,4	168 ± 8	160 ± 7 *
Pliegue tríceps (mm)	17,3 ± 7,2	16,8 ± 8,2	17,6 ± 6,4	18,7 ± 9,2	14,9 ± 9,1	22 ± 8,1 *
Pliegue subescapular (mm)	11 ± 5,2	10,6 ± 5,2	11,4 ± 5,2	13,2 ± 6,6	11,5 ± 6,8	14,7 ± 6,2 *
Perímetro de la cintura (cm)	60,9 ± 7,4	61,5 ± 8,1	60,5 ± 7	70,5 ± 7,7	65,4 ± 14	67,8 ± 5,6 *
Índice de masa corporal (kg/m^2)	18,8 ± 2,9	18,7 ± 2,9	19 ± 3	21,6 ± 3,9	21,6 ± 4,5	21,5 ± 3,5
Normopeso (%)	**62,5**	**65,4**	**60**	**69,7**	**68,6**	**70,7**
Sobrepeso (%)[1]	**37,5**	**34,6**	**40**	**30,3**	**31,4**	**29,3**
Grasa corporal (%)[2]	24,4 ± 8,6	24,2 ± 9,8	24,5 ± 6,7	25,6 ± 10,5	21,8 ± 12	29,1 ± 7,5 *
Dinamometría manual (kg)[3]	26,9 ± 8,3	26,6 ± 7,5	27,1 ± 9	56,1 ± 14,4	65,4 ± 14	48,1 ± 8,9 *
Salto horizontal (cm)	119,9 ± 25,7	126 ± 26	115 ± 25	160,3 ± 33,3	185 ± 26	139 ± 22 *
Course-Navette (palier)	3,5 ± 1,9	4 ± 2	3 ± 2	5,5 ± 2,2	7 ± 1	4 ± 2 *
VO_2max. (ml/kg/min)[4]	46,6 ± 3,6	47,7 ± 3,5	45,6 ± 3,5 *	43,4 ± 5,9	47,4 ± 4,8	39,9 ± 4,2 *
Con riesgo CV fututo (%)[5]	**4**			**14**		
Sin riesgo CV futuro (%)[5]	**96**			**86**		

Datos expresados en media ± DT y % (en negrita). *P≤0,05 (t-student) entre sexos. CV: cardiovascular
[1] Según criterios tomados de Cole et al. (2000). [2] Según ecuación de Slaughter et al. (1988)
[3] Suma de ambas manos. [4] Consumo máximo de oxígeno según la fórmula de Leger et al. (1988)
[5] Riesgo CV asociado a la capacidad aeróbica según criterios del Grupo FITNESSGRAM del Cooper Institute (2007)

Tabla 1. Resultados de la condición física relacionada con la salud en niños (rango de edad 6-11,9 años) y adolescentes (rango de edad: 12-18 años)

En la Figura 1, cada participante fue clasificado en muy baja, baja, normal y buena condición, según sexo y edad tomando como referencia los percentiles descritos por Castro-Piñero et al. (2009, en prensa) en niños y Ortega et al. (2005) en adolescentes. Los resultados obtenidos en los tests Course-Navette, dinamometría manual y salto de longitud sin impulso, desvelan que la capacidad aeróbica del 51% de los participantes evaluados se encuentra igual o por encima del percentil 50, lo que es en la práctica equivalente a que sea igual o por encima de la media si comparamos con los datos obtenidos en otros participantes españoles de su mismo sexo y edad. Respecto a la fuerza máxima de prensión manual y a la fuerza explosiva de piernas, el 40% y 54% de los participantes, respectivamente, también se sitúa en el mismo nivel o por encima de la media de la muestra de referencia.

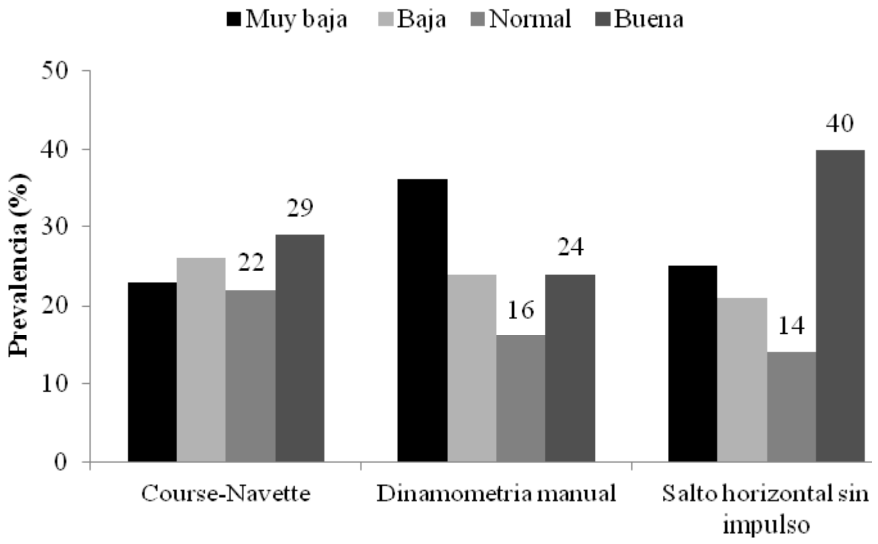

Figura 1. Estimación del nivel alcanzado para los tests: Course-Navette, dinamometría manual y salto horizontal sin impulso, según percentiles de referencia (Castro-Piñero et al., 2009; Castro-Piñero et al., In press; Ortega et al., 2005). Condición muy baja ($X < P_{20}$), baja ($P_{20} \leq X > P_{50}$), normal ($P_{50} \leq X > P_{80}$) o buena($X \geq P_{80}$))

Las Tablas 2 y 3 y la Figura2 muestran información sobre el estudio de la frecuencia de consumo de alimentos y el cumplimiento con las IR según la SENC de la muestra de estudio. Los grupos de alimentos registrados, así como los alimentos que conforman cada uno de ellos, pueden observarse en la Tabla 2. Además, se presenta la IR para cada uno de los grupos de alimentos, según las indicaciones de la SENC (2004). Basándose en estas recomendaciones, en la Tabla 3 se estudia la proporción de la muestra que cumple con las IR. Existe una tendencia general a no cumplir con la IR en la mayoría de los grupos de alimentos estudiados. Destacamos la notable inclinación hacia un patrón inadecuado para determinados grupos de alimentos, entre ellos: frutas (73%), verduras (95%), legumbres (92%), bebidas carbonatadas (70%), huevos (78%) y embutidos (82%). En niños, se mantiene dicho patrón, aunque con porcentajes algo más bajos que los anteriores (70%, 88%, 61%, 46%, 73% y 79%, respectivamente). En la misma línea, esta prevalencia es aún mayor entre adolescentes: verduras (100%), legumbres (95%) o bebidas carbonatadas (78%). El 55% de los adolescentes consume dulces más de 2 veces en semana frente al 27% de los niños. El consumo inadecuado de productos precocinados (misceláneas) es mayor entre los niños que entre los adolescentes (36% vs. 18%). En contraposición, observamos un consumo adecuado de pescado en el 63% de los adolescentes y el 79% de los niños, o carne magra en el 88% de los adolescentes y el 78% niños.

Grupos de alimentos	**Alimentos**	**IR SENC**
Frutas	Frutas	3 r/d
Vegetales	Verduras y hortalizas, incluidas patatas	2r/d
Legumbres	Lentejas, alubias, garbanzos, guisantes…	2-4 r/s
Cereales	Pan banco/integra, cereales de desayuno, cereales integrales, pasta, arroz, cuscús, pizza…	4-6 r/d
Dulces	Chocolate, magdalenas, galletas, pastel, donut, bollo crema, bollo chocolate…	≤ 2 r/s*
Aceite de oliva	Aceites de oliva	3-5 r/d
Otros ácidos grasos	Margarina, mantequilla y otros aceite vegetales	≤ 2 r/s*
Salsas	Mayonesa , kétchup, tomate frito y otras salsas	≤ 2 r/s*
Agua	Agua	4-8 r/d
Bebidas carbonatadas	Light y azucaradas	≤ 1 r/s*
Bebidas no carbonatadas	Bebidas isotónicas y zumos	≤ 1 r/s*
Lácteos	Leche, yogurt, queso, helado…	2-4 r/d
Huevos	Huevos	3-4 r/s
Carnes magras	Carne de cerdo o ternera magra, pollo, pavo…	3-4 r/s
Carnes grasas	Carne de cerdo o ternera grasa, hamburguesa, tocino, bacón, panceta, chorizo, morcilla…	≤ 2 r/s*
Embutidos	Salchichón, chorizo, mortadela, jamón york, jamón serrano…	≤ 1 r/s*
Pescado	Pescado blanco y azul	3-4 r/s
Miscelánea	Patatas fritas, croquetas, empanadillas, pescado o carne empanado, churros, buchuelos...	≤ 2-3 r/s*

* Se recomienda un consumo ocasional.
r/d: raciones al día.
r/s: raciones a la semana.

Tabla 2. Grupos de alimentos e Ingestas Recomendadas (IR) según Sociedad Española de Nutrición Comunitaria (SENC)

	Todos (n=73)				Niños (n=33)				Adolescentes (n=40)			
	IR Adecuada		IR Inadecuada		IR Adecuada		IR Inadecuada		IR Adecuada		IR Inadecuada	
	%	(n)	%	(n)	%	(n)	%	(n)	%	(n)	%	(n)
Fruta	27,4	(20)	72,6	(53)	30,3	(10)	69,7	(23)	25,0	(10)	75,0	(30)
Verduras	5,5	(4)	94,5	(69)	12,1	(4)	87,9	(29)	0	(0)	100	(40)
Legumbres	8,2	(6)	91,8	(67)	12,1	(4)	87,9	(29)	5,0	(2)	95,0	(38)
Cereales	52,1	(38)	47,9	(35)	48,5	(16)	51,5	(17)	55,0	(22)	45,0	(18)
Dulces	57,5	(42)	42,5	(31)	72,7	(24)	27,3	(9)	45,0	(18)	55,0	(22)
Aceite de oliva	46,6	(34)	53,4	(39)	57,6	(19)	42,4	(14)	37,5	(15)	62,5	(25)
Otros ácidos grasos	72,6	(53)	27,4	(20)	60,6	(20)	39,4	(13)	82,5	(33)	17,5	(7)
Salsas	64,4	(47)	35,6	(26)	72,7	(24)	27,3	(9)	57,5	(23)	42,5	(17)
Bebidas carbonatadas	30,1	(22)	69,9	(51)	39,4	(13)	60,6	(20)	22,5	(9)	77,5	(31)
Bebidas no carbonatadas	57,5	(42)	42,5	(31)	54,5	(18)	45,5	(15)	60,0	(24)	40,0	(16)
Agua	74,0	(54)	26,0	(19)	90,9	(30)	9,1	(3)	60,0	(24)	40,0	(16)
Lácteos	58,3	(42)	41,7	(30)	63,6	(21)	36,4	(12)	53,8	(21)	46,2	(18)
Huevos	23,3	(17)	76,7	(56)	27,3	(9)	72,7	(24)	20,0	(8)	80,0	(32)
Carne magra	83,3	(60)	16,7	(12)	78,1	(25)	21,9	(7)	87,5	(35)	12,5	(5)
Carne grasa	75,3	(55)	24,7	(18)	84,8	(28)	15,2	(5)	67,5	(27)	32,5	(13)
Embutido	17,8	(13)	82,2	(60)	21,2	(7)	78,8	(26)	15,0	(6)	85,0	(34)
Pescado	69,9	(51)	30,1	(22)	78,8	(26)	21,2	(7)	62,5	(25)	37,5	(15)
Miscelánea	74,0	(54)	26,0	(19)	63,6	(21)	36,4	(12)	82,5	(33)	17,5	(7)

Datos presentados para toda la muestra y segmentados por grupos de edad, niños (rango de edad 8-11,9 años) y adolescentes (rango de edad: 12-18 años).

Tabla 3. Porcentaje de individuos que cumplen con las recomendaciones de ingesta propuestas por la Sociedad Española de Nutrición Comunitaria (SENC)

En la Figura 2 se compara la adhesión a la IR adecuada en niños y adolescente. Los datos se presentan agrupados según: a) consumo diario, b) consumo semanal, c) consumo ocasional, y d) bebidas. Se observa una significativa mayor adhesión al consumo adecuado de verduras, aceite de oliva, dulces y agua en los niños.

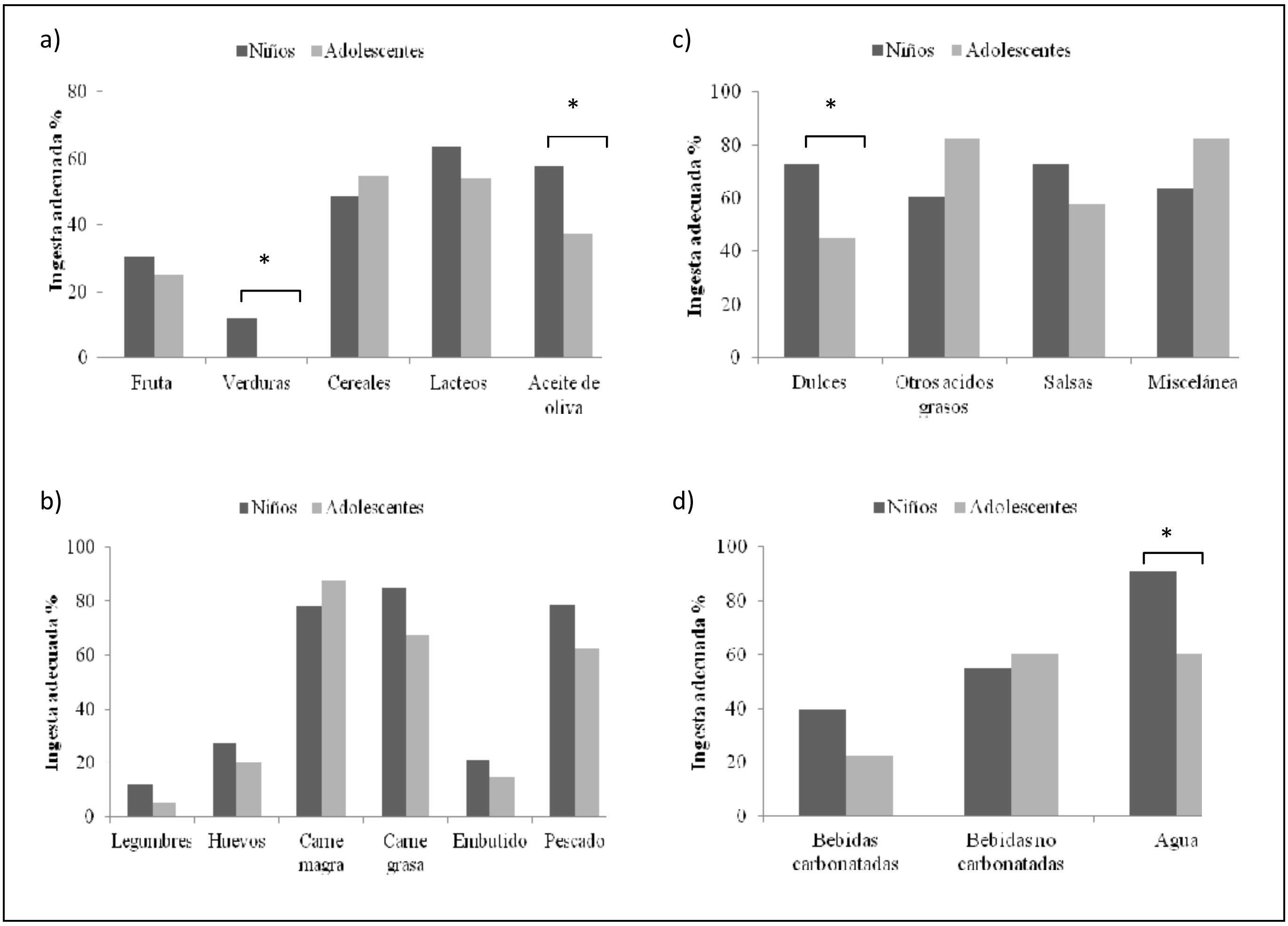

Figura 2. Comparación de la adhesión a las IR en los en niños y adolescentes. a) Consumo diario, b) Consumo semanal, c) Consumo ocasional, y d) Bebidas. * P≤0,05

4. DISCUSIÓN

El presente estudio muestra una aplicación en la práctica de una serie de pruebas diseñadas para evaluar en el medio escolar el nivel de condición física relacionada con la salud y unos determinados hábitos alimentarios saludables. La selección de los tests propuestos en este estudio se ha basado en criterios de validez (Castro-Piñero et al., 2010) y en la directa implicación que cualidades como la capacidad aeróbica y la fuerza muscular, o mantener un correcto IMC, ejercen sobre el estado de salud futuro (Ruiz et al., 2009). Se seleccionó el CFCA por ser una herramienta de fácil aplicación e interpretación por personal no experto (Martín-Moreno et al., 1993). Además, se presentan las fórmulas más apropiadas, según criterios de validez (Cole et al., 2000; Leger et al., 1988; Liu et al., 1992; Rodríguez et al., 2005), para obtener parámetros como el IMC, el porcentaje de GC o el VO_2máx., así como puntos de corte y valores de referencia (Castro-Piñero et al., 2009; Castro-Piñero et al., en prensa; Moreno et al., 2006; Moreno et al., 2007; Ortega et al., 2005). De forma que toda esta información puede ser de utilidad para interpretar los resultados de los tests y mejorar el “Informe de Salud Escolar”, (ver Anexo 1) con la intención de proponer a padres, profesionales sanitarios y docentes de la E.F. el seguimiento individualizado de los escolares a lo largo del periodo de escolarización.

La prevalencia de sobrepeso constatada en nuestro estudio (37,5% en niños y 30,3% en adolescentes) coincide con otros estudios previos en niños y adolescentes españoles (Moreno et al., 2005; Serra-Majem et al., 2003), por lo que se confirma la existencia del elevado índice de sobrepeso entre los más jóvenes. Los resultados obtenidos en los tests de condición física están en concordancia con los encontrados por Castro-Piñero et al. (en prensa). La comparación de los resultados obtenidos en los tests de condición física con otros valores de referencia en percentiles encontrados en la bibliografía (Castro-Piñero et al., 2009; Castro-Piñero et al., en prensa; Ortega et al., 2005) nos permite realizar una clasificación intuitiva del individuo, basándose en la siguiente escala: condición muy baja ($X < P_{20}$), baja ($P_{20} \leq X > P_{50}$), normal ($P_{50} \leq X > P_{80}$) o buena ($X \geq P_{80}$). Aproximadamente el 50% de los participantes estudiados poseen una capacidad aeróbica calificada como normal o buena, la misma calificación fue obtenida por el 40% de los participantes cuando se les evaluó la fuerza máxima de prensión manual, y el 54% en relación a la fuerza explosiva de piernas. El 86% de los adolescentes no presentan riesgo CV futuro, basándose en el cálculo del VO_2máx. actual. Estos resultados están en concordancia con los encontrados por Ortega et al. (2005) en el estudio AVENA. Otras investigaciones en niños mostraron porcentajes superiores a los obtenidos en nuestro estudio (Mota, Flores, Flores, Ribeiro y Santos, 2006). Pero el objetivo último de este trabajo no ha sido exclusivamente el de comparar los resultados desprendidos de la muestra estudiada, sino que de forma global pretendía proporcionar las pautas para obtener un informe adecuado e individualizado con la intención de controlar y prevenir casos extremos, como pueden ser el bajo nivel de condición física u obesidad. De ahí la importancia dedicada a lo largo de este artículo al diseño de un addendum al informe escolar de salud física basándose en una correcta lectura y manipulación de los resultados (ver Anexo 1, a título de ejemplo).

En lo que se refiere a las pautas de alimentación, se aprecia una tendencia generalizada hacia conductas no saludables que sería aconsejable corregir, especialmente entre los adolescentes. Por ejemplo, la fruta y la verdura son alimentos que se deben consumir diariamente. A pesar de ello, tan sólo un 27% y 6% de los participantes, respectivamente, cumplen con las recomendaciones. O las legumbres, dónde sólo el 8% las consume al menos 2 veces en semana. El consumo de bebidas con alto aporte calórico, como es el caso de las bebidas carbonatadas y otras bebidas azucaradas, se considera elevado, ya que el 70% y 43% de los participantes, respectivamente, las consumen a diario. En la misma línea, un 43% de los participantes presenta un consumo excesivo de dulces. Como aspecto positivo, habría que destacar que el 70%, 83% y 75% de los participantes del estudio cumplen con la IR de pescado, carne magra y carne grasa, respectivamente. Nuestros resultados siguen la línea de otros estudios previos en escolares y universitarios (Bayona-Marzo et al., 2007; Gómez-Candela et al., 2007). En alumnos universitarios de Soria se observó un consumo adecuado para los grupos de alimentos como carne, pescado, leche y derivados en un alto porcentaje de los participantes; mientras que para el resto de los grupos de alimentos, pasta, pan y cereales, verduras y hortalizas, frutas, legumbres, y aceite de oliva, su consumo distó mucho de cumplir las recomendaciones (Bayona-Marzo et al., 2007).

Los diferentes ítems propuestos pueden ser analizados fácilmente por el docente de E.F. para clasificar a sus alumnos según su consumo, lo que le permitirá conocer la tendencia de los hábitos alimentarios y detectar conductas de alto riesgo. Ello sugiere que es de vital importancia facilitar a los propios escolares, padres y profesores una herramienta de eficiente aplicación y fácil interpretación, siendo el CFCA el método más fácil para tipificar el consumo habitual de alimentos (Martín-Moreno et al., 1993).

Una de las principales limitaciones de nuestro estudio ha sido el tamaño de la muestra referente a la evaluación nutricional. Además, determinados ítems del CFCA, aceite de oliva y otros ácidos grasos, no son correctamente interpretados por los participantes y no registran el consumo real de estos productos, ya que no son capaces de identificar el uso de estos alimentos en la elaboración de las principales comidas. Como fortaleza presente en nuestro estudio se encuentra la importante evidencia científica subyacente al mismo y que ha permitido aplicar una batería de pruebas perfectamente validada y estandarizada en particular en lo que se refiere al estudio de la condición física relacionada con la salud, así como la proposición de un addendum al Informe de Salud Escolar que puede ser una herramienta adecuada para conocer la situación de nuestros escolares y promover cambios en estilo de vida hacia hábitos más saludables.

5. CONCLUSIONES

Nuestro estudio muestra que la medida de la condición física relacionada con la salud y los hábitos alimentarios, es factible de ser evaluada en el ámbito escolar e incorporada al Informe de Salud Escolar. Esta información es relevante basándose en la reciente evidencia científica disponible. Por ello, establecer estos registros periódicamente puede ayudar a detectar a aquellos alumnos con un bajo nivel de condición física y/o problemas de sobrepeso. Nuestro objetivo a largo plazo, gracias a la implicación del docente de E.F., debería ser que los jóvenes alcancen la madurez siendo capaces de mantener hábitos de vida saludables que les hagan posible prevenir la enfermedad y mantenerse en un estado de salud óptimo.

AGRADECIMIENTOS

Este estudio se ha desarrollado integrado en el proyecto de investigación ALPHA financiado por la Comisión de la Unión Europea, Dirección General de Sanidad y Consumo y Protección, en el marco del Programa de Salud Pública 2003-2008 (Ref: 2006120), por el Ministerio de Educación de España (EX-2008-0641; EX2009-0899; AP2004-2745; AP2005-4358; AP2008-03806), fondo FEDER (Acciones Complementarias DEP2007-29933-E), y el Ministerio de Ciencia y Tecnología (RYC-2010-05957).

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LIMITATIONS AND STRENGTHS

[LIMITACIONES Y FORTALEZAS]

LIMITATIONS AND STRENGTHS [LIMITACIONES Y FORTALEZAS]

Some limitations and strengths of the results presented in this Doctoral Thesis are mentioned below.

- A common limitation in all studies included in the present Doctoral Thesis (HELENA study, EHYS, British study and ALPHA study) is that they are cross-sectional studies and which does not allow us to identify causal relationships.
- Self-report dietary data are prone to a variety of unintentional measurement errors and, misreporting is a common problem in assessing dietary habits among adolescents.
- Dietary intake was assessed on two non-consecutive 24h dietary recalls. Although, this method has shown to be appropriate to collect detailed dietary information from adolescents, more than two measurements of 24h dietary recalls would be desirable. 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 (MSM) (https://nugo.dife.de/msm/).
- Results about lifestyle groups compose by different combinations of diet and physical activity should be interpreted cautiously because diet data were self-reported by the adolescents, while physical activity was objectively measured using accelerometers. The error of dietary assessment could have been larger than for physical activity, which could have led to an underestimation of the influence of diet on the study outcomes.
- A major strength of the present Doctoral Thesis is the inclusion of objective indicators of health in adolescents, such as physical fitness components, fatness markers and cardiovascular disease risk factors; which provide valuable information about the cardio-metabolic status in adolescents. As well as objectively measured physical activity by accelerometry.
- In the HELENA study, an important strength are the large sample size and the highly standardized procedures that were used, particularly for physical fitness, body composition and cardiovascular disease risk factors assessment; which are a major outcome presented in this Doctoral Thesis.
- Other important strength is that the HELENA study group has recently carried out a number of systematic reviews and methodological studies in order to evaluate the validity and reliability scores of the physical activity and sedentarily behaviours questionnaires, 24h dietary recalls, physical fitness tests and body composition measurements.

CONCLUSIONES

[CONCLUSIONS]

CONCLUSIONES

I. La combinación de una dieta saludable y un estilo de vida físicamente activo se asocia con un perfil cardiovascular más favorable en adolescentes. Además, un estilo de vida activo puede disminuir los efectos negativos de una dieta poco saludable.

II. Se han observado agrupaciones de múltiples factores de estilos de vida o patrones de comportamiento; dichos patrones difieren en función del género y la edad y se relacionan con la condición física pero no con la composición corporal.

III. Los adolescentes más activos y delgados tienen un mayor consumo de energía que los menos activos y delgados.

IV. Un mayor consumo de productos lácteos y cereales/pan, y un menor consumo de bebidas endulzadas se asocia con una alta capacidad aeróbica.

V. El hecho de tomar el desayuno no parece estar relacionado con la actividad física, el sedentarismo y algunos componentes de la condición física (fuerza muscular y habilidad motora) en adolescentes. Tomar el desayuno, sin embargo, se asocia con una mayor capacidad aeróbica medida de forma objetiva y subjetiva.

VI. Un mayor consumo de chocolate se asocia con una menor adiposidad central y total en adolescentes.

VII. El consumo de huevo no se asocia con factores de riesgo cardiovascular en adolescentes. La actividad física no influencia dicha falta de asociación.

VIII. La actividad física de intensidad moderada a vigorosa se asocia con un mejor control glucémico en personas jóvenes con diabetes tipo 1.

IX. Los hábitos alimentarios, la composición corporal y la condición física pueden ser evaluados en el ámbito escolar y dicha información puede ser incluida en el Informe de Salud Escolar.

Conclusión general:

La presente memoria de Tesis Doctoral muestra que una dieta saludable y ser físicamente activo se asocia con una menor obesidad, un alto nivel de condición física (entendida como un indicador fisiológico de salud) y un perfil cardiovascular favorable en adolescentes. Además, los resultados muestran que un estilo de vida físicamente activo puede reducir las consecuencias adversas de una dieta poco saludable. También se muestra que la actividad física de intensidad moderada a vigorosa se asocia con un mejor control glucémico en personas jóvenes con diabetes. Finalmente, se propone un addendum al Informe de Salud Escolar basado en el estudio de la dieta, la composición corporal y la condición física, el cual permitirá detectar a niños y adolescentes con una dieta poco saludable, sobrepeso y/o baja condición física.

CONCLUSIONS

I. The combination of healthy diet and active lifestyle is related to a favorable cardiovascular profile in adolescents. In addition, an active lifestyle may reduce the adverse consequences of an unhealthy diet.

II. Clustering of different lifestyle behaviours is observed; these behaviour patterns differ by gender and age, and are associated with physical fitness while body composition is not.

III. More physically active and leaner adolescents have higher energy intakes than less active and fatter adolescents.

IV. A higher intake of dairy products and bread/cereals, and a lower consumption of sweetened beverages is associated with a high cardiorespiratory fitness.

V. Breakfast consumption does not seem to be related to physical activity or sedentary time of the adolescent, neither of some physical fitness components as muscular fitness or speed/agility. Breakfast consumption, however, is associated with both measured and self-reported cardiorespiratory fitness.

VI. A higher chocolate consumption is associated with lower central and total fatness in European adolescents.

VII. Egg intake is not associated with a less favorable lipid or cardiovascular disease risk in adolescents. This lack of association is not explained by physical activity.

VIII. Moderate-to-vigorous physical activity is associated with better glycaemic control in young people with type 1diabetes.

IX. Dietary habits, body composition and physical fitness can be regularly evaluated at the school setting and this information can be included into the Report of School Health.

Overall conclusion:

This Doctoral Thesis shows that a combination of healthy diet and active lifestyle is associated with less obesity, a high level of physical fitness (which is a physiological indicator of health) and a favorable cardiovascular profile in adolescents. It also suggests that an active lifestyle can reduce the adverse consequences of an unhealthy diet. Moreover, moderate-to-vigorous physical activity is related with better glycaemic control in young people with diabetes. Finally, we propose an addendum to the Report of School Health based on the evaluation of food habits, body composition and physical fitness, which will be able to identify children and adolescents with an unhealthy diet, overweight and/or low fitness.

ANEXOS

[ANNEXES]

ANEXOS [ANNEXES]

1. Informe de Salud Escolar [Report of School Health]

2. HELENA study’s co-authorship. Relevant scientific contribution on the topic of diet, physical activity, sedentary behaviours and cardiovascular health in adolescents [Coautoría en el estudio HELENA. Contribución científica en al área de dieta, actividad física, comportamientos sedentarios y salud cardiovascular en adolescentes]

Anexo I *[Annex I]*

Informe de Salud Escolar *[Report of School Health]*

INFORME DE PRUEBAS

DATOS DEL PARTICIPANTE

Nombre: Edad: Sexo:

Talla: Peso: Fecha de evaluación:

"Conocer su nivel de condición física o forma física es importante, ya que estudios científicos han demostrado que una mejor condición física está asociada con un mejor estado de salud tanto en su edad actual como cuando sea adulta/o"

COMPOSICIÓN CORPORAL

ÍNDICE DE MASA CORPORAL (Kg/m^2)

Valores normales: Bajo peso Peso normal Sobrepeso Obeso

Usted se encuentra: 26,14

P_{85}

GRASA CORPORAL (%)

Valores normales: Bajo Normal Exceso

Usted se encuentra: 35,26

FUERZA MUSCULAR

FUERZA MAXIMA PRENSION MANUAL (Dr + Iz)

Valores normales: Bajo 37,8 Medio 48,1 Alto 58,7

Usted se encuentra: 42,4

FUERZA MAXIMA DE PIERNAS (cm)

Valores normales: Bajo 116 Medio 143.2 Alto 170,9

Usted se encuentra: 120

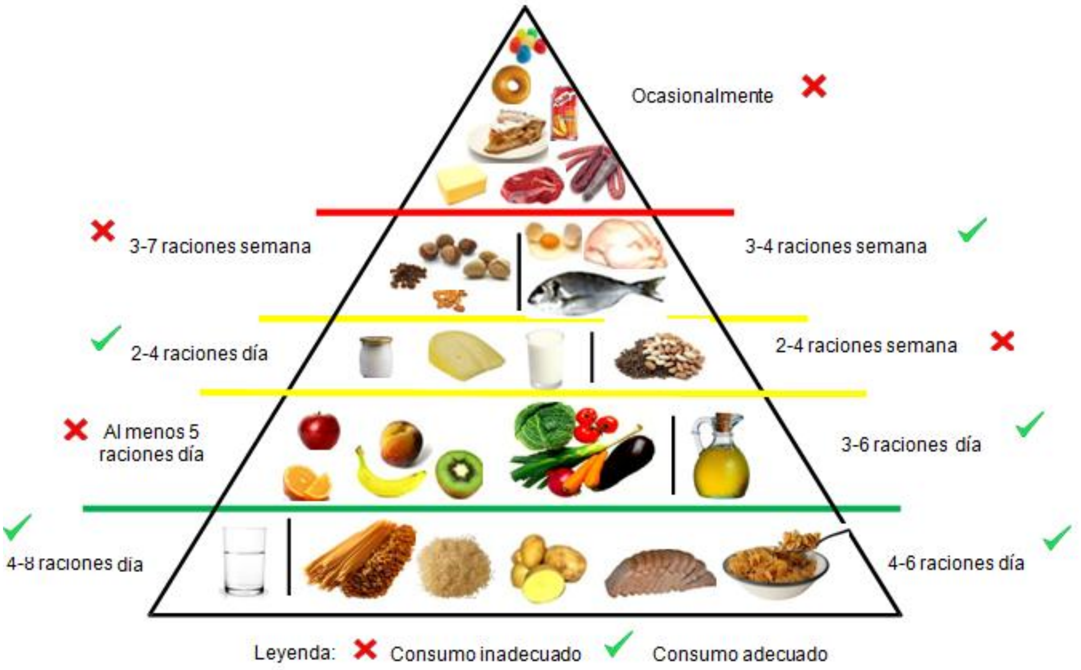
RESISTENCIA AERÓBICA

COURSE NAVETTE (Palier nº)	Valores normales:	Bajo 1,5	Medio 3,0	Alto 5,1
	Usted se encuentra:			4,5
CAPACIDAD AERÓBICA (VO_{2max})	Valores normales:	Riesgo cardiovascular	38	Cardosaludable
	Usted se encuentra:			42,5

Su forma física general se localiza dentro del rango considerado como:

Muy baja	Baja	Normal	Alta	Muy alta
		▲		

HÁBITOS DE ALIMENTACIÓN



Recomendación nutricional: Consume demasiados alimentos 'poco saludables' (ver cúspide de la pirámide), no debe consumirlos más de 2 veces a la semana. Debe consumir más frutas y verduras, así como frutos secos y legumbres.

Anexo II *[Annex II]*

HELENA study' co-authorship. Relevant scientific contribution in the topic of diet, physical activity, sedentary behavior and cardiovascular health in adolescents *[Coautoría en el estudio HELENA. Contribución científica en al área de dieta, actividad física, comportamientos sedentarios y salud cardiovascular en adolescentes]*

Diet-physical activity interaction [Interacción dieta y actividad física]

1. Ottevaere C, Huybrechts I, Beghin L, Cuenca-García M, De Bourdeaudhuij I, Gottrand F, Hagstromer M, Kafatos A, Le Donne C, Moreno LA, Sjostrom M, Widhalm K, De Henauw S. Relationship between self-reported dietary intake and physical activity levels among adolescents: the HELENA study. **Int J Behav Nutr Phys Act.** 2011; 8:8.

This study described the relationship between energy, nutrient and food intake and the physical activity level among a large group of European adolescents. The results showed that dietary habits diverge between adolescents with different self-reported physical activity levels. For some food groups differences in intake could be found, which were reflected in differences in some nutrient intakes. Physically active adolescents are not always inclined to eat healthier diets than their less active peers.

Diet-sedentary behavior interaction [Interacción dieta y comportamiento sedentario]

2. Ottevaere C, Huybrechts I, Benser J, De Bourdeaudhuij I, Cuenca-García M, Dallongeville J, Zaccaria M, Gottrand F, Kersting M, Rey-Lopez JP, Manios Y, Molnar D, Moreno LA, Smpokos E, Widhalm K, De Henauw S. Clustering patterns of physical activity, sedentary and dietary behavior among European adolescents: The HELENA study. **BMC Public Health.** 2011; 11:328.

This study examined the prevalence and clustering of physical activity, sedentary and dietary patterns among European adolescents and investigates if the identified clusters could be characterized by socio-demographic factors. The main findings showed that males were highly presented in the cluster with high levels of moderate to vigorous physical activity (MVPA) and low quality diets. The clusters with low levels of MVPA and high quality diets comprised more female adolescents. Adolescents with low educated parents had diets of lower quality and spent more time in sedentary activities. In addition, the clusters with high levels of MVPA comprised more adolescents of the younger age category.

3. Santaliestra-Pasías AM, Mouratidou T, Huybrechts I, Beghin L, Cuenca-García M, Castillo MJ, Galfo M, Hallstrom L, Kafatos A, Manios Y, Marcos A, Molnar D, Plada M, Pedrero R, Kurt Widhalm K, De Bourdeaudhuij I and Moreno LM. Dietary patterns in European adolescents participating in the HELENA study: associations with sedentary behaviours. *Submitted*

This study examined dietary patterns (DPs) in European adolescents and their relationship with several indicators of sedentary behaviour. The analyses showed four DPs for boys ("plant based", "snacking", "breakfast" and "health conscious") and five DPs for girls ("confectionary and snacking", "plant based", "breakfast", "animal protein" and "health conscious"). Adolescents' DPs (particularly the less healthy patterns) were related with more time spent in several sedentary behaviours.

4. Rey-Lopez JP, Vicente-Rodriguez G, Repasy J, Mesana MI, Ruiz JR, Ortega FB, Kafatos A, Huybrechts I, Cuenca-García M, Leon JF, Gonzalez-Gross M, Sjostrom M, de Bourdeaudhuij I, Moreno LA. Food and drink intake during television viewing in adolescents: the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study. **Public Health Nutr.** 2011; 14;9:1563-1569.

This study compared food consumption during television (TV) viewing among adolescents who watched >2 h/d v. ≤2 h/d; and examined the association between sociodemographic variables and the consumption of energy-dense foods and drinks during TV viewing. The main findings showed that excessive TV watching may favour concurrent consumption of energy-dense snacks and beverages. Adolescents from low-SES families were more likely to consume unhealthy drinks while watching TV.

5. Santaliestra-Pasias AM, Mouratidou T, Verbestel V, Huybrechts I, Gottrand F, Le Donne C, Cuenca-García M, Diaz LE, Kafatos A, Manios Y, Molnar D, Sjostrom M, Widhalm K, De Bourdeaudhuij I, Moreno LA. Food Consumption and Screen-Based Sedentary Behaviors in European Adolescents: The HELENA Study. **Arch Pediatr Adolesc Med.** 2012:1-11.

This study examined the association between time spent on different sedentary behaviors and consumption of certain food and beverage groups in a sample of European adolescents. The main results showed that a higher spend television viewing and computer and internet use during adolescence was associated with higher odds of consumption of sweetened beverages and lower odds of fruit consumption.

Diet-sleep interaction [Interacción dieta y sueño]

6. Garaulet M, Ortega FB, Ruiz JR, Rey-Lopez JP, Beghin L, Manios Y, Cuenca-García M, Plada M, Diethelm K, Kafatos A, Molnar D, Al-Tahan J, Moreno LA. Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. **Int J Obes (Lond).** 2011; 35;10:1308-1317.

This study described sleep duration in European adolescents, assessed the association of short sleep duration with excess adiposity and elucidated if physical activity (PA), sedentary behaviors and/or inadequate food habits underlie this association. The main findings showed that short sleep duration was associated with higher adiposity markers in European adolescents, particularly in females. Adolescents who slept <8 h per day were more sedentary and spent more time watching TV. Also, the proportion of adolescents who eat adequate amounts of fruits, vegetables and fish was lower in shorter sleepers than in adolescents who slept ≥8 h per day, and so was the probability of having adequate food habits.

7. Bel S, Michels N, De Vriendt T, Patterson E, Cuenca-García M, Diethelm K, Gutin B, Grammatikaki E, Manios Y, Leclercq C, Ortega FB, Moreno LA, Gottrand F, Gonzalez-Gross M, Widhalm K, Kafatos A, Garaulet M, Molnar D, Kaufman J, Gilbert C, Hallström L, Michael Sjöström M, Marcos A, De Henauw S and Huybrechts I. Association between self-reported sleep duration and dietary intake in European adolescents. **Brit J Nutr** 2012. [Epub ahead of print]

This study examined the relationship between sleep duration and dietary quality in European adolescents. The main findings demonstrated that short sleep duration was associated with a lower Diet Quality Index for Adolescents (DQI-A).

Nutrition-Food Intake in European Adolescents [Nutritión e ingesta de alimentos en adolescentes europeos]

8. Diethelm K, Huybrechts I, Moreno LA, De Henauw S , Manios Y, Beghin L , González-Gross M, Le Donne C, Castillo M, Cuenca-García M, Widhalm K, Patterson E, Kersting M. Nutrient intake of European adolescents: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. **Public Health Nutr.** 2012. [Epub ahead of print]

This study described and evaluated the nutrient intake in a European sample using the D-A-CH nutrient intake recommendations and the Nutritional Quality Index. The analyses showed that the intake of most nutrients was adequate. However, the quality of fat intake needs to be improved and salt intake needs to be decreased.

9. Diethelm K, Jankovic N, Moreno LA, Huybrechts I, De Henauw S, De Vriendt T, Gonzalez-Gross M, Leclercq C, Gottrand F, Gilbert CC, Dallongeville J, Cuenca-García M, Manios Y, Kafatos A, Plada M, Kersting M. Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. **Public Health Nutr**. 2012; 15; 3: 386-398.

This study described and evaluated the food consumption of European adolescents against food-based dietary guidelines for the first time. The main findings showed that food intake of adolescents in Europe was not optimal compared with the two food-based dietary guidelines, Optimized Mixed Diet and Food Guide Pyramid, examined. Adolescents eat half of the recommended amount of fruit and vegetables and less than two-thirds of the recommended amount of milk (and milk products), but consume much more meat (and meat products), fats and sweets than recommended. However, median total energy intake may be estimated to be nearly in line with the recommendations.

10. Vyncke KE, Libuda L, De Vriendt T, Moreno LA, Van Winckel M, Manios Y, Gottrand F, Molnar D, Vanaelst B, Sjostrom M, Gonzalez-Gross M, Censi L, Widhalm K, Michels N, Gilbert CC, Xatzis C, Cuenca García M, De Heredia FP, De Henauw S and Huybrechts I. Dietary fatty acid intake, its food sources and determinants in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. **Br J Nutr**. 2012 Dec;108(12):2261-2273.

This study described the fatty acid (FA) intake and its main food sources in a population of healthy European adolescents and to assess the variation in intake as a function of non-dietary factors. The results showed that the mean total fat intake was 33.3% of total energy intake (%E). The mean saturated FA intake was 13.8 %E, with 99.8% of the population exceeding the recommendations. Saturated FA was mainly delivered by meat and cake, pies and biscuits. In most adolescents, the poly-unsaturated FA intake was too low, and 35.5% of the population did not achieve the minimum recommended intake for a-linolenic acid. The main determinants of FA intake in the present study population were age and sex, as well as physical activity in the male subgroup. No contributions of body composition, socio-economic status or sexual maturation to the variance in FA intake were observed.

11. Hallstrom L, Vereecken CA, Labayen I, Ruiz JR, Le Donne C, Cuenca-García M, Gilbert CC, Martinez SG, Grammatikaki E, Huybrechts I, Kafatos A, Kersting M, Manios Y, Molnar D, Patterson E, Widhalm K, De Vriendt T, Moreno LA, Sjostrom M. Breakfast habits among European adolescents and their association with sociodemographic factors: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. **Public Health Nutr**. 2012; 15;10:1879-1889.

This study described breakfast habits at food group level in European adolescents and investigated the associations between these habits and sociodemographic factors. The main findings showed that the majority of the adolescents reported a breakfast that scored poorly on the breakfast quality index. Older adolescents, adolescents from the southern part of Europe and adolescents from families with low socio-economic status were more likely to consume a low-quality breakfast.

12. Béghin L, Dauchet L, Tineke De Vriendt, Cuenca-García M, Manios Y, Toti E, Plada M, Wildham K, Repasy J, Inge Huybrechts, Moreno LA and Dallongeville J. Influence of geographic location within Europe (north *versus* south) on diet quality in European adolescents: results from the HELENA study**.** *Submitted*

This study assessed whether adolescents' nutritional habits are affected by their parents' educational level and occupation and whether these associations differ in northern versus southern Europe. The main results showed that diet quality observed was higher in the south than in the north. Parent's educational level has an impact on adolescents' diet quality in Europe. However, these relationships differ when comparing northern and southern Europe.

Food intake and biomarkers [Ingesta de alimentos y biomarcadores]

13. Vyncke K, Cruz Fernandez E, Fajo-Pascual M, Cuenca-García M, De Keyzer W, Gonzalez-Gross M, Moreno LA, Beghin L, Breidenassel C, Kersting M, Albers U, Diethelm K, Mouratidou T, Grammatikaki E, De Vriendt T, Marcos A, Bammann K, Bornhorst C, Leclercq C, Manios Y, Dallongeville J, Vereecken C, Maes L, Gwozdz W, Van Winckel M, Gottrand F, Sjostrom M, Diaz LE, Geelen A, Hallstrom L, Widhalm K, Kafatos A, Molnar D, De Henauw S and Huybrechts I. Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study. **Br J Nutr.** 2012 Oct 30:1-12. [Epub ahead of print]

The study investigated whether the developed Diet Quality Index for Adolescents (DQI-A) is a good surrogate measure for adherence to food-based dietary guidelines, and whether adherence to these food-based dietary guidelines effectively leads to better nutrient intakes and nutritional biomarkers in adolescents. The main finding showed that the DQI-A scores were associated with food intake in the expected direction. On the nutrient level, the DQI-A was positively related to the intake of water, fibre and most minerals and vitamins. No association was found between the DQI-A and total fat intake. Furthermore, a positive association was observed with 25-hydroxyvitamin D, holo-transcobalamin and n-3 fatty acid serum levels. In summary, this study showed good validity of the DQI-A by confirming the expected associations with food and nutrient intakes and some biomarkers in blood.

14. Vandevijvere S, Geelen A, Gonzalez-Gross M, Van't Veer P, Dallongeville J, Mouratidou T, Dekkers A, Bornhorst C, Breidenassel C, Crispim SP, Moreno LA, Cuenca-García M, Vyncke K, Beghin L, Grammatikaki E, De Henauw S, Catasta G, Hallstrom L, Sjostrom M, Warnberg J, Esperanza L, Slimani N, Manios Y, Molnar D, Gilbert CC, Kafatos A, Stehle P, Huybrechts I. Evaluation of food and nutrient intake assessment using concentration biomarkers in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study. **Br J Nutr.** 2012 May 23:1-12. [Epub ahead of print]

This study evaluated food and nutrient intake assessment among European adolescents from two 24h recalls and one Food Frequency Questionnaire (FFQ) using concentration biomarkers. This study concluded that two non-consecutive 24h recalls in combination with a FFQ seem to be appropriate to rank subjects according to their usual food intake.

15. Valtueña J, González-Gross M, Huybrechts I, Breidenassel C, Ferrari M, Gottrand F, Dallongeville J, Cuenca-García M, Gómez S, Azzini E, Sioen I, Kersting M, Stehle P, Anthony Kafatos A, Manios Y, Widhalm K and Moreno LA. Determinants of vitamin D status in European adolescents. The HELENA study. **J Nutr Sci Vitaminol (Tokyo)** [Epub ahead of print]

This study identified potential influencing factors of 25(OH)D concentrations. The main findings showed that winter season (-), higher latitude (-), fitness (+), adiposity (-), sleep time (+) and micronutrient supplementation (+) were highly related to 25(OH)D concentrations found in European adolescents.

16. Vandevijvere S, Michels N, Verstraete S, Ferrari M, Leclercq C, Cuenca-García M, Grammatikaki E, Manios Y, Gottrand F, Valtueña J, Kersting M, Gonzalez-Gross M, Moreno L, Mouratidou T, Stevens K, Meirhaeghe A, Dallongeville J, Sjöström M, Hallstrom L, Kafatos A, Widhalm K, Molnar D, De Henauw S and Huybrechts I. Intake and dietary sources of haem and non-haem iron among European Adolescents and its association with iron status and different lifestyle and socio-economic factors. *Submitted*

This study identified iron intake, its determinants, its most important food sources and evaluated the relation of iron intake and status in European adolescents. The main findings showed that girls had lower iron intakes (11.0 vs. 13.8 mg/day) and ratio of haem/non-haem iron intake than boys. The main total iron and haem iron source was meat, while the main non-haem iron source was bread and rolls.

17. Ferrari M, Valtuena J, González-Gross M, Censi L, Moreno LA, Manios Y, Gilbert CC, Huybrechts I, Dallongeville J, Sjöström M, Molnar D, De Henauw S, Cuenca-García M, Gomez S, Kafatos A, Widhalm K and Leclercq. Are obese adolescents in Europe at higher risk of iron deficiency? Inflammatory parameters implications. *Submitted*

This study assessed the relationship between iron (SF, Serum Ferritin; sTfR, soluble Transferrin Receptor) and inflammatory (CRP, C-Reactive Protein; AGP, α1-Acid Glycoprotein) and fatness indicators in European adolescents. The main findings showed higher levels of inflammatory proteins (CRP and AGP) in overweight and obese adolescents. sTfR values were not increased to obesity for both boys and girls.

Nutrition and its metabolic consequences [Nutrición y sus consecuencias metabólicas]

18. Sese MA, Jimenez-Pavon D, Gilbert CC, Gonzalez-Gross M, Gottrand F, de Henauw S, Breidenassel C, Warnberg J, Widhalm K, Molnar D, Manios Y, Cuenca-García M, Kafatos A, Moreno LA. Eating behaviour, insulin resistance and cluster of metabolic risk factors in European adolescents. The HELENA study. **Appetite**. 2012; 59;1:140-147

The present study examined the associations of food behaviours and preferences with markers of insulin resistance and clustered metabolic risk factors score in European adolescents. The main results indicated that skipping breakfast, as well as the preference of some foods such as nuts, chocolate, burgers and pizzas, soft drinks or juices, explain part of homeostasis model assessment (HOMA) index variance. In addition, snacking regularly during school day is associated with higher metabolic risk score in females.

19. Gomez-Martinez S, Martinez-Gomez D, Perez de Heredia F, Romeo J, Cuenca-García M, Martin-Matillas M, Castillo M, Rey-Lopez JP, Vicente-Rodriguez G, Moreno L, Marcos A. Eating habits and total and abdominal fat in Spanish adolescents: influence of physical activity. The AVENA study. **J Adolesc Health.** 2012; 50;4:403-409

The present study examined the association between specific dietary habits and body fatness in Spanish adolescents, and analyzed the role of leisure-time physical activity (LTPA) in this association. The main findings showed that certain healthy dietary habits (i.e., mid-morning snack, afternoon snack, >4 meals per day, adequate eating speed) were associated with lower body fatness in Spanish adolescents, independently of engaging in LTPA. In addition, among boys with non-LTPA, those who skipped breakfast showed the highest body fatness values.

20. Jiménez-Pavón D, Sesé MA, Huybrechts I, Cuenca-García M, Palacios G, Ruiz JR, Breidenassel C, Leclercq C, Beghin L, Plada M, Manios Y, Androutsos O, Dallongeville J, Kafatos A, Widhalm K, Molnar D, Moreno LA. Dietary quality indexes with/without physical activity and markers of insulin resistance in European adolescents. *Submitted*

The present study examined the association of several dietary quality indexes, with and without physical activity, in relation to markers of insulin resistance after controlling for potential confounders. The main results indicated that the dietary index including physical activity was inversely associated with homeostasis model assessment (HOMA) index and directly with the quantitative insulin sensitivity check index (QUICKI) in females, but not in males, after adjusting for pubertal status, centre, body mass index and cardiorespiratory fitness.

21. Vyncke E, Huybrechts I, Dallongeville J, Mouratidou, T, Van Winckel MA, Cuenca-García M, Ottevaere C, González-Gross M, Moreno LA, Kafatos A, Leclercq C, Sjöström M, Molnár D, Stehle P, Breidenassel C, Ascension M, Manios Y, Widhalm K, Gilbert C, Gottrand F and De Henauw S. Intake and serum profile of fatty acids are only weakly correlated with the global dietary quality in European adolescents. **Nutrition** 2013 Feb;29(2):411-419

The present study assessed whether compliance with Food Based Dietary Guidelines (expressed by calculating the Diet Quality Index in Adolescents (DQI-A)) is related with habitual fatty acid (FA) intake and blood lipid parameters. The main findings showed that better DQI-A scores were related with increased proportional intakes of energy from total fat, saturated FA, mono-unsaturated FA and cholesterol, whilst no significant association was observed with poly-unsaturated FA intakes. Adolescents with higher compared to lower DQI-A scores, dairy products contributed more and low-nutrient, energy-dense items contributed less to the intake of total fat. A positive association was observed between the DQI-A scores and serum concentrations of eicosapentaenoic acid and docosahexaenoic acid in girls. In boys, higher DQI-A scores were inversely associated with serum cholesterol concentrations.

CURRICULUM VITAE ABREVIADO [SHORT CV]

DATOS PERSONALES

Nombre: Mª Magdalena Cuenca García
Fecha de nacimiento: 3 de julio de 1983
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ACTIVIDAD ACADÉMICA

- Licenciada en Ciencias de la Actividad Física y Deportes. Facultad de Ciencias del Deporte. Universidad de Granada, España (2003-2008).
- Máster con mención de calidad en Nutrición Humana (404/56.1). Facultad de Farmacia. Universidad de Granada, España (2008-2009).
- Estancia de investigación en el Departamento de Salud Pública, Universidad de Gante, Bélgica (1 septiembre – 19 diciembre 2010). Tutor: Stefaan De Henauw.
- Estancia de investigación en la Unidad de Nutrición Preventiva en NOVUM, Instituto Karolinska, Estocolmo, Suecia (4 junio – 4 julio 2011). Tutor: Michael Sjöström.
- Estancia de investigación en el Departamento de Ejercicio, Nutrición and Salud Pública, (http://www.bristol.ac.uk/enhs/) Universidad de Bristol, UK (1 septiembre – 22 diciembre 2011). Tutor: Jago Russ.
- Estancia de investigación en el Departamento de Salud Pública (Arnold School Public Health, http://www.sph.sc.edu/), Universidad del Sur de Carolina, USA (1 agosto – 1 diciembre 2012). Tutor: Steven Blair.
- Docencia oficial en el Departamento de Fisiología, Universidad de Granada.
  - Curso 2011/2012
    Fisiología (Grado en Fisioterapia): 1,5 créditos teóricos, 3 créditos prácticos.
    Fisiología cardiovascular y endocrina (Grado de Fisioterapia): 1 crédito teórico.
    Fisiología del ejercicio (Grado en Medicina): 0,5 crédito práctico.
  - Curso 2012/2013
    Fisiología (Grado en Fisioterapia): 0,75 crédito teórico, 2,25 créditos prácticos.
    Fisiología cardiovascular y endocrina (Grado de Fisioterapia): 0,75 crédito teórico, 2,25 créditos prácticos.

PARTICIPACIÓN EN PROYECTOS DE INVESTIGACIÓN

- El estudio **HELENA** (2005-2008). El estudio HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) es un proyecto financiado por la Unión Europea (FP6-2003-Food- 2A). Página Web: www.helenastudy.com.

- El estudio **ALPHA** (2007-2009). El estudio ALPHA (Assessing levels of Physical Activity) es un proyecto financiado por la Unión Europea (Nº de convenio: 2006120), en el marco del Programa de Salud Pública. Página Web: www.thealphaproject.net.

ORGANIZACIÓN DE EVENTOS

- "Healthy International Workshop: Exercise for Health Effects" organizado en Granada, 15-16 enero 2010. Como secretaria del comité organizador en el diseño y desarrollo del evento internacional.
- Seminarios científicos impartidos por el Laboratorio de Evaluación Funcional y Fisiología del Ejercicio, Ciencia y Tecnología para la Salud-262, Facultad de Medicina, Universidad de Granada. Labor desempeñada como secretaria del comité organizador en el diseño y/o desarrollo del evento.
    - Sesión intensiva de abdominales hipopresivos (23 febrero 2010)
    - Uso del isocinético GYMNEX (10 marzo 2010)
    - Uso de la plataforma vibratoria en fitness (24 marzo 2010)
    - Uso del densitómetro NORLAND EXCELL (7 abril 2010)
    - Cellular health & medicine? Improving health and performance by optimizing cell function? (27 - 28 abril 2011)
    - Rehydration with beer after exercise. Effectiveness and safety for consumers (26 mayo 2011)

PUBLICACIONES CIENTÍFICAS

Revistas contempladas en el JCR

1. España-Romero V, Artero EG, Jimenez-Pavón D, **Cuenca-García M**, Ortega FB, Castro-Piñero J, Sjöstrom M, Castillo-Garzon MJ, Ruiz JR. Assessing health-related fitness tests in the school setting: reliability, feasibility and safety; the ALPHA Study. **Int J Sports Med**. 2010 Jul; 31(7):490-7. Epub 2010 Apr 29.

2. Ruiz JR, Castro-Piñero J, España-Romero V, Artero EG, Ortega FB, **Cuenca MM**, Jimenez-Pavón D, Chillón P, Girela-Rejón MJ, Mora J, Gutiérrez A, Suni J, Sjöström M, Castillo MJ. Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. **Br J Sports Med**. 2010 Oct 19.

3. Ottevaere C, Huybrechts I, De Meester F, De Bourdeaudhuij I, **Cuenca-García M**, De Henauw S. The use of accelerometry in adolescents and its implementation with non-wear time activity diaries in free-living conditions. **J Sports Sci**. 2011 Jan; 29 (1):103-13.

4. Ottevaere C, Huybrechts I, Béghin L, **Cuenca-García M**, De Bourdeaudhuij I, Gottrand F, Hagströmer M, Kafatos A, Le Donne C, Moreno L., Sjöström M, Widhalm K. and De Henauw S. Relationship between self-reported dietary intake and physical activity levels among adolescents: The HELENA study. **Int J Behav Nutr Phys Act**. 2011 Feb 6;8(1):8.

5. Rey-López P, Vicente-Rodríguez G, Mesana MI, Répassy J, Kafatos A, Huybrechts I, **Cuenca-García M**, González-Gross M, Sjöström M, De Bourdeaudhuij I and Moreno LA**.** Food and drink during TV viewing in adolescents: the HELENA study**. Public Health Nutr**. 2011 Feb 22:1-7.

6. Rey-López JP, Ruiz JR, Ortega FB, Verloigne M, Vicente-Rodriguez G, Gracia-Marco L, Gottrand F, Molnar D, Widhalm K, Zaccaria M, **Cuenca-García M**, Sjöström M, De Bourdeaudhuij I, Moreno LA; HELENA Study Group. Reliability and validity of a screen time-based sedentary behaviour questionnaire for adolescents: The HELENA study. **Eur J Public Health**. 2012 Jun;22(3):373-7

7. Ottevaere C, Huybrechts I, Al-Tahan J, De Bourdeaudhuij I, **Cuenca-García M**, Dallongeville J, Ferrari M, Gottrand F, Kersting M, Rey-López P, Mannios Y, Molár D, Moreno LA, Smpokos E, Widhalm K and De Henauw S, Dr. Clustering patterns of physical activity, sedentary and dietary behavior among European adolescents: The HELENA study. **BMC Public Health:** 2011 May 17, 11: 328.

8. **Cuenca-García M,** Ortega FB, Huybrechts I, Ruiz JR, González-Gross M, Ottevaere C, Sjöström M, Dìaz LE, Ciarapica D, Molnar D, Gottrand F, Plada M, Manios Y, Moreno LA, De Henauw S, Kersting M, Castillo MJ on behalf of the HELENA study group. Cardiorespiratory fitness and dietary intake in European adolescents: The HELENA study. **Br J Nutr.** 2012 Jun;107(12):1850-9.

9. Diethelm K, Jankovic N, Moreno LA, Huybrechts I, De Henauw S, De Vriendt T, Gonzalez-Gross M, Leclercq C, Gottrand F, Gilbert CC, Dallongeville J, **Cuenca-Garcia M**, Manios Y, Kafatos A, Plada M, Kersting M. Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. **Public Health Nutr**. 2012; 15; 3: 386-398.

10. Garaulet M, Ortega FB, Ruiz JR, Rey-López JP, Béghin L, Manios Y, **Cuenca-García M,** Plada M, Diethelm K, Kafatos A, Molnár D, Al-Tahan J, Moreno LA. Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study. **Int J Obes.** 2011 Oct; 35(10):1308-17.

11. Ruiz JR, España Romero V, Castro Piñero J, Artero EG, Ortega FB, **Cuenca García M**, Jiménez Pavón D, Chillón P, Girela Rejón MJ, Mora J, Gutiérrez A, Suni J, Sjöstrom M. [ALPHA-fitness test battery: health-related field-based fitness tests assessment in children and adolescents]. Nutr Hosp. 2011 Dec; 26 (6):1210-4.

12. Gómez-Martínez S, Martínez-Gómez D, Perez de Heredia F, Romeo J, **Cuenca-García M**, Martin-Matillas M, Castillo MJ, Rey-López J, Vicente-Rodriguez G, Moreno LA, Marcos A. Eating Habits and Total and Abdominal Fat in Spanish Adolescents: Influence of Physical Activity. The AVENA Stud. **J Adolesc Health**. 2012 Apr;50 (4):403-9. Epub 2011 Oct 28.

13. Martinez-Gomez D, Gomez-Martinez S, Ruiz JR, Diaz LE, Ortega FB, Widhalm K, **Cuenca-Garcia M**, Manios Y, De Vriendt T, Molnar D, Huybrechts I, Breidenassel C, Gottrand F, Plada M, Moreno S, Ferrari M, Moreno LA, Sjöström M, Marcos A; HELENA Study Group. Objectively-measured and self-reported physical activity and fitness in relation to inflammatory markers in European adolescents: the HELENA Study. **Atherosclerosis.** 2012 Mar; 221(1):260-7.

14. Vyncke KE, Libuda L, De Vriendt T, Moreno LA, Van Winckel M, Manios Y, Gottrand F, Molnar D, Vanaelst B, Sjöström M, González-Gross M, Censi L, Widhalm K, Michels N, Gilbert CC, Xatzis C, **Cuenca García M**, de Heredia FP, De Henauw S, Huybrechts I. Dietary fatty acid intake, its food sources and determinants in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. **Br J Nutr**. 2012 Feb 28:1-13.

15. Santaliestra-Pasías AM, Mouratidou T, Verbestel V, Huybrechts I, Gottrand F, Le Donne C, **Cuenca-García M,** Díaz LE, Kafatos A, Manios Y, Molnar D, Sjöström M, Widhalm K, De Bourdeaudhuij I, Moreno LA; for the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-sectional Study Group. Food Consumption and Screen-Based

Sedentary Behaviors in European Adolescents: The HELENA Study. **Arch Pediatr Adolesc Med**. 2012 Sep 3:1-11.

16. Vandevijvere S, Geelen A, Gonzalez-Gross M, Van't Veer P, Dallongeville J, Mouratidou T, Dekkers A, Börnhorst C, Breidenassel C, Crispim SP, Moreno LA, **Cuenca-García M**, Vyncke K, Beghin L, Grammatikaki E, De Henauw S, Catasta G, Hallström L, Sjöström M, Wärnberg J, Esperanza L, Slimani N, Manios Y, Molnár D, Gilbert CC, Kafatos A, Stehle P, Huybrechts I. Evaluation of food and nutrient intake assessment using concentration biomarkers in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study**. Br J Nutr.** 2012 May 23:1-12.
17. Sesé MA, Jiménez-Pavón D, Gilbert CC, González-Gross M, Gottrand F, de Henauw S, Breidenassel C, Wärnberg J, Widhalm K, Molnar D, Manios Y**, Cuenca-García M**, Kafatos A, Moreno LA; HELENA Study Group. Eating behaviour, insulin resistance and cluster of metabolic risk factors in European adolescents. The HELENA study. **Appetite.** 2012 Aug; 59(1):140-7.
18. **Cuenca-García M**, Jago R, Shield J PH, Burren C P. How does physical activity and fitness influence glycaemic control in young people with type 1 diabetes?. **Diabet Med**. 2012 Oct 29 (10): e369-76.
19. Vyncke E, Huybrechts I, Dallongeville J, Mouratidou, T, Van Winckel MA, **Cuenca-García M**, Ottevaere C, González-Gross M, Moreno LA, Kafatos A, Leclercq C, Sjöström M, Molnár D, Stehle P, Breidenassel C, Ascension M, Manios Y, Widhalm K, Gilbert C, Gottrand F and De Henauw S. Intake and serum profile of fatty acids are only weakly correlated with the global dietary quality in European adolescents. **Nutrition** 2013 Feb;29(2):411-419
20. Vyncke K, Cruz Fernandez E, Fajo-Pascual M, **Cuenca-García M**, De Keyzer W, Gonzalez-Gross M, Moreno LA, Beghin L, Breidenassel C, Kersting M, Albers U, Diethelm K, Mouratidou T, Grammatikaki E, De Vriendt T, Marcos A, Bammann K, Bornhorst C, Leclercq C, Manios Y, Dallongeville J, Vereecken C, Maes L, Gwozdz W, Van Winckel M, Gottrand F, Sjostrom M, Diaz LE, Geelen A, Hallstrom L, Widhalm K, Kafatos A, Molnar D, De Henauw S and Huybrechts I. Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study. **Br J Nutr.** 2012 Oct 30:1-12. [Epub ahead of print]
21. **Cuenca-García M**, Ortega FB, Ruiz JR, González-Gross M, Labayen I, Jago R, Martínez-Gómez D, Dallongeville J, Bel-Serrat S, Marcos A, Manios Y, Breidenassel C, Widhalm K, Gottrand F, Ferrari M, Kafatos A, Molnár D, Moreno LA, De Henauw S, Castillo MJ and Sjöström M, on behalf of the HELENA study group*. Combined influence of healthy diet and active lifestyle on cardiovascular disease risk factors in adolescents. **Scand J Sci Sports** 2012, Dic 12. [Epub ahead of print].
22. Diethelm K, Huybrechts I, Moreno LA, De Henauw S , Manios Y, Beghin L , González-Gross M, Le Donne C, Castillo M, **Cuenca-García M**, Widhalm K, Patterson E, Kersting M. Nutrient intake of European adolescents: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study: **Public Health Nutr.** 2012, Dic. [Epub ahead of print].
23. Bel S, Michels N, De Vriendt T, Patterson E, **Cuenca-García M,** Diethelm K, Gutin B, Grammatikaki E, Manios Y, Leclercq C, Ortega FB, Moreno LA, Gottrand F, Gonzalez-Gross M, Widhalm K, Kafatos A, Garaulet M, Molnar D, Kaufman J, Gilbert C, Hallström L, Michael Sjöström M, Marcos A, De Henauw S and Huybrechts I. Association between self-reported sleep duration and dietary intake in European adolescents. **Brit J Nutr**. 2012; Dic. [Epub ahead of print]

24. Soriano-Maldonado A, **Cuenca-García M,** Moreno LA, Leclercq C, Androutsos O, Guerra-Hernández EJ, Castillo MJ and Ruiz JR. [Egg intake and cardiovascular risk factors in adolescents; role of physical activity]. The HELENA study. **Nutr Hosp,** 2012. Dic. [Epub ahead of print].

25. **Cuenca-García M,** Ortega FB, Huybrechts I, Ottevaere C, Ruiz JR, Vicente-Rodríguez G, González-Gross M, Molnár D, Polito A, Manios Y, Plada M, Vanhelst J, Widhalm K, Moreno LA, Kersting M, Sjöström M and Castillo MJ on behalf of the HELENA study group. Clustering of multiple lifestyle behaviours and its relationship with gender, age and health-related physical fitness in European adolescents: The Healthy lifestyle in European by Nutrition in Adolescents Study. *Accepted in* ***J Nutr Educ Behav***.

26. **Cuenca-García M**, Ortega FB, Ruiz JR, Labayen I, Moreno LA, Patterson E, Vicente-Rodríguez G, González-Cross M, Marcos A, Polito A, Manios Y, Beghin L, Wästlund A, Molnár D, Kidhalm K, Kafatos A, De Henauw S, Sjöström M, Gutin B, & Castillo, MJ on behalf of the HELENA study group*. More physically active and leaner adolescents have higher energy intake: consistent results using different methods and different studies (HELENA and EYHS Studies). *Submitted*

27. **Cuenca-García M,** Ruiz JR, Ortega FB, Labayen I, González-Gross M, Moreno LA, Gomez-Martinez S, Ciarapica D, Hallstrom L, Wästlund A, Molnar D, Gottrand F, Manios Y, Widhalm K, Kafatos A, De Henauw S, Sjöström M & Castillo MJ on behalf of the HELENA study group. Breakfast Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: The HELENA study. *Submitted*

28. **Cuenca-García M,** Ruiz JR, Ortega FB, Castillo MJ and The HELENA study group. Association between chocolate consumption and fatness in European adolescents. *Submitted*

29. Santaliestra-Pasías AM, Mouratidou T, Huybrechts I, Beghin L, **Cuenca-García M,** Castillo MJ, Galfo M, Hallstrom L, Kafatos A, Manios Y, Marcos A, Molnar D, Plada M, Pedrero R, Kurt Widhalm K, De Bourdeaudhuij I and Moreno LM. Dietary patterns in European adolescents participating in the HELENA study: associations with sedentary behaviours. *Submitted*

30. De Vriendt T, Huybrechts I, Breidenassel C, Rogiers J, Vanaelst B, **Cuenca-García M**, Moreno LA, M González-Gross, Roccaldo R, Kafatos A, Clays E, Bueno G, Beghin L, Sjöstrom M, Manios Y, D Molnár D and De Henauw S. Relationship between mechanisms of stress, energy homeostasis and metabolism in European adolescents – the HELENA study. *Submitted*

31. Pérez de Heredia F, Garaulet M, Gómez-Martínez S, Díaz LE, Wärnberg J, Breidenassel C, Androutso O, **Cuenca-García M**, Huybrechts I, Ferrari M, Gottrand F, Michels N, Kafatos A, Manios Y, Molnár D, Moreno LA, Sjöstrom M, Widhalm K, Marcos A. Sleep duration is associated with blood T lymphocyte counts in European adolescents. The HELENA Study. *Submitted*

32. Béghin L, Dauchet L, Tineke De Vriendt, **Cuenca-García M,** Manios Y, Toti E, Plada M, Wildham K, Repasy J, Inge Huybrechts, Moreno LA and Dallongeville J. Influence of geographic location within Europe (north *versus* south) on diet quality in European adolescents: results from the HELENA study. *Submitted*

33. Valtueña J, González-Gross M, Huybrechts I, Breidenassel C, Ferrari M, Gottrand F, Dallongeville J, **Cuenca-García M**, Gómez S, Azzini E, Sioen I, Kersting M, Stehle P,

Anthony Kafatos A, Manios Y, Widhalm K and Moreno LA. Determinants of vitamin D status in European adolescents. The HELENA study. *Submitted*

34. Vandevijvere S, Michels N, Verstraete S, Ferrari M, Leclercq C, **Cuenca-García M,** Grammatikaki E, Manios Y, Gottrand F, Valtueña J, Kersting M, Gonzalez-Gross M, Moreno L, Mouratidou T, Stevens K, Meirhaeghe A, Dallongeville J, Sjöström M, Hallstrom L, Kafatos A, Widhalm K, Molnar D, De Henauw S and Huybrechts I. Intake and dietary sources of haem and non-haem iron among European Adolescents and its association with iron status and different lifestyle and socio-economic factors. *Submitted*

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CAPÍTULOS DE LIBRO

1. Castillo MJ, **Cuenca M**, Gutiérrez A. Importancia del Ejercicio y la Condición Física en el Control Global del Riesgo Cardiometabólico. En: Tratado de Medicina Cardio-metabólica. Volumen II. Pp. 147-166. Editorial Diaz de Santos Madrid.

2. **Cuenca García M**, Ortega FB, Ruiz JR y Castillo MJ. Actividad física en niños y adolescentes. En: Ejercicio físico y salud en poblaciones especiales. EXERNET. Volumen I. Pp. 123-145. ISBN (edición impresa): 978-84-7949-216-8; ISSN (edición impresa): 2172-2161. CSD. Madrid, 2011 diciembre.

PREMIOS CIENTÍFICOS

1. El trabajo titulado "***Clustering of multiple lifestyle behaviours and its relationship to gender, age and physical fitness***" fue premiado por el Comité Científico de la 11th European Nutrition Conference como “The best poster presentation of young research”. Fecha: October 30, 2011, Madrid (Spain).

AGRADECIMIENTOS [ACKNOWLEDGEMENTS]

Esta tesis ha sido posible gracias a la contribución de grandes profesionales, a todos ellos quiero agradecerles todo lo que me han enseñado, su implicación, apoyo y asesoramiento:

A mis directores de tesis, Manuel, Jonatan y Francisco. Por ser los pilares que sustentan esta tesis, por su profesionalidad y calidad humana. Gracias por dejarme aprender de vosotros, gracias por compartir vuestra sabiduría. **Manuel**, gracias por tantos buenos y prudentes consejos. Por las brillantes ideas plasmadas en esta tesis. Por enseñarme que un gran esfuerzo no puede tener un único resultado. **Jonatan**, gracias por calmar mis innecesarias preocupaciones, por cargarme de energía en cada reunión, por tener siempre respuestas, por las mil y una lecciones. Gracias por volver. **Fran**, gracias por transmitirme seguridad y confianza en mi trabajo, por hacer simple lo difícil, por tu humildad y tu paciencia. ¡Qué fácil es entender estadística cuando tú la explicas!. Gracias por los momentos compartidos en Estocolmo. A todos, gracias por ayudarme a conseguirlo.

A **Ángel**, por hacerme entender la fisiología del ejercicio desde la práctica, por compartir tus conocimientos y por tu asesoramiento docente. Por los apasionantes momentos compartidos en el laboratorio en cada test, comentando datos, encontrando respuestas. Porque la tesis no es el único fruto de esta cosecha, gracias.

A mis compañeros David, Vanesa, Enrique. Porque fue un alivio teneros cerca al principio, gracias por mostrarme el camino. **David**, porque el primer trabajo nunca se olvida, por tu incalculable ayuda y por enseñarme a *empezar*. Por tus esperanzadores consejos tanto en lo profesional como en lo personal. **Vanesa**, gracias por los momentos compartidos desde el minuto cero, por mostrarme el rigor científico desde el trabajo de campo, por ser un ejemplo de sinceridad, profesionalidad y tesón. **Enrique**, excelente lección y dosis de motivación en la recta final. Gracias, por tu excelente atención durante mi estancia en Carolina del Sur. Por los intensos debates sobre nutrición, por las palabras de ánimo en momentos de pesimismo, por los sabios consejos sobre en la ciencia de la vida, por *'cervezar'* y por los kilos demás.

To **Stefaan**, for giving me the opportunity to share professional and personal experiences with you and your scientific groups. To **Inge**, for your support about nutrition data and your hospitality during my stay in Ghent.

To **Russ,** it was a pleasure to work with you, thanks for your scientific support and advice from the future. **Rowan**, thanks for your key advice and review of English.

A **Alberto**, por tu confianza y generosidad. Te esperan muchas experiencias que serán difíciles de olvidar, disfruta y aprovecha el tiempo. Bienvenido a la familia de los FPU.

Agradecer a todos investigadores y colaboradores involucrados en los proyectos HELENA, EYHS, ALPHA y British study por hacer de ellos una realidad y, muy especialmente a **Luis Moreno**, **Marcela Gonzales-Cross**, **Michael Sjöström**, **Russ Jago** y **Christine Burren** por su líder implicación. A todos aquellos niños y adolescentes, sus padres y tutores, por su voluntaria participación. Gracias a todos.

Agradecer, también, a familiares y amigos por los buenos momentos compartidos y el cariño recibido:

A mis **padres** por vuestra confianza y paciencia. Por aceptar todas mis decisiones y apoyarme en todos mis proyectos. Papá, gracias por enseñarme a enfrentarme a los obstáculos con decisión y en *pie*. Mamá, gracias por todo y más. A mis **hermanas**, gracias por vuestras visitas cargaditas de regalos, por las anécdotas acumuladas, de nada por las meriendas. A mis abuelos, **Isabel y Andrés,** por regalarme una infancia llena de alegría, felicidad y salud. Por vuestra generosidad, humildad y contagiosa vitalidad. Gracias, por los cálidos y '*energéticos*' recibimientos, por mantenernos unidos. A mis tíos, Miguel, Antonio, Loli. **Miguel,** gracias por mostrarme que sólo hay una forma de hacer las cosas, y que la clave del éxito es la constancia en el trabajo. **Antonio**, gracias por dejarme ocupar el sitio más privilegiado. **Loli**, gracias por tu confianza, carriño y crítica '*esperanzadora*', propia de una hermana mayor. Gracias a todos, por no mimarme demasiado.

A todos los amigos conseguidos por el camino. A Signe, Palma, Virginia y Miguelón, gracias por vuestra cálida acogida. **Signe**, por tu complicidad y amistad, gracias por escucharme y aconsejarme. **Palma**, por hacernos reír con tus locuras y aventuras. **Miguelón**, siempre tan preocupado por nuestra *'alimentación'*. **Virginia**, gracias por tu compañía en Estocolmo, una experiencia corta pero intensa. **Estefanía Cruz**, porque no hay un mal día, sino una buena taza de chocolate. **Raquel Diaz**, thanks for sharing the sunny lunches. **Paul, Jess** and **Emmie** (the Diken family), thanks for appear in my way, for your friendship, kindness and hospitality. **Kate, Erica, Raymond**, *coffee, chocolate, plans for holiday time… interesting scientific proposals*!. All will be welcome.

A mis amigas sexitanas, **Mari Carmen, Inma, Hara, Mónica V, Lourdes, Mónica M**. Gracias, por hacerme sentir tan cerca a pesar de la distancia. **Julia**, **Carmen**, ¡bienvenidas!.

A los máximos responsables de que me iniciase en este proyecto, **Antonio, Pepi, Félix** y **Grego.** Gracias, por animarme, por vuestro constante interés en mi formación, por toda la ayuda. Gracias, **Félix**, por arriesgarte a confiar en mí.

A **Raúl**. Gracias por ser mi *'imprescindible'* compañero de viaje, por confiar ciegamente en mí, por ayudarme a alcanzar todos mis objetivos y por tu sensatez. Por incluir a *optimismo* y *motivación* en este viaje. Por un largo etc. Gracias por darlo todo y no pedir nada a cambio.