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FACULTAD DE HUMANIDADES Y CIENCIAS DE LA EDUCACIÓN

DEPARTAMENTO DE DIDÁCTICA DE LA EXPRESIÓN MUSICAL, PLÁSTICA Y CORPORAL

TESIS DOCTORAL

INFLUENCIA DE LA ACTIVIDAD FÍSICA Y NIVEL DE CONDICIÓN FÍSICA SOBRE VARIABLES PSICOLÓGICAS Y COGNICIÓN EN EDUCACIÓN SECUNDARIA

PRESENTADA POR:

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A mi familia, amigos y compañeros, a todos ellos.
Simplemente… GRACIAS por permitirme estar hoy aquí.

"UBUNTU: Si yo soy, es porque nosotros somos"

Una vez leí que un antropólogo propuso un juego a unos niños de una tribu africana. Colocó un cesto con frutas al pie de un árbol, y a la señal debían correr para llegar primeros y llevarse el cesto. Entonces, dio la voz de salida, y ante su asombro, los niños se cogieron de las manos y corriendo todos juntos, llegaron al cesto, se sentaron alrededor de él y empezaron a repartirse las frutas riendo. Cuando el antropólogo preguntó por qué lo habían hecho así, le respondieron simplemente: "UBUNTU, yo soy porque nosotros somos…", y le aclararon que uno no puede ser feliz si todos los demás no lo son. Hoy en día se usa la expresión "tener UBUNTU", explicándose como que:

"Una persona solo es lo que es, a través de otras personas".

Si hoy soy quien soy, es gracias a todos vosotros...

🚀 

"Siempre busca aquello que te emocione el alma"

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INFLUENCE OF PHYSICAL ACTIVITY AND PHYSICAL FITNESS LEVEL ON PSYCHOLOGICAL VARIABLES AND COGNITION IN SECONDARY SCHOOL

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CERTIFICA:

Que la Tesis Doctoral con mención internacional titulada "*Influencia de la actividad física y nivel de condición física sobre variables psicológicas y cognición en Educación Secundaria*" que presenta D. ALBERTO RUIZ ARIZA al superior juicio del Tribunal que designe la Universidad de Jaén, ha sido realizada bajo mi dirección durante los años 2014-2018, siendo expresión de la capacidad técnica e interpretativa de su autor en condiciones tan aventajadas que le hacen merecedora del Título de Doctor, siempre y cuando así lo considere el citado Tribunal.

En Jaén, a 17 de septiembre de 2018

Fdo. Emilio J. Martínez López

El doctorando D. **Alberto Ruiz Ariza**, ha realizado la presente Tesis Doctoral Internacional como beneficiario de un contrato de Formación de Profesorado Universitario (FPU) del Ministerio de Educación, Cultura y Deporte del Gobierno de España (FPU-014/01185).

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BECAS, PREMIOS Y ESTANCIAS DE INVESTIGACIÓN [RESEARCH GRANTS, AWARDS, AND RESEARCH STAYS]

Para el inicio, y durante el desarrollo de la presente Tesis Doctoral, se han obtenido una serie de becas, premios, y estancias de investigación, que se detallan a continuación:

1. Contrato para Formación de Profesorado Universitario (FPU 014/01185)
Fecha de Inicio: 15/09/2015
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Rol: Personal Docente e Investigador Predoctoral

2. Primer Premio en el "XIX Premio Nacional de Investigación del Colegio de Licenciados de Educación Física de Andalucía (COLEF)"
Título del trabajo: Asociación entre distintos componentes de condición física y rendimiento académico en adolescentes, teniendo en cuenta el status socioeducativo y el fatness.
Fecha: 2015
Entidad: Colegio de Licenciados de Educación Física de Andalucía

3. Premio a mejores Trabajos Fin de Máster.
Máster: Máster en Profesorado de ESO y Bachillerato, FP y Enseñanza de Idiomas.
Título del trabajo: Asociación entre condición física cardiovascular y rendimiento académico en adolescentes andaluces. Una estrategia de promoción del rendimiento académico a través de la Educación Física.
Curso: 2013-2014
Entidad: Universidad de Jaén

4. Premio a mejores Trabajos Fin de Máster.
Máster: Máster en Investigación y Docencia en CC. de la Actividad Física y la Salud
Título del trabajo: Asociación entre la Atracción hacia la Actividad Física y Desplazamiento Activo al instituto con factores del Bienestar Psicológico y Rendimiento Académico en adolescentes
Curso: 2012-2013

Entidad: Universidad de Jaén

5. **Título:** Beca de Colaboración con Departamentos Universitarios, en el Departamento de Didáctica de la Expresión Musical, Plástica y Corporal de la Universidad de Jaén.

Curso: 2012-2013

Entidad: Ministerio de Educación, Cultura y Deporte (Gobierno de España)

Rol: Becario

6. **Título:** Estancia de Investigación en el Instituto Politécnico de Beja, Escola Superior de Educaçao (Beja, Portugal)

Fecha: 01/03/2016-31/05/2016

Código: EST15/00181

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7. **Título:** Estancia de Investigación en el National Institute for Health and Welfare (Helsinki, Finlandia)

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8. **Título:** Estancia de Investigación en la Escuela de Educación Física de la Pontificia Universidad Católica de Valparaíso (Valparaíso, Chile).

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9. **Título:** Estancia de Investigación en la Facultad de Educación de la Universidad de Helsinki (Helsinki, Finlandia).

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PUBLICACIONES [PUBLICATIONS]

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

I. **Ruiz-Ariza, A.,** Ruiz, J. R., de la Torre-Cruz, M. J., Latorre-Román, P., & Martínez-López, E. J. (2016). Influence of level of attraction to physical activity on academic performance of adolescents. *Revista Latinoamericana de Psicología*, *48*, 42–50. http://doi.org/10.1016/j.rlp.2015.09.005 (**JCR: 0,717**, ***Q3 Psychology, Multidisciplinary;*** **SJR: 0,329**, ***Q2 Social Science, Miscellaneous***).

II. **Ruiz-Ariza, A.,** de la Torre-Cruz, M. J., Redecillas-Peiró, M. T., & Martínez-López, E. J. (2015). Influence of active commuting on happiness, well-being, psychological distress and body shape in adolescents. *Gaceta sanitaria*, *29*(6), 454–457. http://doi.org/10.1016/j.gaceta.2015.06.002 (**JCR: 1,509**, ***Q3 Public, Environmental & Occupational Health***).

III. **Ruiz-Ariza, A.,** de la Torre-Cruz, M. J., Suárez-Manzano, S., & Martínez-López, E. J. (2017). Active commuting to school influences on academic performance of Spanish adolescent girls. *Retos, 32*, 39–43. (**SJR: 0,260**, ***Q3 Education***).

IV. **Ruiz-Ariza, A.,** Grao-Cruces, A., de Loureiro, N. E. M., & Martínez-López, E. J. (2017). Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015. *International Review of Sport and Exercise Psychology*, *10*(1), 108–133. http://doi.org/10.1080/1750984X.2016.1184699 (**JCR: 2,391**, ***Q2 Psychology, Applied***).

V. Martínez-López, E. J., Grao-Cruces, A., de la Torre-Cruz, M. J., & **Ruiz-Ariza, A.** (XXXX). Associations of physical fitness with academic performance in teenagers. *South African Journal for Research in Sport, Physical Education & Recreation,* ***Submitted (2nd round).*** (**JCR: 0,318, *Q4 Social Science, Interdisciplinary***).

VI. **Ruiz-Ariza, A.,** & Martínez-López, E. J. (2016). Association between different components of physical fitness and academic performance in adolescents, taking into account the social-educational status and fatness. *Habilidad Motriz, 47*, 23-30. (Primer Premio en el "XIX Premio Nacional de Investigación del COLEF 2015").

VII. **Ruiz-Ariza, A.,** Suárez-Manzano, S., López-Serrano, S., & Martínez-López, E. J. (2017 *in press*). The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school. *European Physical Education Review, 1356336X1773927.* https://doi.org/10.1177/1356336X17739271 **(JCR: 2,422, *Q1 Education & Educational Research***).

VIII. Martínez-López, E. J., De la Torre-Cruz, M. J., Suárez-Manzano, S., & **Ruiz-Ariza, A.** (XXXX). 24 sessions of monitored cooperative high-intensity interval training improves attention-concentration and mathematical calculation in secondary school. *Journal of Physical Education and Sport,* ***Submitted.*** (**SJR: 0,284. *Q4 Sports Science***).

RESUMEN

Los beneficios de la práctica de actividad física en la salud física han sido ampliamente contrastados en la literatura científica. Sin embargo, el análisis de la relación de la práctica de actividad física con mejoras en el bienestar psicológico y cognición ha sido aún poco explorado.

El objetivo general de la presente Tesis Doctoral ha sido analizar la relación de algunas variables de actividad física y condición física, con variables psicológicas y cognición en adolescentes, así como los efectos de un programa de intervención de actividad física de alta intensidad interválica y cooperativa (de sus siglas en inglés: C-HIIT), en clases de Educación Física. Para ello, se han llevado a cabo estudios de revisión sistemática, de asociación, y de intervención en jóvenes estudiantes de Educación Secundaria.

Para satisfacer este objetivo general se requirieron una serie de estudios que finalmente se tradujeron en ocho artículos agrupados en tres temáticas afines: i) Relación de la actividad física con variables psicológicas y cognición (Papers I, II, III); ii) Influencia de la condición física en la cognición (Papers IV, V, VI); iii) Efectos de un programa de actividad física de alta intensidad interválica y cooperativa (Papers VII, VIII).

Los principales resultados de la Tesis sugieren que: a) El disfrute con la actividad física vigorosa es el principal factor de atracción hacia la actividad física que se relaciona, en chicas, con mejores calificaciones en Matemáticas y Lengua. En chicos, el disfrute con juegos y deportes, y con la práctica de actividad física vigorosa no influyen en su rendimiento académico, sin embargo aquellos que dan más importancia al ejercicio físico obtienen peores calificaciones en Lengua y Matemáticas. Asimismo, el desplazamiento activo al Centro educativo empleando más de 15 minutos al día, se asocia con más altos niveles de felicidad subjetiva y bienestar psicológico, así como con niveles más bajos de angustia psicológica. En chicas, realizar al menos 5 trayectos activos a la semana de más de 15 minutos, se asocia con un mayor rendimiento académico en Matemáticas, Educación Física, y mayor rendimiento académico general. En chicos, no se halló relación entre desplazamiento activo y rendimiento escolar. b) La

revisión sistemática mostró que un mejor nivel de condición física cardiorrespiratoria, velocidad-agilidad, coordinación motora, y habilidad perceptivo-motora, son los componentes del fitness que se relacionan en mayor medida con un mejor rendimiento cognitivo y académico en adolescentes. En relación con lo anterior, nuestros estudios de asociación mostraron que un mejor nivel de condición física se asocia con mejoras en el rendimiento académico durante la adolescencia, teniendo en cuenta importantes covariables como el nivel socioeducativo parental o el fatness. c) Un programa de C-HIIT de 12 semanas de duración, al comienzo de las clases de Educación Física, afecta positivamente sobre algunas variables de rendimiento cognitivo e inteligencia emocional en estudiantes de Educación Secundaria.

Los resultados de la presente memoria de Tesis ponen de manifiesto la importancia del fomento de la atracción por la práctica de actividad física vigorosa, sobre todo en chicas, la práctica de actividad física por ejemplo a través del desplazamiento activo al Centro educativo. Así como el fomento del nivel de condición física, y la puesta en marcha de programas específicos de actividad física de alta intensidad y cooperativos, dentro del contexto escolar, con el objetivo de mejorar importantes variables psicológicas y cognitivo-académicas durante la adolescencia.

SUMMARY

The benefits of practicing physical activity in physical health have been widely contrasted in the scientific literature. However, the analysis of the relationship of the practice of physical activity with improvements in psychological well-being and cognition has still been little explored.

The general objective of this Doctoral Thesis has been to analyse the relationship of some variables of physical activity and physical fitness, with psychological variables and cognition in adolescents, as well as the effects of a program of intervention of cooperative high-intensity interval physical activity (of its abbreviations in English: C-HIIT), in classes of Physical Education. For this, studies of systematic review, of association, and of intervention, have been carried out in young students of Secondary School.

In order to satisfy this general objective, a series of studies were required that were finally translated into eight papers, grouped into three related topics: i) Relationship of physical activity with psychological variables and cognition (Papers I, II, III); ii) Influence of physical fitness on cognition (Papers IV, V, VI); iii) Effects of a program of cooperative high intensity interval physical activity (Papers VII, VIII).

The main results of the Thesis suggest that: a) The enjoyment with vigorous physical activity is the main factor of attraction to physical activity that is related, in girls, with better grades in Math and Language. In boys, the enjoyment with games and sports, and the practice of vigorous physical activity do not influence their academic performance; however those who give more importance to physical exercise, get worse grades in Language and Math. Likewise, the active commuting to the Educational Center employing more than 15 minutes per day, is associated with higher levels of subjective happiness and psychological well-being, as well as with lower levels of psychological distress. In girls, performing at least 5 active travels a week of more than 15 minutes is associated with a higher academic performance in Mathematics, Physical Education, and greater general academic performance. In boys, no relationship was found between active commuting and school performance. b) The systematic review showed that a better level of cardiorespiratory fitness, speed-agility, motor coordination, and perceptual-motor

skills are the components of fitness that are related to a greater extent with better cognitive and academic performance in adolescents. In relation to the above, our association studies showed that a better level of physical fitness is associated with improvements in academic performance during adolescence, taking into account important confounders such as the parental socio-educational level or fatness. c) A 12-week C-HIIT program, at the beginning of Physical Education classes, positively affects some variables of cognitive performance and emotional intelligence in Secondary School students.

The results of this Thesis report highlight the importance of promoting attraction by the practice of vigorous physical activity, especially in girls, the practice of physical activity for example through active commuting to the educational Center. As well as the promotion of the level of physical fitness, and the implementation of specific programs of cooperative physical activity at high intensity, within the school context, with the aim of improving important psychological and cognitive-academic variables during adolescence.

ABREVIATURAS [ABBREVIATIONS]

A continuación mostramos un listado de abreviaturas en orden alfabético, tanto en castellano como en inglés, usadas en los diferentes apartados de la presente Tesis Doctoral, excepto las usadas en los papers, que se identifican según convenga en cada uno de ellos de forma individual y específica.

Abreviaturas en castellano

AF	Actividad física
AFINOS	Actividad Física como Agente Preventivo del Desarrollo de Sobrepeso, Obesidad, Alergias, Infecciones y Factores de Riesgo Cardiovascular en adolescentes
ANCOVA	Análisis de Covarianza
ANOVA	Análisis de Varianza
AVENA	Alimentación y Valoración del Estado Nutricional en Adolescentes
DT	Desviación Típica
EF	Educación Física
FCmax	Frecuencia Cardíaca Máxima
GC	Grupo Control
GE	Grupo Experimental
IE	Inteligencia Emocional
IMC	Índice de Masa Corporal
RA	Rendimiento Académico
RC	Rendimiento Cognitivo
ppm	pulsaciones por minuto
UD	Unidad Didáctica
UP & DOWN	Proyecto de Investigación con niños sanos y con niños con síndrome de down

Abbreviations in english

ACSM	American College Sport Medicine
AP	Academic performance
ALPHA	Assessing Levels of Physical Activity
BMI	Body mass index
BDNF	Brain Derived Neurotrofic Factor
BSQ	Body Shape Questionnaire
bpm	Beats per minute
CAPA	Children's Attraction to Physical Activity
CG	Control Group
C-HIIT	Cooperative high intensity interval training
CRF	Cardiorespiratory fitness
CP	Cognitive performance
EG	Experimental Group
EI	Emotional Intelligence
FNDC5	Fibronectin domain-containing protein 5
HR	Heart rate
MVPA	Moderate to vigorous physical activity
PA	Physical activity
PE	Physical Education
PGC1-Alpha	Peroxisome proliferator-activated receptor-gamma coactivator (PGC)-1alpha
ROC	Receiver Operating Characteristic
SD	Standard deviation
VO_2Max	Maximal oxygen uptake

Actividad física: Breve acercamiento sobre los beneficios en la salud física

La actividad física (AF) hace referencia a la realización de cualquier movimiento corporal producido por el sistema músculo-esquelético y que requiera consumo energético (García-Artero et al., 2007). Los efectos de la práctica de AF sobre la salud física, han sido ampliamente estudiados durante las últimas décadas (Blair y Morris, 2009; Ortega, Ruiz, Castillo y Sjöström, 2008). A nivel general, la práctica frecuente de AF se relaciona con una mejora muscular y ósea (Gracia-Marco, Vicente-Rodríguez, Casajús, Molnar, Castillo y Moreno, 2011), incremento en la capacidad antioxidante de la sangre (Carlsohn, Rohn, Mayer y Schweigert, 2010), mayor mineralización del hueso (Pitukcheewanont, Punyasavatsut y Feuille, 2010), disminución de la probabilidad de sufrir problemas cardíacos (Walker, MacIntosh, Kozyrskyj, Becker y McGavock, 2013), o con un aumento de la longevidad y esperanza de vida (Kujala, 2018). En este sentido, Wen et al. (2011), comprobaron diferentes volúmenes de práctica de AF con el objetivo de analizar si realizar alrededor de 150 minutos semanales de AF, era suficiente para reducir la mortalidad y extender la esperanza de vida. Para ello, realizaron un estudio prospectivo de cohortes con 416.175 sujetos desde 1996 hasta 2008, y hallaron que realizar 92 minutos semanales o 15 minutos diarios de AF reducía un 14% el riesgo de mortalidad por todas las causas y aumentaba la esperanza de vida un mínimo de 3 años. Sin embargo, los individuos que eran inactivos, aumentaban en un 17% el riesgo de mortalidad. Otra reciente investigación que analizó a 123.000 personas en Estados Unidos durante 30 años, mostró que realizar más de 6 horas de AF a la semana puede alargar la vida hasta en 8 años (Li et al., 2018).

A pesar de los beneficios descritos, estudios recientes demuestran que la práctica de AF ha sufrido un descenso progresivo durante los últimos años en los jóvenes españoles, especialmente entre los 12 y 18 años (Mielgo-Ayuso et al., 2016). Según Vicente-Rodríguez et al. (2016), los jóvenes españoles invierten únicamente un 10% del tiempo a AF de intensidad moderada o vigorosa (MVPA). Esta baja práctica de AF parece estar motivada por una falta de atracción hacia la AF, que ha quedado eclipsada de forma creciente por hábitos sedentarios relacionados principalmente con el consumo de televisión y videojuegos (Norris, Hamer y Stamatakis, 2016). Entre el entramado de variables que componen la AF y que juegan un papel fundamental durante la adolescencia, se encuentran la atracción por la práctica de AF, el desplazamiento activo al Centro educativo, el nivel de condición física, y el aprovechamiento de las clases de EF.

Atracción hacia la práctica de actividad física

La atracción hacia la AF se ha definido como la intención o deseo de una persona por involucrarse en la realización de tareas que impliquen esfuerzo físico o movimiento de cierta intensidad a través de juegos o deportes (Rose, Larkin, Hands, Howard y Parker, 2009). Martínez-Baena et al. (2012), realizaron un estudio descriptivo de corte transversal en el que se empleó la encuesta de comportamientos, actitudes y valores sobre actividad físico-deportiva del estudio AVENA (*Alimentación y Valoración del Estado Nutricional en Adolescentes*). Participaron 2839 adolescentes españoles de 13-18 años. Los resultados mostraron que casi la mitad de los encuestados tenían un nivel de práctica de AF insuficiente respecto a lo que realmente querrían practicar. La exigencia de los estudios, la pereza y desgana, suponen los principales motivos de abandono de la misma. Respecto a los motivos de no práctica, la falta de tiempo, seguido por la pereza, la falta de gusto hacia la AF y el cansancio por las tareas escolares, son los más señalados por los adolescentes. En cuanto a las diferencias entre sexos, Ruiz y Sherman (2005), en una investigación llevada a cabo en Estados Unidos durante las clases de EF, obtuvieron diferencias significativas entre sexos en la atracción hacia la AF, a favor de los chicos. Por su parte, Martínez-Baena et al. (2012), también mostraron diferencias significativas a favor del sexo masculino en cuanto a interés y gusto por la práctica físico-deportiva. Sin embargo, otros estudios no hallaron diferencias entre sexos y mostraron que chicos y chicas obtenían resultados similares en el disfrute con los juegos y deportes, con la AF y con la AF vigorosa (Brustad, 1993, 1996). Lo anterior es especialmente relevante debido a que las experiencias de AF vividas durante la infancia constituyen la base para la atracción hacia la AF durante la adolescencia e influyen para ser físicamente activo en la edad adulta (Rose et al., 2009; Thompson, Humbert y Mirwaldit, 2003). Aunque los principales motivos que determinan la práctica habitual de AF son el disfrute, la salud, y las relaciones sociales (Frederick-Recascino y Schuster-Smith, 2003; Moreno-Murcia, Cervelló y Martínez, 2007), la atracción hacia la AF es considerada un factor determinante, ya que incita a acrecentar la práctica físico-deportiva y a que se mantenga en el tiempo, generando una adherencia hacia su práctica (Cantón, Mayor y Pallarés, 1995). Tanto Brustad (1993, 1996) como Rose et al. (2009), crearon un instrumento, comúnmente conocido como *CAPA* (*Children's Attraction to Physical Activity Questionnaire*), para medir la atracción de los jóvenes hacia la AF en diferentes edades. De este modo, se puede conocer la motivación intrínseca de cada individuo hacia la práctica de AF, el juego y el deporte. Conocer el nivel de atracción hacia la AF de los adolescentes es, por tanto, un aspecto a tener en cuenta en la educación, ya que podría reconducir los niveles de práctica de AF en adolescentes, con los consecuentes beneficios asociados (**Paper I**).

Desplazamiento activo en adolescentes

Por otro lado, el desplazamiento activo se define como la acción de dirigirse al Centro educativo por medio de transportes que conlleven gasto energético como andar o usar la bicicleta (Chillón et al., 2010). Se ha demostrado que el tiempo medio diario empleado en el desplazamiento activo en adolescentes es de 18 minutos (Mendoza, Watson, Nguyen, Cerin, Baranowski y Nicklas, 2011), y podría incrementar un 13% la AF total practicada durante el día (Smith et al., 2012). En otro estudio, Van Dijk, De Groot, Van Acker, Savelberg y Kirschner (2014), hallaron que el desplazamiento activo constituía el 28% del total de práctica de AF semanal. Investigaciones previas muestra que el desplazamiento activo puede prevenir el riesgo de padecer enfermedades cardiovasculares (Pizarro, Ribeiro, Marques, Mota y Santos, 2013), ayudar a mantener niveles más bajos de grasa corporal y mejorar la condición física (Chillón et al., 2011; Davison, Werder y Lawson, 2008). Sin embargo, sus efectos sobre aspectos psicológicos y académicos han sido poco explorados (**Paper II** y **III**).

El desplazamiento activo se evalua mediante cuestionario que registra el modo, tiempo, y cantidad de desplazamientos semanales empleados para ir y volver del Centro educativo (Chillón et al., 2009; 2011). Posteriormente, para llevar a cabo estudios comparativos, los participantes se pueden clasificar en inactivos y activos: inactivos (emplean transporte motorizado o realizan menos de cinco trayectos/semana andando) y activos (realizan cinco o más trayectos andando —superiores a 15 minutos— durante la semana). Los valores oscilarán entre cero y 10 trayectos. Se toma la cifra de 15 minutos en base a lo establecido en estudios previos (Martínez-Gómez et al., 2011).

Condición física en adolescentes

Entre las variables que componen la AF, el nivel de condición física juega un papel fundamental. La condición física se define como el conjunto de cualidades físicas que engloban la capacidad cardiorrespiratoria, la fuerza muscular, la velocidad-agilidad, la coordinación, la flexibilidad o la composición corporal (Castro-Piñero et al., 2010; Ruiz et al., 2009). Numerosas investigaciones han mostrado el rol del nivel de condición física para mejorar el sistema músculo-esquelético, disminuir el riesgo de enfermedades cardiometabólicas (Ortega et al., 2008), y reducir el riesgo de mortalidad prematura por todas las causas (Ortega, Silventoinen, Tynelius y Rasmussen, 2012).

El nivel de condición física en adolescentes, se puede evaluar con la batería de test físicos relacionados con la salud en jóvenes, ALPHA-Fitness (Ruiz et al., 2011). Estos tests se pueden llevar a cabo en las clases de EF según el protocolo de Esteban-Cornejo et al. (2014). Por ejemplo, la capacidad cardiorrespiratoria se evalua mediante el test de 20 m de ida y vuelta, que se realiza en gran grupo al final de la sesión. La puntuación es el número de periodos completados. Los participantes deben correr entre dos líneas a 20 m de distancia, al ritmo de los pitidos de la señal sonora. El test finaliza cuando el sujeto se detiene debido a la fatiga, o cuando no llega a la línea correspondiente en dos ocasiones consecutivas. Los participantes deben ser constantemente animados durante la prueba (Esteban-Cornejo et al., 2014). El número de periodos se puede transformar en el consumo máximo de oxígeno (VO_2Max, mL/kg/min) a través de la ecuación de Lèger (Lèger, Mercier, Gadoury y Lambert, 1988). La fuerza muscular se obtiene través de la prueba de prensión manual y del salto de longitud a dos piernas. Para la prueba de prensión manual, se usa un dinamómetro con mango ajustable (TKK 5101 Grip D; Takey, Tokyo, Japan) (Esteban-Cornejo et al., 2014). El test se realiza dos veces para cada mano, y se registra la máxima puntuación en kilogramos. La puntuación media de la mano derecha e izquierda se puede calcular para obtener una puntuación media total. El test de salto de longitud a dos piernas también se evalua dos veces. Se realiza con los pies detrás de la línea, con una apertura de piernas aproximadamente a la anchura de los hombros. Se registra la distancia más larga en centímetros (Esteban-Cornejo et al., 2014). Una única puntuación z de fuerza muscular puede ser obtenida entre los dos test musculares. La puntuación individual de cada test se estandariza de la siguiente manera: z-valor estandarizado = (valor-media)/DT. La puntuación z total de fuerza muscular se calcula con la media de las dos puntuaciones individuales (Esteban-Cornejo et al., 2014). Por su parte, la habilidad motora se evalua con el test de ida y vuelta 4x10 m de velocidad de movimiento, agilidad y coordinación. Los participantes realizan 4 carreras de ida y vuelta a máxima velocidad en una distancia de 10 m transportando en cada trayecto (a partir del segundo) unas esponjas colocadas en cada extremo. El test se repite dos veces y se registra la más rápida en segundos (Esteban-Cornejo et al., 2014). Es importante indicar, que la puntuación obtenida en esta prueba debe ser interpretada de forma inversa, es decir, a más segundos empleados en completarla, menor habilidad motora (**Paper IV, V** y **VI**).

Beneficios psicológicos de la práctica de actividad física

Más allá de los beneficios sobre la salud física que pueda ocasionar la práctica sistemática de AF, una corriente científica actual se ha centrado en analizar los efectos sobre aspectos psicológicos (Holder, Coleman y Sehn, 2009; Jiménez-Moral, Zagalaz-Sánchez, Molero, Pulido-Martos y Ruiz; 2013; Padilla-Moledo et al., 2012). Según Padilla-Moledo et al. (2012), algunas de las variables psicológicas más importantes pueden ser la felicidad, el bienestar subjetivo, o la propia autopercepción de la imagen corporal. La felicidad subjetiva es una valoración personal sobre la propia felicidad (Lyubomirsky, Tkach y DiMatteo, 2006), es decir, la respuesta que da una persona cuando se le pregunta si es feliz o no (Lyubomirsky y Lepper, 1999). Lyubomirsky, Sheldon y Schkade (2005), relacionaron la felicidad subjetiva con el bienestar subjetivo. En este sentido, el bienestar subjetivo comprende elementos emocionales, relacionados con la experimentación de emociones y estados de ánimo positivos o negativos, estaría relacionado con ostentar un buen estado de bienestar psicológico y bajo nivel de malestar o angustia psicológica (Heubeck y Neill, 2000). Por otro lado, la autopercepción de los adolescentes acerca de su imagen corporal, también forma parte de un adecuado nivel de salud psicológica (Padilla-Moledo et al., 2012). La autoevaluación de la imagen corporal da lugar al grado de insatisfacción de los adolescentes con su propio cuerpo (Vázquez et al., 2011). Para su estudio se han creado constructos válidos y fiables (Cooper, Taylor, Cooper y Fairburn, 1987). La insatisfacción corporal afecta más a las chicas que a los chicos, y son ellas las que suelen estar más insatisfechas con su apariencia física (Smolak, 2004). Unido a esta insatisfacción, también presentan más síntomas de debilidad mental que los chicos, manifestada en forma de ansiedad, depresión, malestar o angustia psicológica (Ohannessian, Lerner, Lerner y von Eye, 1999).

Lyubomirsky et al. (2005), desarrollaron un modelo en el que afirmaban que el nivel de felicidad y bienestar mental de una persona estaba determinado por variables como la predisposición genética, el estado de salud, el estado civil, el aumento salarial o la realización de actividades por voluntad propia que supongan esfuerzo y dedicación. Entre estas últimas actividades se encuentra la AF, que según los anteriores autores, explicaría el 40% de la varianza de los niveles crónicos de felicidad. Por tanto, la AF puede jugar un papel fundamental en la mejora de la salud psicológica de los jóvenes. Un ejemplo es el estudio desarrollado por Holder et al. (2009), que observaron una asociación positiva entre AF, estimada mediante un cuestionario a padres y a niños de entre 8 y 12 años, y felicidad, valorada mediante una prueba gráfica. Jiménez-Moral et al. (2013), concluyeron que una mejor capacidad cardiorrespiratoria se asociaba positivamente con la felicidad. Igualmente, otro estudio pionero llevado a cabo con más de 5000 adolescentes ingleses, llegó a la conclusión de que el deporte y la AF recreativa de tipo vigorosa tenían efectos positivos sobre el bienestar mental y emocional (Steptoe y Butler, 1996). Un estudio similar, mostró que los adolescentes que durante un año empleaban 1 hora diaria promedio de AF presentaban un mejor bienestar emocional (Wiles, Jones, Haase, Lawlor, Macfarlane y Lewis, 2008). También se asemejan a los resultados de Sund, Larsson y Wichstrøm (2011), que en un estudio longitudinal de un año de duración, observaron que el aumento del ejercicio vigoroso y la reducción de actividades sedentarias mejoraban la salud mental de los adolescentes.

Sim embargo, la relación entre las variables específicas de AF tratadas en la presente Tesis Doctoral y parámetros relacionados con la salud psicológica en adolescentes no es tan evidente (Xu, Wen y Rissel, 2013), y son requeridos más estudios en esta línea (**Paper II**).

Actividad física, desplazamiento activo y condición física: Relación con la cognición

Cognición es un término amplio que engloba al rendimiento cognitivo (RC) y al rendimiento académico (RA). Su definición hace referencia a la función mental involucrada en adquirir conocimiento y comprensión (Esteban-Cornejo, Tejero-Gonzalez, Sallis y Veiga, 2015). Sin embargo, la adolescencia es una etapa crítica para la cognición, y un alto nivel de cognición en esas edades puede ser un importante predictor de salud en la edad adulta (Esteban-Cornejo et al., 2015).

El RC está afectado por el control inhibitorio y las funciones ejecutivas, que son los factores responsables del mantenimiento de la información en la memoria de trabajo, la planificación o la organización mental, la atención selectiva o el control del comportamiento (Diamond, 2013; Haapala, 2013). Para evaluar la memoria, se puede usar un test *ad hoc* de un minuto de duración, basado en las ideas originales de Wechsler (1945) y Tombaugh (1996), y en la versión española del test RIAS (Santamaría-Fernández y Fernández-Pinto, 2013). Para ello se puede usar un póster de 3-2m donde se pegan 15 cartas de la baraja Española, a tamaño folio. Este póster se proyecta en la pizarra durante 20 segundos e inmediatamente después, hay que anotar durante 40 segundos en una ficha de registro estandarizada el mayor número de cartas recordadas. Este test de memoria ha sido también usado previamente en otras recientes investigaciones, con una fiabilidad test-retest (48 horas, n = 21) de 0.919 (Ruiz-Ariza, Casuso, Suarez-Manzano y Martínez-López, 2018). La atención selectiva y concentración ha sido evaluada comúnmente en le contexto escolar mediante el test D2 en su versión española (Seisdedos, 2012). El cálculo matemático se puede evaluar con un test *ad hoc* en base a lose studios de Jastak y Wilkinson (1993), y Passolunghi y Siegel (2004), donde se solicita al estudiante realizar una serie de operaciones básicas con 6 dígitos (por ejemplo, 8 – 6 + 5 + 8 – 6 = 9). Los participantes tienen 1 minuto para resolver el máximo número de operaciones posible. Estudios previos muestran una fiabilidad test–retest (48 horas, n = 21) de 0.887 (Ruiz-Ariza et al., 2018). El razonamiento lingüístico evalúa la velocidad de lectura y la comprensión semántica. Para evaluar esta variable han sido desarrollados diferentes tests *ad hoc* en base a los estudios de Lervåg y Aukrust (2010), y al Neale Analysis of Reading Ability [NARA test] (https://www.glassessment.co.uk/products/neale-analysis-of-reading-ability-nara/), que consistente en 30 filas de 4 palabras cada una. En cada fila, 3 palabras pertenecen a la misma familia semántica y una no (por ejemplo; coche, perro, moto, camión). En un minuto el participante debe tachar todas las palabras intrusas que sea posible. Estudios previos muestran una fiabilidad test–retest (48 horas, n = 21) de 0.841 (Ruiz-Ariza et al., 2018). Otra variable cognitiva importante es la creatividad, considerada clave para la cognición porque contribuye notablemente al éxito personal y laboral de una persona (Heilman, 2016). La creatividad se ha definido como la capacidad para inventar un producto de valor nuevo y original (Steinberg, Sykes, Moss, Lowery, LeBoutillier y Dewey, 1997), y según Heilman, distigue tres etapas: (1) preparación, en la que una persona adquiere el conocimiento y habilidades necesarias para descubrir, desarrollar y producir un producto creativo; (2) inovación, en la que una persona busca inconscientemente una respuesta, la descubre y la unifica; y (3) verificación, que abarca el resultado final. Esta última etapa es particularmente importante en el proceso creativo, ya que la creatividad es difícil de cuantificar. La creatividad se relaciona con el pensamiento divergente (Torrance, 1966), un estilo de pensamiento que permite generar nuevas ideas donde es correcta más de una solución ante el mismo problema (Santos, Memmert, Sampaio y Leite, 2016). Por ejemplo, el "*brainstorming*", es un tipo de pensamiento divergente ampliamente conocido (Colzato, Szapora, Pannekoek y Hommel, 2013). Altos niveles de creatividad se relacionan con bajos niveles de angustia psicológica y depresión (Corbalán y Limiñana-Gras, 2010). La práctica de AF podría optimizar las anteriores funciones y promover un incremento del riego sanguíneo cerebral y de la plasticidad sináptica (Pareja-Galeano et al., 2013), entre otras adaptaciones neuronales que son clave para el aprendizaje (Chaddock-Heyman et al., 2014; Wrann et al., 2013) y para el posterior RA, tal y como profundizaremos en los apartados posteriores (Chaddock-Heyman et al., 2014; Tomporowski, McCullick, Pendleton y Pesce, 2015).

El RA se refiere al éxito de los adolescentes en el contexto escolar, medido a través de una media de las puntuaciones académicas en las diferentes asignaturas o a través de tests estandarizados de rendimiento (Haapala, 2013). Aparte del RC, otros factores que pueden influir en el RA son la evaluación por parte de los profesores de las actitudes, interés, participación y atención de los alumnos en clase (Gutiérrez y López, 2012). Asimismo, el RA puede estar mediatizado por otras variables socioeconómicas como el nivel educativo o profesión de los padres (Castillo et al., 2011), contexto sociocultural, opinión de los profesores (Keeley y Fox, 2009), duración de la lactancia materna (Victora et al., 2015), el bienestar general del niño (Morales y López-Zafra, 2009), autopercepción de competencia o la proposición de metas, y las estrategias de estudio (Caso-Niebla y Hernández-Guzmán, 2007). Además, es importante conocer el papel de covariables como la edad, sexo, IMC, o estatus socioeconómico, en la relación AF-cognición durante la adolescencia. De hecho, una de las principales limitaciones de las investigaciones actuales es la falta de control de covariables (Esteban-Cornejo et al., 2014).

Cuando los aspectos cognitivos interaccionan con factores emocionales y respuestas comportamentales, aparece la inteligencia emocional (IE) (Salovey y Mayer, 1990). La IE es un constructo compuesto por el bienestar, autocontrol, emocionabilidad y sociabilidad (Petrides, 2009; Petrides, Mikolajczak, Mavroveli, Sanchez-Ruiz, Furnham y Perez-Gonzalez, 2016). Un buen nivel de IE se asocial con comportamientos adaptativos y mejores habilidades sociales (Frederickson, Petrides y Simmonds, 2012), capacidad de liderazgo, y bajas posibilidades de comportamientos disruptivos, agresividad y dependencia dentro del contexto escolar (Mavroveli, Petrides, Sangareau y Furnham, 2009). Un estudio llevado a cabo en adolescentes británicos, mostró que la soledad es una de las variables más relacionadas con un déficit de IE (Wols, Scholte y Qualter, 2015). Además, la IE puede inhibir acciones como el bullying, victimización o psicopatologías en adolescentes (Kokkinos y Kipritsi, 2012; Petrides et al., 2016; Salovey y Mayer, 1990). Finalmente, mejores niveles de IE durante la adolescencia pueden asociarse con un mejor RA en el Centro educativo y con un mayor éxito laboral en el futuro (Frederickson et al., 2012; Mavroveli y Sanchez-Ruiz, 2011; Perera y DiGiacomo, 2013; Petrides et al., 2016). Recientes estudios han asociado la práctica de AF con mejor creatividad (Blanchette, Ramocki, O'del y Casey, 2005; Colzato et al., 2013; Santos et al., 2016) y mejor desarrollo de los factores de IE como bienestar (Padilla-Moledo et al., 2012), autocontrol (Donnelly y Lambourne, 2011), emocionabilidad (Azevedo, Burges-Watson, Haighton y Adams, 2014) y sociabilidad (Kato et al., 2016; Tateno, Skokauskas, Kato, Teo y Guerrero, 2016).

En los últimos años, cada vez más estudios se están centrando en el análisis de la relación entre AF y cognición en adolescentes (Ardoy, Fernández-Rodríguez, Jiménez-Pavón, Castillo, Ruiz y Ortega, 2014; Chen, Fox, Ku y Taun, 2013; Coe, Peterson, Blair, Schutten y Peddie, 2013). Por ejemplo, Martínez-Gómez et al. (2011), hallaron que las adolescentes españolas que realizaban desplazamiento activo al instituto tenían mejores índices de RC, medido a través de un cuestionario estandarizado de inteligencia y habilidades básicas de aprendizaje. Y Stock et al. (2012), en una muestra de 10380 adolescentes daneses, comprobaron que los jóvenes con una percepción más alta de su RA se desplazaban de forma activa en mayor medida que aquellos con una percepción más baja. Van Dijk et al., (2014), asociaron el desplazamiento activo y el RA en adolescentes, analizando las posibles diferencias en función del sexo, pero sin encontrar resultados significativos. Otros autores sí han concluido que desplazarse de forma activa al instituto se asocia con mejores calificaciones en Matemáticas (Domazet et al., 2016). Incluso la práctica de AF ha sido relacionada con mejoras en le aprendizaje de un segundo idioma (Liu, Sulpizio, Kornpetpanee, Job, Bagriyanik y Gonenca, 2017). Otro estudio llevado a cabo en jóvenes de unos 10 años de edad en Estados Unidos, mostró que tras realizar una caminata de 20 minutos al 60% de su VO_2Max, mejoraba la atención o la velocidad de procesamiento mental, en comparación con el grupo que se mantuvo en reposo (Hillman, Pontifex, Raine, Castelli, Hall y Kramer, 2009). La figura 1 muestra un encefalograma que mide la actividad eléctrica fijándose en una señal (P3), que muestra los niveles de atención. Cuanto más grande es la señal de P3, mayor es la cantidad de atención.

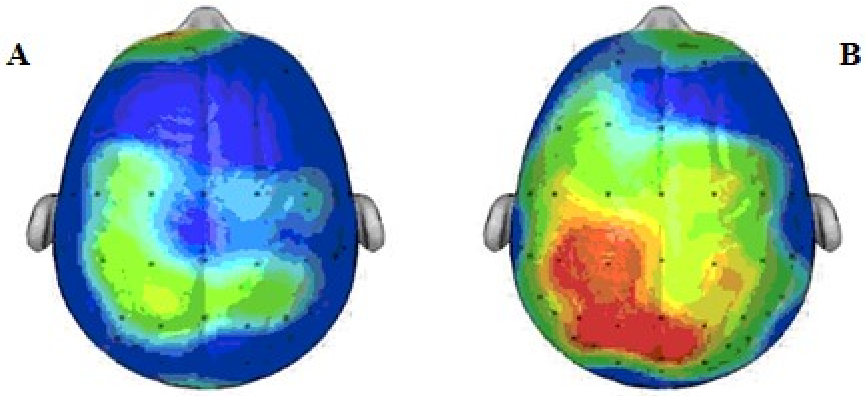

Figura 1. Encefalograma sobre la actividad cerebral tras 20 minutos de reposo (A) y tras 20 minutos caminando (B). Niveles de atención P3 (Hillman et al., 2009).

En un modelo propuesto por Howie y Pate (2012) y revisado más recientemente por Tomporowski et al. (2015), se plantea la secuencia de cómo la práctica de AF puede afectar sobre el RA: Primero, la AF en cualquiera de sus modalidades (desplazamiento activo, clases de EF, nivel de condición física, etc.), afecta a nivel cognitivo sobre la función ejecutiva, la atención, la memoria, la inteligencia y la creatividad; esto, en segundo lugar, se perfecciona mediante la metacognición, que refleja la comprensión de un individuo de lo que ya sabe y cómo utilizar ese conocimiento para regular el comportamiento. Y por último, las mejoras en RC, reguladas por la metacognición, provocan una mejoría en el RA en función de las calificaciones obtenidas, resultado en tests estandarizados o el comportamiento en clase valorado positivamente por el profesorado. En la figura 2 se puede observar una adaptación propia de dicho modelo, con la inclusión de otras variables consideradas muy importantes en relación al RA.

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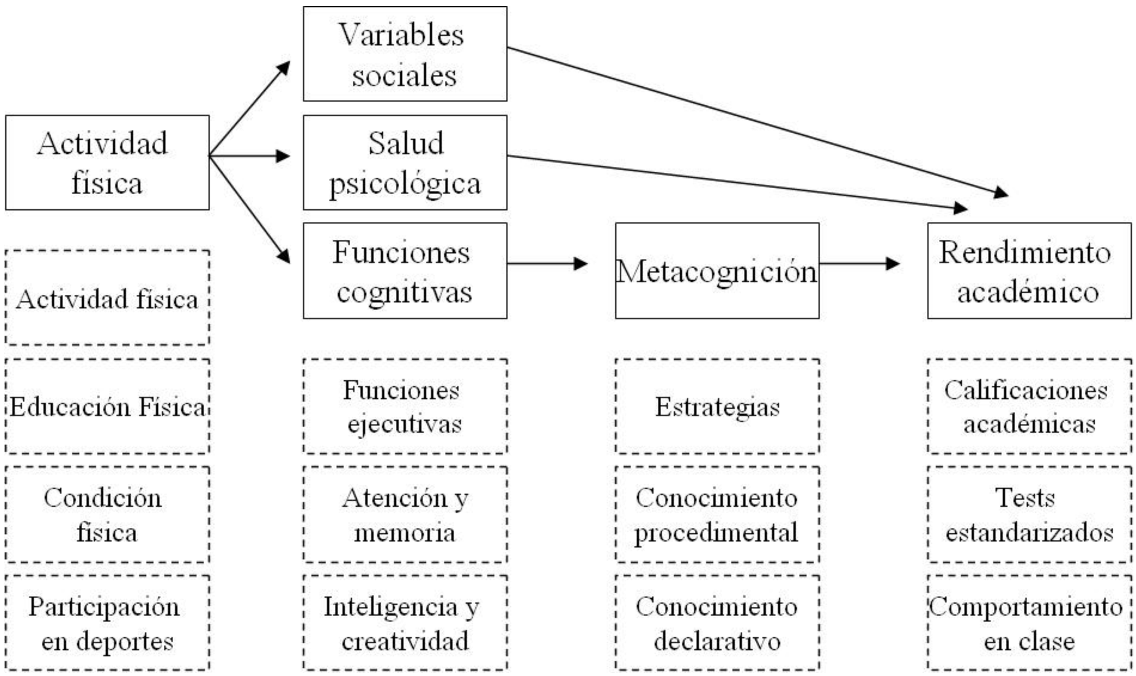

Figura 2. Adaptación propia de la secuencia de cómo la actividad física puede afectar al rendimiento académico escolar, propuesta por Howie y Pate (2012) y Tomporowski et al. (2015).

Con respecto a la condición física, la mayoría de estudios muestran una asociación positiva con el RC en adolescentes (Åberg et al., 2009; Ardoy et al., 2014; Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro y Tidow, 2008; Hogan, Kiefer, Kubesch, Collins, Kilmartin y Brosnan, 2013; Morales, González, Guerra, Virgili y Unnithan, 2011; Planinsec y Pisot, 2006; Ruiz et al., 2010; Soga, Shishido y Nagatomi, 2015; Stroth, Kubesch, Dieterle, Ruchsow, Heim y Kiefer, 2009; Travlos, 2010). Por ejemplo, en un estudio longitudinal en el que participaron más de un millón de suecos, Åberg et al. (2009), demostraron que la condición física cardiorrespiratoria adquirida entre los 15 y los 18 años, predecía la capacidad intelectual a los 18 años de edad, medida con una serie de pruebas de lógica, verbales, visuoespaciales y de inteligencia técnica (Figura 3). Dos estudios de intervención mostraron efectos positivos sobre el RC tras 10 minutos de ejercicio coordinativo (Budde et al., 2008) o 20 minutos de ejercicio aeróbico moderado (Hogan et al., 2013). Sin embargo, dos estudios similares, basados en 13 (Soga et al., 2015) o 20 (Stroth et al., 2009) minutos de ejercicio aeróbico de moderada intensidad, no encontraron hallazgos significativos. Finalmente, mientras dos estudios transversales mostraron una relación positiva entre condición física y RC (Morales et al., 2011; Planinsec y Pisot, 2006), otro estudio no halló asociación entre ambas (Ruiz et al., 2010).

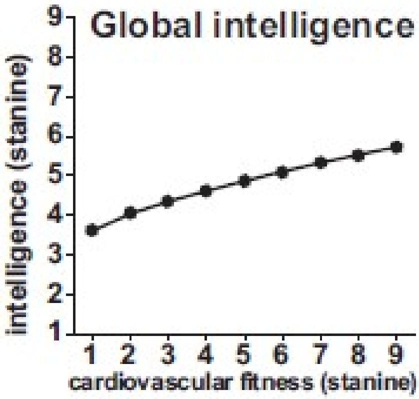

Figura 3. Aumento de la inteligencia global en relación al aumento de la capacidad cardiorrespiratoria (Åberg et al., 2009).

Con respecto al RA, London y Castrechini (2011) encontraron que los jóvenes en forma conseguían mejores notas en Matemáticas y Lengua que los que no estaban en buena forma física. Dos estudios asociaron también una mejora de la condición física desde la niñez con mejor RA durante la adolescencia (Bezold et al., 2014; Kantomaa et al., 2013). Sin embargo, al separar los análisis por componentes de condición física, se observa que es mayormente la capacidad cardiorrespiratoria la que se relaciona con un mejor RA (Chen et al., 2013). Por su parte, Ardoy et al. (2014) mostraron que aumentando el número y la intensidad de las clases semanales de EF se mejora el RA, sin embargo, mejoras en la capacidad cardiorrespiratria, fuerza muscular o velocidad-agilidad no llevaban a un incremento del RA (Ardoy et al., 2014). Finalmente, cuatro estudios tranversales muestran una asociación positiva entre capacidad cardiorrespiratoria y RA tras ajustar por potenciales covariables (Janak, Gabriel, Oluyomi, Peréz, Kohl y Kelder, 2014; Kwak, Kremers, Bergman, Ruiz, Rizzo y Sjöström, 2009; Sardinha, Marques, Martins, Palmeira y Minderico, 2014; Welk, Jackson, Morrow, Haskell, Meredith y Cooper, 2010), aunque en uno de ellos la asociación fue débil (Welk et al., 2010). Otro estudio mostró también una relación positiva entre la capacidad cardiorrespiratoria y el RA en Matemáticas y Lectura tras ajustar por el estatus socioeconómico y la edad, en mayor medida en chicas que en chicos (Bass, Brown, Laurson y Coleman, 2013). Raine, Biggan, Baym, Saliba, Cohen y Hillman (2018) concluyeron que mejoras en la capacidad cardiorrespiratria entre el sexto y octavo grado se relacionaba positivamente con mejoras en Lectura. Esteban-Cornejo et al. (2014), en otro estudio transversal, encontraron asociación entre la capacidad cardiorrespiratoria, agilidad motora y RA, aunque esta asociación no fue significativa con respecto a la fuerza muscular. En contra, Coe et al. (2013) informaron de que la fuerza muscular se asociaba con mejor RA entre los 8 y los 15 años.

En base a lo anterior, se puede observar una gran controversia y que los resultados aún no son concluyentes, posiblemente debido a la naturaleza multifactorial de la AF (Esteban-Cornejo et al., 2015; Haapala, 2013), que puede referirse a las clases de EF (Ardoy et al., 2014), desplazamiento activo al Centro educativo (Martínez-Gómez et al., 2011), o a la influencia diferencial de los diferentes componentes de la condición física (Haapala, 2013). Port tanto, se necesitan más estudios analizando las diferentes variables que pueden afectar a la cognición (**Paper I, III, IV, V, VI, VII** y **VIII**).

Empleo de alta intensidad en clase de EF para la mejora del bienestar psicológico y cognición en adolescentes: La posibillidad del HIIT en contexto escolar

Con respecto a la importancia de la EF como asignatura en el ámbito escolar, un estudio reciente en base a los proyectos AVENA, AFINOS y UP&DOWN, analizó si es un mito o una realidad que a los estudiantes que obtienen mejores calificaciones escolares no les gusta la EF durante la adolescencia (Cañadas et al., 2015). Estos investigadores hallaron que en los estudios AVENA y AFINOS, el hecho de que a un adolescente le guste o no la EF, no influía en su RA en materias como Matemáticas o Lengua. Por lo que junto a los estudios mostrados en los anteriores apartados, la EF se muestra clave para el fomento de importantes variables cognitivas, emocionales y académicas en jóvenes (Ardoy et al., 2014).

Calahorro-Cañada, Torres-Luque, López-Fernández y Carnero (2017), mostraron que durantes los días de clases de EF, los jóvenes españoles practican más AF que durante los días sin EF. A pesar de ello, solo dedican entre 5.7 y 8.7 minutos a MVPA durante las clases de EF (Calahorro-Cañada et al., 2017). Además, un estudio llevado a cabo por Yli-Piipari, Kulmala, Jaakkola, Hakonen, Fish y Tammelin (2016) ha mostrado que durante los días de EF la cantidad de MVPA es mayor (nueve minutos más en Estados Unidos y 16 minutos más en Finlandia), en comparación con los días sin EF. No obstante, los niveles de sedentarismo siguen incrementando en los últimos años (Cheung, 2017), y más del 62% de lo adolescentes no alcanzan el mínimo recomendado de 1h/día de MVPA, durante al menos 5 días/semana (Mielgo-Ayuso et al., 2016). Asimismo, la EF tiene un escaso tiempo curricular en la mayoría de países ─alrededor de 2 h/semana─ (Román-Viñas et al., 2016). Debido a lo anterior, son requeridos novedosos y efectivos métodos para incrementar los efectos de la AF en el menor tiempo posible de práctica.

El entrenamiento interválico de alta intensidad (HIIT, por las siglas en inglés de "*High-intensity interval training*") es un método que permite maximizar el escaso tiempo diario de AF, las actividades de alta intensidad han mostrado un mayor impacto sobre resultados de salud en adolescentes que las de baja intensidad (Eddolls, McNarry, Stratton, Winn y Mackintosh, 2017; Logan, Harris, Duncan y Schofield, 2014). Este método incluye intervalos cortos de ejercicio a alta intensidad (por ejemplo; de 45 segundos hasta 2–4 minutos a >85% de la FCmax), y periodos cortos de descanso entre los ejercicios intensos (Costigan, Eather, Plotnikoff, Hillman y Lubans, 2016). Hasta donde hemos podido saber, tan solo algunos estudios han analizado el potencial de incorporar AF a alta intensidad dentro del contexto escolar (Ardoy et al., 2014; Costigan et al., 2016). Costigan et al. (2016) mostraron que tras un programa HIIT de 8-10 minutos, 3 sesiones/semana durante 8 semanas, con ratios trabajo-descanso de 30:30 segundos, mejoraba el bienestar psicológico en adolescentes. Otro estudio halló que aumentar la intensidad de las clases de EF (> 85% FCmax), a través de carreras aeróbicas interválicas, tiene una influencia positiva en la velocidad numérica y para la resolución de problemas matemáticos simples (Travlos, 2010). De forma similar, un único estímulo de AF vigorosa en clase de EF al 70–85% FCmax mejoró en un 11-22% los resultados en un test estandarizado de Matemáticas tras 30 minutos después de la intervención (Phillips, Hannon y Castelli, 2015). Ardoy et al. (2014) demostraron también un positivo impacto a largo plazo sobre RC y RA, de aumentar las clases de EF a la semana y la intensidad de las mismas durante 4 meses. Emplearon dos grupos experimentales, uno de alta frecuencia/normal intensidad (cuatro días/semana; FC media = 129 ppm), y otro de alta frecuencia/alta intensidad (cuatro días/semana; FC media = 147 ppm). Las variables cognitivas mejoraron en el grupo de alta frecuencia/alta intensidad. Además, según una reciente revisión sistemática llevada a cabo por Li, O'Connor, O'Dwyer y Orr (2017), el tamaño del efecto fue mayor en el grupo de alta intensidad (4.87; $p < 0.001$).

Además, cuando la AF es realizada de forma cooperativa —actividades en parejas o en pequeños grupos—, los efectos sobre aspectos psicológicos o cognitivos podrían aumentar (Santos et al., 2016). Para algunos investigadores, el carácter social de la AF cooperativa, el entretenimiento lúdico y la toma de decisiones grupales en los ejercicios cooperativos, son factores determinantes de este tipo de AF (Agbuga, Xiang y McBride, 2012; Davis, Taylor y Cohen, 2015; Jaakkola, Washington y Yli-Piipari, 2012; Marker y Staiano, 2015; Santos et al., 2016). En este sentido, usar un nuevo método con un mayor carácter educativo como el HIIT cooperativo (C-HIIT) ─definido como ejercicios por parejas o pequeños grupos a alta intensidad─, podría ser una novedosa estrategia para aumentar los beneficios de la AF. Sin embargo, los efectos de la AF a alta intensidad podrían no afectar a todos los participantes del mismo modo (Costigan et al., 2016). Los adolescentes físicamente inactivos podrían tener más margen de mejora debido al efecto dosis-respuesta (Martínez-Gómez et al., 2011). En base a lo anterior, los adolescentes se pueden clasificar en inactivos (< cinco días/semana al menos 1h de MVPA) y activos (5 o más días/semana) (Martínez-López et al., 2015; Prochaska, Sallis y Long, 2001). Por su parte, Vanhelst et al. (2016) concluyeron que es necesario alcanzar más de 12 minutos/día de ejercicio de alta intensidad para mejorar la capacidad atencional en adolescentes de 12–17 años. Según la ACSM, el HIIT, el entrenamiento en grupo y el uso de la teconología como podría ser a través de pulsometría, son las tres tendencias que ocupan el "*Top 3*" en los rankings para el año 2018 (Thompson, 2017).

El programa C-HIIT empleado en nuestra investigación consiste en 4 minutos de calentamiento + 16 minutos de alta intensidad interválica al comienzo de las clases de EF, 2 sesiones/semana, durante 12 semanas (**Papers VII** y **VIII**). Así los profesores de EF pueden dedicar el resto del tiempo de clase con normalidad a sus UD programadas. En base al estudio con HIIT de Costigan et al. (2016), cada sesión de nuestro programa incluyó 4 series de cada uno de los 4 ejercicios correspondientes, con una progresión en los ratios trabajo-descanso desde 20:40 a 40:20 segundos en las últimas dos semanas (semana 1–2 = ratio 20:40 segundos; semana 3–4 = ratio 25:35 segundos; semana 5–8 = 30:30 segundos; semana 9–10 = 35:25 segundos; semana 11–12 = 40:20 segundos). Este entrenamiento combina ejercicios cardiorrespiratrios, de velocidad-agilidad y coordinativos porque son los componentes mayormente asociados con la cognición (Santana, Azevedo, Cattuzzo, Hill, Andrade y Prado, 2017). Todas las actividades fueron realizadas en parejas, que llevaban a cabo rotaciones tras cada serie, para promover el contexto cooperativo y social (Marker et al., 2015). Los participantes portaban pulsómetros (Seego Realtracksystems®, Spain) para animar al mantenimento de la intensidad requerida y fomentar la motivación e interés por la práctica. Los jóvenes participantes debían mantener una intensidad del 85% de su FCmax (Costigan et al., 2016). En la figura 4 se puede ver un ejemplo de la pantalla de control grupal de FC que se observa al llevar a cabo una sesión C-HIIT monitorizada.

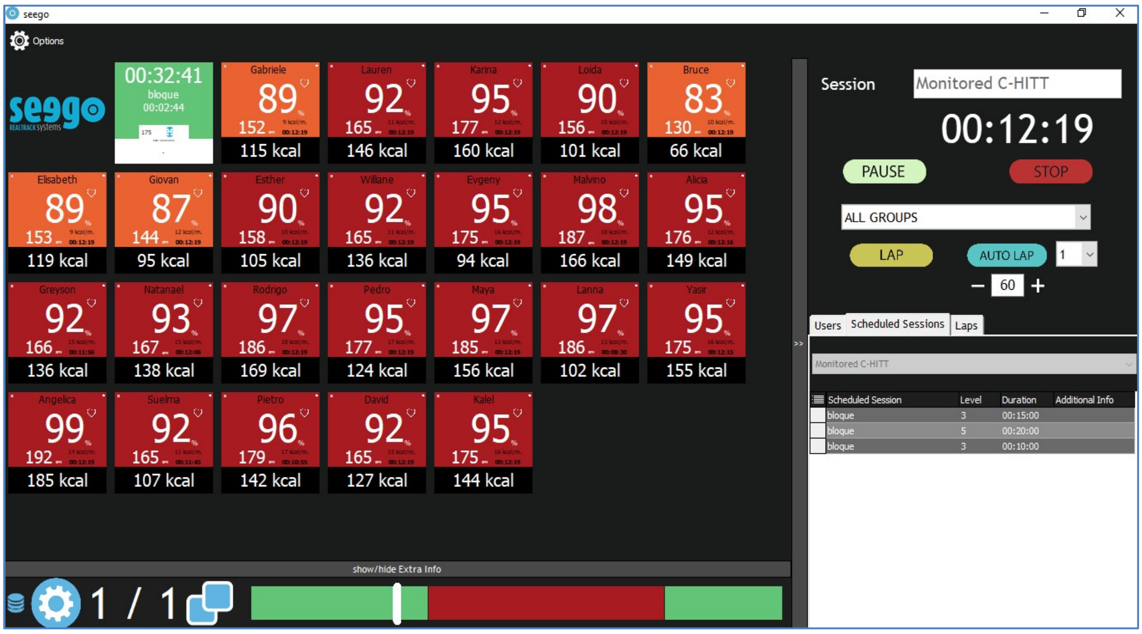

Figura 4. Ejemplo de monitorización de la frecuencia cardiaca durante una sesión grupal de C-HIIT en clase de EF.

Posibles explicaciones que justifican la influencia de la práctica de la actividad física en la mejora de la salud psicológica y la cognición en adolescentes

Hace un quinquenio, Wrann et al. (2013) concluyeron que la práctica de AF estimula la expresión del gen de la irisina (Fndc5) a través del complejo de transcripción PGC1-alfa/Err-alfa, y parece que el aumento de la expresión del gen Fndc5 estimula a su vez al gen del Factor Neurotrófico Derivado del Cerebro (BDNF). Otro estudio más reciente, muestra que la AF a alta intensidad podría estimular la acumulación de un cuerpo cetónico (D-bhidroxibutirato) en el hipocampo, que sirve como una fuente de energía y un inhibidor de las desacetilasas de histonas de clase I, induciendo específicamente al BDNF (Sleiman et al., 2016). El BDNF es un regulador maestro de la supervivencia celular, diferenciación y plasticidad en el cerebro. Así se logra una mejora en la función cognitiva, el aprendizaje y la memoria [figura 5] (Chang y Etnier, 2015; Noakes y Spedding, 2012; Piepmeier y Etnier, 2015; Wrann et al., 2013). Además, el BDNF actúa como neuroprotector ante posibles enfermedades neurodegenerativas y trastornos psiquiátricos como la depresión, autismo, trastorno obsesivo compulsivo, trastorno de hiperactividad o déficit de atención (Balaratnasingam y Janca, 2012).

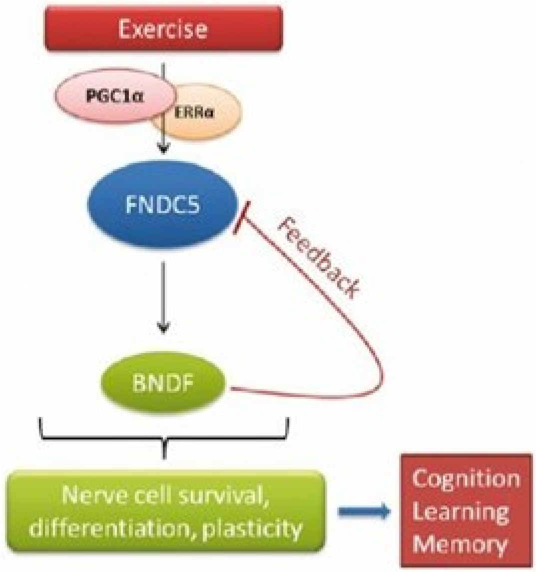

Figura 5. Esquema de cómo la práctica de AF estimula el gen Fndc5 a través del complejo de transcripción PGC1-alfa/Err-alfa. Y este a su vez, el BDNF, un regulador maestro de la supervivencia celular, diferenciación y plasticidad en el cerebro. Así se logra una mejora en la función cognitiva, el aprendizaje y la memoria (Wrann et al., 2013).

En segundo lugar, la práctica de AF mejora la microestructura de la materia blanca del cerebro, incrementando la velocidad y eficiencia de la actividad neuronal (Chaddock-Heyman et al., 2014). Además, promueve la angiogénesis, neurogénesis y sinaptogénesis, que son fenómemos que mejoran la densidad capilar, la vascularización cerebral, o el número de neuronas o la calidad de las conexiones sinápticas, afectando a la cognición (Adkins, Boychuk, Remple, y Kleim, 2006). La madurez biológica también puede determinar la relación entre por ejemplo el nivel de condición física y el RA (Haapala, 2013). Esto significa que los jóvenes más maduros podrían tener un sistema neuromuscular más desarrollado, y por consiguiente conseguir mejores puntuaciones en los test físicos y cognitivos paralelamente (Ardoy et al., 2014; Esteban-Cornejo et al., 2014). Goldstein (1987) demostró que los adolescentes con un esqueleto más maduro obtuvieron un mayor RC en comparación con los que tenían menos madurez esquelética (Haapala, 2013). Por otro lado, mejoras en velocidad-agilidad y coordinación, podrían provocar una preactivación del neocerebelo y corteza prefrontal dorsolateral (Diamond, 2000), llevando a mejoras en la atención (Budde et al., 2008; Kwak et al., 2009). Por tanto, mejoras en estas variables podrían favorecer al sistema neuromotor, mejorar la velocidad de conducción del impulso nervioso, e influir en la velocidad de procesamiento cerebral (Esteban-Cornejo et al., 2014; Torrijos-Niño, Martínez-Vizcaíno, Pardo-Guijarro, García-Prieto, Arias-Palencia y Sánchez-López, 2014).

Adicionalmente, una mayor práctica de AF puede motivar al alumnado a emplearse con más interés en la escuela, mostrar más atención y mejor comportamiento en clase. Además de aumentar el autoestima y reducir el estrés y a ansiedad, pudiendo mejorar el rendimiento escolar (Torrijos-Niño et al., 2014; Tremblay, Inman y Willms, 2000). A todo lo anterior hay que añadir que: 1) La práctica de AF incrementa los niveles de neurotrasmisores cerebrales como la serotonina y las endorfinas, produciendo sensación de felicidad, bienestar y relajación (Lojovich, 2010); y 2) si la AF se realiza en grupos aumenta la motivación, la autoeficacia y los comportamientos prosociales, facilitando la toma de decisiones, y las relaciones entre iguales (Agbuga et al., 2012; Davis et al., 2015; Jaakkola et al., 2012; Marker et al., 2015; Santos et al., 2016). Por tanto, la combinación de todas las anteriores mejoras, pueden favorecer la salud psicológica y la cognición de los adolescentes.

INTRODUCTION

Physical activity: Brief approach on the benefits in physical health

Physical activity (PA) refers to the accomplishment of any corporal movement produced by the musculoskeletal system and that requires energy consumption (García-Artero et al., 2007). The effects of PA practice on the physical health have been widely studied during the last decades (Blair & Morris, 2009, Ortega, Ruiz, Castillo & Sjöström, 2008). In general, the frequent PA practice is related to muscle and bone improvement (Gracia-Marco, Vicente-Rodríguez, Casajús, Molnar, Castillo & Moreno, 2011), increase in the antioxidant capacity of blood (Carlsohn, Rohn, Mayer & Schweigert, 2010), bone mineralization (Pitukcheewanont, Punyasavatsut & Feuille, 2010), decrease likelihood of heart problems (Walker, MacIntosh, Kozyrskyj, Becker & McGavock, 2013), or with an increase in longevity and life expectancy (Kujala, 2018). In this sense, Wen et al. (2011), tested different volumes of PA practice with the aim of analysing whether to perform around 150 minutes of PA weekly, was enough to reduce mortality and extend life expectancy. To do this, they conducted a prospective cohort study with 416,175 subjects from 1996 to 2008, and found that performing 92 minutes per week or 15 minutes per day of PA reduced the risk of mortality from all causes by 14% and increased life expectancy in a minimum 3 years. However, individuals who were inactive, increased the risk of mortality by 17%. Another recent research that analysed 123,000 people in the United States for 30 years, showed that performing more than 6 hours of PA per week can extend life up to 8 years (Li et al., 2018).

Despite the described benefits, recent studies show that the PA practice has suffered a progressive decline in recent years in Spanish young, especially between 12 and 18 years (Mielgo-Ayuso et al., 2016). According to Vicente-Rodríguez et al. (2016), Spanish youth invest only 10% of the time in moderate or vigorous intensity PA (MVPA). This low PA practice seems to be motivated by a lack of attraction to PA, which has been increasingly eclipsed by sedentary habits related mainly to the consumption of television and video games (Norris, Hamer & Stamatakis, 2016). Among the network of variables that make up the PA and that play a fundamental role during adolescence, are the attraction for the PA practice, the active commuting to the Educational Center, the level of physical fitness, and the use of PE classes.

Attraction to the practice of physical activity

The attraction to PA has been defined as the intention or desire of a person to be involved in the accomplishment of tasks that imply physical effort or movement of certain intensity through games or sports (Rose, Larkin, Hands, Howard & Parker, 2009). Martínez-Baena et al. (2012), conducted a descriptive cross-sectional study with the survey of behaviours, attitudes and values about PA and sports of the AVENA study (*Nutrition and Assessment of Nutritional Status in Adolescents*). 2839 Spanish adolescents aged 13-18 years took part in this study. The results showed that almost half of the participants had an insufficient level of PA practice regarding what they would really like to practice. The exigency of the studies, laziness and reluctance, are the main reasons for abandoning it. Regarding the reasons for not practicing, the lack of time, followed by laziness, lack of taste for PA and fatigue due to schoolwork, are the most indicated by adolescents. Regarding the differences between sexes, Ruiz & Sherman (2005), in a research carried out in the United States during PE classes, obtained significant differences between sexes in the attraction to PA in favour of boys. On the other hand, Martínez-Baena et al. (2012), also showed significant differences in favour of the male sex in terms of interest and attraction for physical-sporting practice. However, other studies did not find differences between sexes and showed that boys and girls obtained similar results in enjoyment with games and sports, with PA and vigorous PA (Brustad, 1993, 1996). This is especially relevant because the experiences of PA during childhood are the basis for the attraction to PA during adolescence, and influence to be physically active in adulthood (Rose et al., 2009; Thompson, Humbert & Mirwaldit, 2003). Although the main reasons that determine the habitual practice of PA are enjoyment, health, and social relationships (Frederick-Recascino & Schuster-Smith, 2003; Moreno, Cervelló & Martínez, 2007), attraction to PA is considered a factor determinant, since it encourages the physical-sport practice to increase and to maintain it over time, generating an adherence to its practice (Cantón, Mayor & Pallarés, 1995). Both, Brustad (1993, 1996) and Rose et al. (2009), created an instrument, commonly known as *CAPA* (*Children's Attraction to Physical Activity Questionnaire*), to measure the attraction of young people to PA at different ages. In this way, you can know the intrinsic motivation of each individual towards the practice of PA, the game and the sport. Knowing the level of attraction to PA of adolescents is, therefore, an aspect to take into account in education, since it could redirect the levels of practice of PA in adolescents, with the consequent associated benefits **(Paper I).**

Active commuting in adolescents

On the other hand, active commuting is defined as the action of going to the Educational Center through transport that involves energy expenditure such as walking or using the bike (Chillón et al., 2010). It has been shown that the average daily time spent in active commuting in adolescents is 18 minutes (Mendoza, Watson, Nguyen, Cerin, Baranowski & Nicklas, 2011), and could increase by 13% overall PA practiced during the day (Smith et al., 2012). In another study, Van Dijk, De Groot, Van Acker, Savelberg & Kirschner (2014) found that the active commuting constituted 28% of total weekly PA practice. Previous research shows that the active commuting can prevent the risk of cardiovascular disease (Pizarro, Ribeiro, Marques, Mota & Santos, 2013), help maintain lower levels of body fat and improve fitness (Chillón et al, 2011; Davison, Werder & Lawson, 2008). However, its effects on psychological and academic aspects have been little explored **(Paper II** and **III).**

Active commuting is assessed with questionnaire that records the mode, time, and number of weekly travels used to go to and from the Educational Center (Chillón et al., 2009, 2011). Later, to carry out comparative studies, the participants can be classified as inactive and active: inactive (using motorized transport or performing less than five travels/week walking) and active (performing five or more travels walking —up to 15 minutes— during the week). The values will oscillate between zero and 10 active travels. The amount of 15 minutes is taken based on what was established in previous studies (Martínez-Gómez et al., 2011).

Physical fitness in young people

Among the variables that make up the PA, the level of physical fitness plays a fundamental role. Physical fitness is defined as the set of physical qualities that include cardiorespiratory capacity, muscular strength, speed-agility, coordination, flexibility or body composition (Castro-Piñero et al., 2010, Ruiz et al., 2009). Numerous investigations have shown the role of the level of physical fitness to improve the musculoskeletal system, reduce the risk of cardiometabolic diseases (Ortega et al., 2008), and reduce the risk of premature death from all causes (Ortega, Silventoinen, Tynelius & Rasmussen, 2012).

The level of physical fitness in adolescents can be evaluated with the battery of physical tests related to health in young people, ALPHA-Fitness (Ruiz et al., 2011). These tests can be carried out in the PE classes according to the protocol of Esteban-Cornejo et al. (2014). For example, cardiorespiratory fitness is assessed by the 20-m shuttle-run test, which is done in a large group at the end of the session. The score is the number of periods completed. The participants must run between two lines 20 m away, to the rhythm of the beeps of the sound signal. The test ends when the subject stops due to fatigue, or when it does not reach the corresponding line on two consecutive occasions. Participants must be constantly encouraged during the test (Esteban-Cornejo et al., 2014). The number of periods can be transformed into the maximum oxygen consumption (VO_2max, mL/kg/min) through the Lèger equation (Lèger, Mercier, Gadoury & Lambert, 1988). Muscular strength is obtained through the manual grip test and the standing long jump test with two legs. For the manual grip test, a dynamometer with adjustable handle (TKK 5101 Grip D; Takey, Tokyo, Japan) is used (Esteban-Cornejo et al., 2014). The test is performed twice for each hand, and the maximum score in kilograms is recorded. The average score of the right and left hand can be calculated to obtain a total average score. The standing long jump test is also evaluated twice. It is performed with the feet behind the line, with an opening of legs approximately the width of the shoulders. The longest distance in centimetres is recorded (Esteban-Cornejo et al., 2014). A single z score of muscular strength can be obtained between the two muscular tests. The individual score of each test is standardized as follows: standardized z-value = (mean-value)/SD. The total z score of muscular strength is calculated with the average of the two individual scores (Esteban-Cornejo et al., 2014). On the other hand, the motor ability is evaluated with the shuttle run test 4x10 m of speed of movement, agility and coordination. The participants make 4 races at maximum speed in a distance of 10 m, transporting in each course (from the second) sponges placed at each end. The test is repeated twice and the fastest is recorded in seconds (Esteban-Cornejo et al., 2014). It is important to indicate that the score obtained in this test must be interpreted in an inverse way, that is to say, to more seconds spent completing it, less motor skill (**Paper IV, V** and **VI**).

Psychological benefits of physical activity practice

Beyond the benefits on physical health that can result from the systematic PA practice, a current scientific line has focused on analysing the effects on psychological aspects (Holder, Coleman & Sehn, 2009, Jiménez-Moral, Zagalaz-Sánchez, Molero, Pulido-Martos & Ruiz; 2013; Padilla-Moledo et al., 2012). According to Padilla-Moledo et al. (2012), some of the most important psychological variables can be happiness, subjective well-being, or the self-perception of the body shape. Subjective happiness is a personal assessment of own happiness (Lyubomirsky, Tkach & DiMatteo, 2006), that is, the response a person gives when asked if he is happy or not (Lyubomirsky & Lepper, 1999). Lyubomirsky, Sheldon & Schkade (2005), related subjective happiness with subjective well-being. In this sense, the subjective well-being includes emotional elements, related to the experimentation of emotions and positive or negative states of mind, it would be related to showing a good state of psychological well-being and low level of psychological distress (Heubeck & Neill, 2000). On the other hand, the self-perception of adolescents about their body shape is also part of an adequate level of psychological health (Padilla-Moledo et al., 2012). The self-assessment of the body shape gives rise to the degree of dissatisfaction of the adolescents with their own body (Vázquez et al., 2011). For its study, valid and reliable constructs have been created (Cooper, Taylor, Cooper & Fairburn, 1987). Body dissatisfaction affects girls more than boys, and it is they who are usually the most dissatisfied with their physical appearance (Smolak, 2004). Together with this dissatisfaction, they also present more symptoms of mental weakness than boys, manifested in the form of anxiety, depression, discomfort or psychological distress (Ohannessian, Lerner, Lerner & von Eye, 1999).

Lyubomirsky et al. (2005), developed a model in which they affirmed that a person's level of happiness and mental wellbeing was determined by variables such as genetic predisposition, health status, marital status, salary increase or the performance of activities that involve effort and dedication. Among these last activities, according to the previous authors, PA would explain 40% of the variance of chronic levels of happiness. Therefore, PA can play a fundamental role in improving the psychological health of young people. An example is the study developed by Holder et al. (2009), who observed a positive association between PA, estimated by means of a questionnaire to parents and children between 8 and 12 years old, and happiness, valued by means of a graphic test. Jiménez-Moral et al. (2013), concluded that a better cardiorespiratory capacity was positively associated with happiness. Likewise, another pioneering study carried out with more than 5000 English teenagers, concluded that sport and vigorous recreational PA had positive effects on mental and emotional well-being (Steptoe & Butler, 1996). A similar study showed that adolescents who spent one year averaging PA for a year had better emotional well-being (Wiles, Jones, Haase, Lawlor, Macfarlane & Lewis, 2008). They also resemble the results of Sund, Larsson & Wichstrøm (2011), which in a one-year longitudinal study found that increasing vigorous exercise and reducing sedentary activities improved the mental health of adolescents. However, the relationship between the specific variables of PA treated in this Doctoral Thesis and parameters related to psychological health in adolescents is not so evident (Xu, Wen & Rissel, 2013), and more studies in this line are required (**Paper II**).

Physical activity, active commuting and physical fitness: Relationship with cognition

Cognition is a broad term that encompasses cognitive performance (CP) and academic performance (AP). Its definition refers to the mental function involved in acquiring knowledge and comprehension (Esteban-Cornejo, Tejero-Gonzalez, Sallis & Veiga, 2015). Nevertheless, adolescence is a critical stage for cognition, and a high level of cognition in these ages can be an important predictor of health in adulthood (Esteban-Cornejo et al., 2015).

CP is affected by inhibitory control and executive functions, which are the factors responsible for the maintenance of information in working memory, planning or mental organization, selective attention or behaviour control (Diamond, 2013; Haapala, 2013). To evaluate the memory, a one-minute *ad hoc* test can be used, based on the original ideas of Wechsler (1945) and Tombaugh (1996), and in the Spanish version of the RIAS test (Santamaría-Fernández & Fernández-Pinto, 2013). For this purpose, a 3x2m poster can be used where 15 cards of the Spanish deck are pasted, at folio size. This poster is projected on the board for 20 seconds and immediately afterwards, the largest number of cards remembered must be recorded for 40 seconds on a standardized record card. This memory test has also been used previously in other recent investigations, with a test-retest reliability (48 hours, n = 21) of 0.919 (Ruiz-Ariza, Casuso, Suarez-Manzano & Martínez-López, 2018). Selective attention and concentration has been commonly evaluated in the school context through the D2 test in its Spanish version (Seisdedos, 2012). The mathematical calculation can be evaluated with an *ad hoc* test based on the studies of Jastak & Wilkinson (1993), and Passolunghi & Siegel (2004), where the student is asked to perform a series of basic operations with 6 digits (for example, 8 - 6 + 5 + 8 - 6 = 9). Participants have 1 minute to solve the maximum number of operations possible. Previous studies show a test-retest reliability (48 hours, n = 21) of 0.887 (Ruiz-Ariza et al., 2018). Linguistic reasoning evaluates reading speed and semantic comprehension. To evaluate this variable, different *ad hoc* tests have been developed based on the studies of Lervåg & Aukrust (2010), and the Neale Analysis of Reading Ability [NARA test] (https://www.glassessment.co.uk/products/neale-analysis-of-reading-ability-nara/), and consisting of 30 rows of 4 words each. In each row, 3 words belong to the same semantic family and one does not (for example, car, dog, motorcycle, truck). In one minute the participant must cross out as many intrusive words as possible. Previous studies show a test-retest reliability (48 hours, n = 21) of 0.841 (Ruiz-Ariza et al., 2018). Another important cognitive variable is creativity, considered key to cognition because it contributes significantly to a person's personal and work success (Heilman, 2016). Creativity has been defined as the ability to invent a product of new and original value (Steinberg, Sykes, Moss, Lowery, LeBoutillier & Dewey, 1997), and according to Heilman, it has three stages: (1) preparation, in which a person acquires the necessary knowledge and skills to discover, develop and produce a creative product; (2) Innovation, in which a person unconsciously seeks an answer, discovers and unifies it; and (3) verification, which covers the final result. This last stage is particularly important in the creative process, since creativity is difficult to quantify. Creativity is related to divergent thinking (Torrance, 1966), a style of thinking that allows generating new ideas where more than one solution is correct before the same problem (Santos, Memmert, Sampaio & Leite, 2016). For example, "*brainstorming*" is a widely known type of divergent thinking (Colzato, Szapora, Pannekoek & Hommel, 2013). High levels of creativity are related to low levels of psychological distress and depression (Corbalán & Limiñana-Gras, 2010). The PA practice could optimize the previous functions and promote an increase in cerebral blood flow and synaptic plasticity (Pareja-Galeano et al., 2013), among other neuronal adaptations that are key to learning (Chaddock-Heyman et al. , 2014, Wrann et al., 2013) and for the subsequent AP (Chaddock-Heyman et al., 2014, Tomporowski, McCullick, Pendleton, & Pesce, 2015).

The AP refers to the success of adolescents in the school context, measured through an average of the academic scores in the different subjects or through standardized performance tests (Haapala, 2013). Apart of CP, other factors that can influence the AP are the teachers 'evaluation of the students' interest, participation and attention attitudes in class (Gutiérrez & López, 2012). Likewise, the AP can be mediated by other socioeconomic variables such as the educational level or profession of the parents (Castillo et al., 2011), sociocultural context, opinion of the teachers (Keeley & Fox, 2009), duration of breastfeeding (Victora et al., 2015), the general well-being of the child (Morales & López-Zafra, 2009), self-perception of competence or the proposition of goals and study strategies (Caso-Niebla & Hernández-Guzmán, 2007). In addition, it is important to know the role of confounders such as age, sex, BMI, or socioeconomic status, in the PA-cognition relationship during adolescence. In fact, one of the main limitations of current research is the lack of control of confounders (Esteban-Cornejo et al., 2014).

When cognitive aspects interact with emotional factors and behavioral responses, emotional intelligence (EI) appears (Salovey & Mayer, 1990). EI is a construct composed of well-being, self-control, emotionality and sociability (Petrides, 2009, Petrides, Mikolajczak, Mavroveli, Sanchez-Ruiz, Furnham & Perez-Gonzalez, 2016). A good level of IE is associated with adaptive behaviors and better social skills (Frederickson, Petrides & Simmonds, 2012), leadership capacity, and low possibilities of disruptive behaviour, aggression and dependence within the school context (Mavroveli, Petrides, Sangareau & Furnham, 2009). A study carried out in British adolescents showed that loneliness is one of the variables most related to an IE deficit (Wols, Scholte & Qualter, 2015). In addition, EI can inhibit actions such as bullying, victimization or psychopathologies in adolescents (Kokkinos & Kipritsi, 2012, Petrides et al., 2016, Salovey & Mayer, 1990). Finally, better levels of EI during adolescence can be associated with a better AR in the educational centre and with greater future employment success (Frederickson et al., 2012, Mavroveli & Sanchez-Ruiz, 2011, Perera & DiGiacomo, 2013; Petrides et al., 2016). Recent studies have associated the practice of PA with better creativity (Blanchette, Ramocki, O'del & Casey, 2005, Colzato et al., 2013, Santos et al., 2016) and better development of EI factors as well-being (Padilla-Moledo et al., 2012), self-control (Donnelly & Lambourne, 2011), emotionality (Azevedo, Burges-Watson, Haighton & Adams, 2014) and sociability (Kato et al., 2016; Tateno, Skokauskas, Kato, Teo & Guerrero, 2016).

In recent years, more and more studies are focusing on the analysis of the relationship between PA and cognition in adolescents (Ardoy, Fernández-Rodríguez, Jiménez-Pavón, Castillo, Ruiz & Ortega, 2014; Chen, Fox, Ku & Taun, 2013; Coe, Peterson, Blair, Schutten & Peddie, 2013). For example, Martínez-Gómez et al. (2011), found that Spanish adolescents who made active commuting to the Secondary School had better rates of CP, measured through a standardized questionnaire of intelligence and basic learning skills. And Stock et al. (2012), in a sample of 10380 Danish adolescents, found that young people with a higher perception of their AP moved more actively than those with a lower perception. Van Dijk et al., (2014), associated active commuting and AP in adolescents, analyzing the possible differences according to sex, but without finding significant results. Other authors have concluded that actively commuting to the Secondary School is associated with better grades in Math (Domazet et al., 2016). Even the PA practice has been related to improvements in learning a second language (Liu, Sulpizio, Kornpetpanee, Job, Bagriyanik & Gonenca, 2017). Another study conducted on young people about 10 years of age in the United States, showed that after a walk of 20 minutes to 60% of their VO_2Max, improved attention or speed of mental processing, compared to the group that was kept at rest (Hillman, Pontifex, Raine, Castelli, Hall & Kramer, 2009). Figure 1 shows an encephalogram, which measures the electrical activity by looking at a signal (P3), that shows the levels of attention. The larger the P3 signal, the greater the amount of attention.

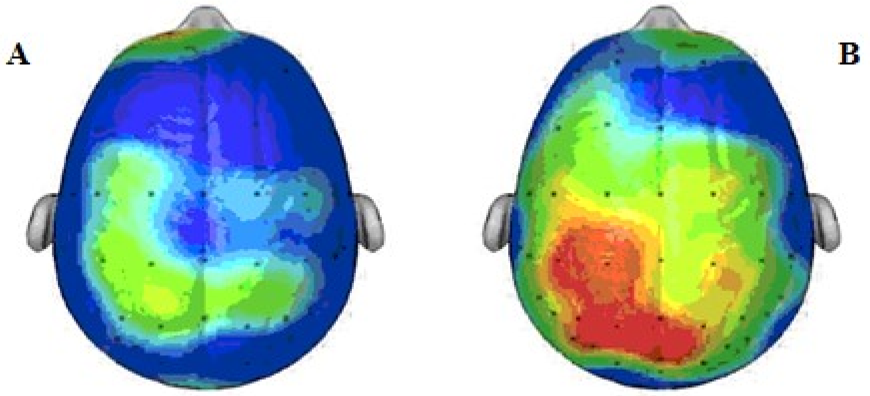

Figure 1. Encephalogram on brain activity after 20 minutes of rest (A) and after 20 minutes walking (B). Levels of attention P3 (Hillman et al., 2009).

In a model proposed by Howie & Pate (2012) and more recently reviewed by Tomporowski et al. (2015), the sequence of how the PA practice can affect the AP is presented: First, PA in any of its modalities (active commuting, PE classes, level of physical fitness...) affect at cognitive level on executive function, attention, memory, intelligence and creativity; this, second, is perfected through metacognition, which reflects an individual's understanding of what he already knows and how to use that knowledge to regulate behaviour. And finally, the improvements in CP, regulated by metacognition, provoke an improvement in the AP based on the grades obtained, result in standardized tests or the behaviour in class valued positively by the teaching staff. Figure 2 shows an adaptation of this model, with the inclusion of other variables considered very important in relation to the AP.

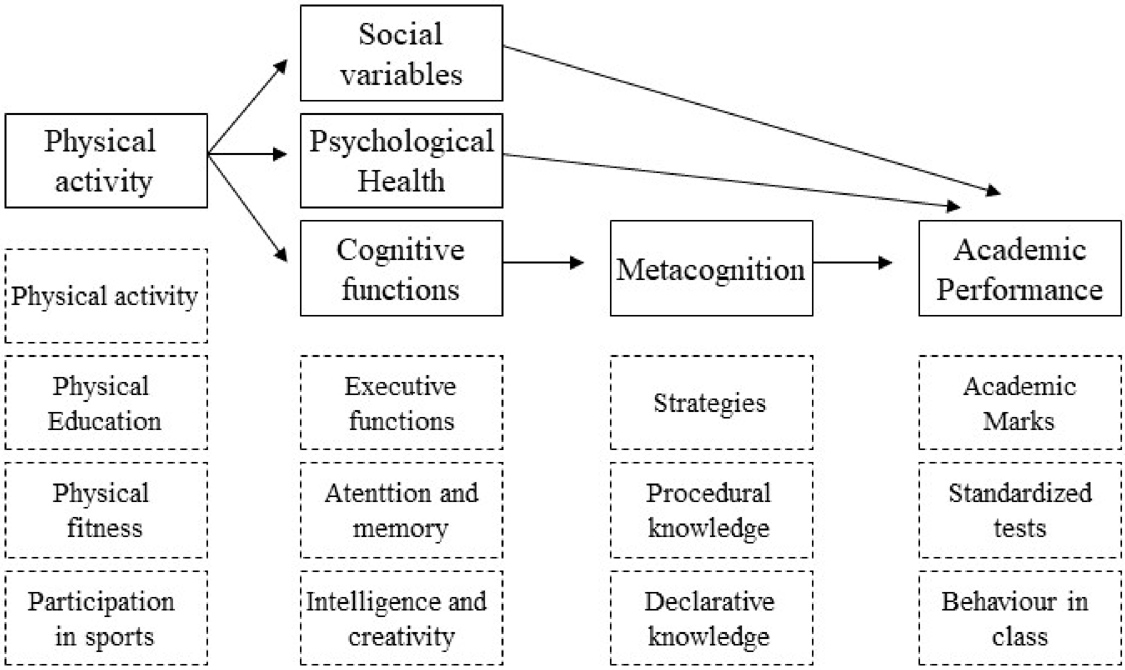

Figure 2. Adaptation of the sequence of how physical activity can affect academic performance, proposed by Howie & Pate (2012) and Tomporowski et al. (2015).

With regard to physical fitness, most studies show a positive association with CP in adolescents (Åberg et al., 2009; Ardoy et al., 2014; Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro & Tidow, 2008; Hogan, Kiefer, Kubesch, Collins, Kilmartin & Brosnan, 2013; Morales, González, Guerra, Virgili & Unnithan, 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010; Soga, Shishido & Nagatomi, 2015; Stroth, Kubesch, Dieterle, Ruchsow, Heim & Kiefer, 2009; Travlos, 2010). For example, in a longitudinal study involving more than one million Swedes, Åberg et al. (2009), showed that the cardiorespiratory fitness acquired between 15 and 18 years, predicted the intellectual capacity at 18 years, measured with a series of logic tests, verbal, visuospatial and technical intelligence (Figure 3). Two intervention studies showed positive effects on CP after 10 minutes of coordination exercise (Budde et al., 2008) or 20 minutes of moderate aerobic exercise (Hogan et al., 2013). However, two similar studies, based on 13 (Soga et al., 2015) or 20 (Stroth et al., 2009) minutes of moderate intensity aerobic exercise, found no significant findings. Finally, while two cross-sectional studies showed a positive relationship between physical fitness and CP (Morales et al., 2011; Planinsec & Pisot, 2006), another study found no association between both (Ruiz et al., 2010).

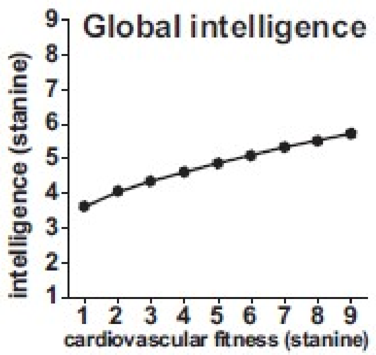

Figure 3. Increase in overall intelligence in relation to the increase in cardiorespiratory fitness (Åberg et al., 2009).

With regard to AP, London & Castrechini (2011) found that fit young people obtained better grades in Math and Language than those who unfit. Two studies also associated an improvement in physical fitness from childhood with better AP during adolescence (Bezold et al., 2014, Kantomaa et al., 2013). However, when separating the analyses by physical fitness components, it is observed that it is mainly the cardiorespiratory capacity that is related to a better AP (Chen et al., 2013). On the other hand, Ardoy et al. (2014) showed that increasing the number and intensity of weekly PE classes improves AP, however, improvements in cardiorespiratory capacity, muscular strength or speed-agility did not lead to an increase in AP (Ardoy et al., 2014). Finally, four cross-sectional studies show a positive association between cardiorespiratory fitness and AP after adjusting for potential confounders (Janak, Gabriel, Oluyomi, Peréz, Kohl & Kelder, 2014; Kwak, Kremers, Bergman, Ruiz, Rizzo & Sjöström, 2009; Sardinha, Marques, Martins, Palmeira & Minderico, 2014; Welk, Jackson, Morrow, Haskell, Meredith & Cooper, 2010), although in one of them the association was weak (Welk et al., 2010). Another study also showed a positive relationship between cardiorespiratory fitness and AP in Math and Reading after adjusting for socioeconomic status and age, to a greater extent in girls than boys (Bass, Brown, Laurson & Coleman, 2013). Raine, Biggan, Baym, Saliba, Cohen & Hillman (2018) concluded that improvements in cardiorespiratory fitness between the sixth and eighth grades were positively related to improvements in reading. Esteban-Cornejo et al. (2014), in another cross-sectional study, found an association between cardiorespiratory fitness, motor agility and AP, although this association was not significant with respect to muscular strength. Against, Coe et al. (2013) reported that muscular strength was associated with better AP between 8 and 15 years.

Based on the above, a great controversy can be observed and the results are not yet conclusive, possibly due to the multifactorial nature of the PA (Esteban-Cornejo et al., 2015a; Haapala, 2013), which may refer to the PE classes (Ardoy et al., 2014), active commuting to the Educational Center (Martínez-Gómez et al., 2011), or the influence of the different components of the physical fitness (Haapala, 2013). Therefore, more studies are needed analysing the different variables that can affect cognition (**Paper I, III, IV, V, VI, VII** and **VIII**).

High intensity employment in PE class for the improvement of psychological well-being and cognition in adolescents: The possibility of HIIT in school context

With regard to the importance of PE as a subject in the school environment, a recent study based on the projects AVENA, AFINOS and UP & DOWN, analyzed whether it is a myth or a reality that students who obtain better marks do not like PE during adolescence (Cañadas et al., 2015). These researchers found that in the studies AVENA and AFINOS, the fact that a teenager likes PE or not does not influence their AP in subjects such as Math or Language. Therefore, along with the studies shown in the previous sections, PE is key to the promotion of important cognitive, emotional and academic variables in young people (Ardoy et al., 2014).

Calahorro-Cañada, Torres-Luque, López-Fernández & Carnero (2017), showed that during the PE days, Spanish young practice more PA than during the days without PE. Despite this, they only dedicate between 5.7 and 8.7 minutes to MVPA during PE classes (Calahorro-Cañada et al., 2017). In addition, a study carried out by Yli-Piipari, Kulmala, Jaakkola, Hakonen, Fish & Tammelin (2016) has shown that during the PE days the amount of MVPA is higher (nine more minutes in the United States and 16 more minutes in Finland), compared to the days without PE. However, the levels of sedentarism continue to increase in recent years (Cheung et al., 2017), and more than 62% of adolescents do not reach the recommended minimum of 1 h/day of MVPA, for at least 5 days/week (Mielgo-Ayuso et al., 2016). Likewise, PE has a short curricular time in most countries ―around 2h/week― (Román-Viñas et al., 2016). Due to the above, new and effective methods are required to increase the effects of PA in the shortest possible time of practice.

High-intensity interval training (HIIT), is a method that allows to maximize the scarce daily time of AF, high-intensity activities have shown a greater impact on health outcomes in adolescents than those of low intensity (Eddolls, McNarry, Stratton, Winn & Mackintosh, 2017; Logan, Harris, Duncan & Schofield, 2014). This method includes short intervals of exercise at high intensity (for example, from 45 seconds to 2-4 minutes at >85% HRmax), and short rest periods between intense exercises (Costigan, Eather, Plotnikoff, Hillman & Lubans, 2016). As far as we have been able to know, only a few studies have analyzed the potential of incorporating PA at high intensity into the school context (Ardoy et al., 2014; Costigan et al., 2016). Costigan et al. (2016) showed that after a HIIT program of 8-10 minutes, 3 sessions/week for 8 weeks, with work-rest ratios of 30:30 seconds, improved psychological well-being in adolescents. Another study found that increasing the intensity of PE classes (>85% HRmax), through aerobic aerobic races, has a positive influence on the numerical speed and the resolution of simple mathematical problems (Travlos, 2010). Similarly, a single vigorous PA stimulus in PE class at 70-85% HRmax improved results in a standardized Math test by 11-22% after 30 minutes after the intervention (Phillips, Hannon & Castelli, 2015). Ardoy et al. (2014) also showed a positive long-term impact on CP and AP, of increasing PE classes per week and their intensity for 4 months. They used two experimental groups, one of high frequency/normal intensity (four days/week, average HR = 129 ppm), and another of high frequency/high intensity (four days/week, mean HR = 147 ppm). Cognitive variables improved in the high frequency/high intensity group. Besides, according to a recent systematic review carried out by Li, O'Connor, O'Dwyer & Orr (2017), the effect size was greater in the high intensity group (4.87, $p<0.001$).

In addition, when PA is carried out cooperatively ─activities in pairs or in small groups─ the effects on psychological or cognitive aspects could increase (Santos et al., 2016). For some researchers, the social nature of cooperative PA, playful entertainment and group decision-making in cooperative exercises are determining factors of this type of PA (Agbuga, Xiang & McBride, 2012; Davis, Taylor & Cohen, 2015; Jaakkola, Washington & Yli-Piipari, 2012; Marker & Staiano, 2015; Santos et al., 2016). In this sense, using a new method with a higher educational character as the cooperative HIIT (C-HIIT) ─defined as exercises in pairs or small groups at high intensity─, could be a novel strategy to increase the benefits of PA. However, the effects of high intensity PA may not affect all participants in the same way (Costigan et al., 2016). Physically inactive adolescents may have more room for improvement due to the dose-response effect (Martínez-Gómez et al., 2011). Based on the above, adolescents can be classified as inactive (<five days/week at least 1h of MVPA) and active (5 or more days/week) (Martínez-López et al., 2015; Prochaska, Sallis & Long, 2001). On the other hand, Vanhelst et al. (2016) concluded that it is necessary to achieve more than 12 minutes/day of high intensity exercise to improve the attention capacity in adolescents aged 12-17 years. According to the ACSM, HIIT, group training and the use of technology as it could be through heart rate, are the three trends that occupy the "*Top 3*" in the rankings for the year 2018 (Thompson, 2017).

The C-HIIT program used in our research consists of 4 minutes of warm-up + 16 minutes of high interval intensity at the beginning of PE classes, 2 sessions/week, for 12 weeks (**Papers VII** and **VIII**). Thus, PE teachers can dedicate the rest of the class time to their programmed training units normally. Based on the study with HIIT by Costigan et al. (2016), each session in our program included 4 series of each of the 4 corresponding exercises, with a progression in the work-rest ratios from 20:40 to 40:20 seconds in the last two weeks (week 1-2 = ratio 20:40 seconds, week 3-4 = ratio 25:35 seconds, week 5-8 = 30:30 seconds, week 9-10 = 35:25 seconds, week 11-12 = 40:20 seconds). This training combines cardiorespiratory, speed-agility and coordination exercises because they are the components most associated with cognition (Santana, Azevedo, Cattuzzo, Hill, Andrade & Prado, 2017). All the activities were carried out in pairs that carried out rotations after each series to promote the cooperative and social context (Marker et al., 2015). Participants carried heart rate monitors (Seego Realtracksystems®, Spain) to encourage the maintenance of the intensity required and encourage motivation and interest in the practice. The young participants had to maintain an intensity of 85% HRmax (Costigan et al., 2016). Figure 4 shows an example of the screen that is observed when carrying out a monitored C-HIIT session.

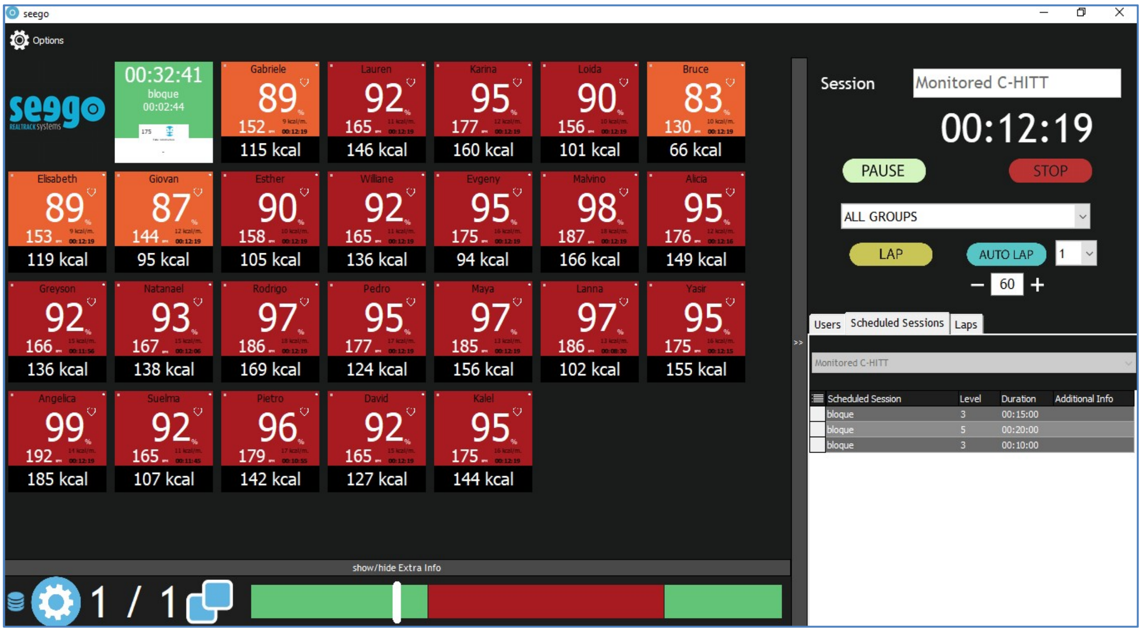

Figure 4. Example of heart rate monitoring during a group HIIT session in PE class.

Possible explanations that justify the influence of the practice of physical activity on the improvement of psychological health and cognition in adolescents

Five years ago, Wrann et al. (2013) concluded that the practice of PA stimulates the expression of the irisin gene (Fndc5) through the transcription complex PGC1-alpha/Err-alpha, and it seems that the increased expression of the Fndc5 gene in turn stimulates the Brain Derived Neurotrophic Factor (BDNF) gene. Another more recent study shows that high intensity PA could stimulate the accumulation of a ketone body (D-bhydroxybutyrate) in the hippocampus, which serves as an energy source and inhibitor of class I histone deacetylases, specifically inducing to BDNF (Sleiman et al., 2016). BDNF is a master regulator of cell survival, differentiation and plasticity in the brain. This is achieved an improvement in cognitive function, learning and memory [figure 5] (Chang & Etnier, 2015, Noakes & Spedding, 2012, Piepmeier & Etnier, 2015, Wrann et al., 2013). In addition, BDNF acts as a neuroprotective against possible neurodegenerative diseases and psychiatric disorders such as depression, autism, obsessive-compulsive disorder, hyperactivity disorder or attention deficit (Balaratnasingam & Janca, 2012).

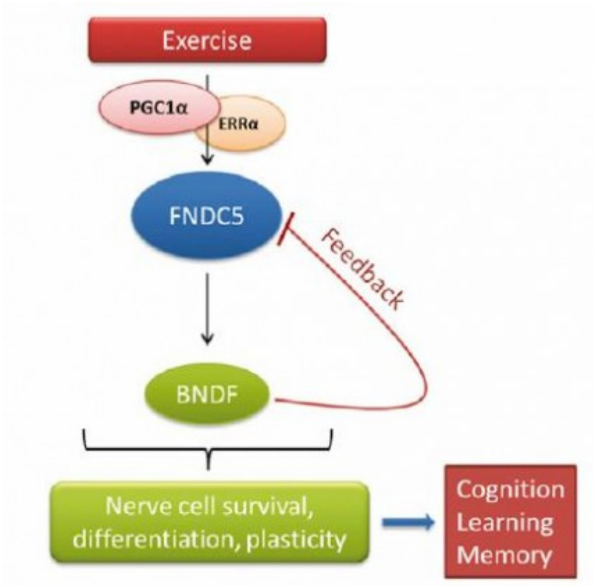

Figure 5. Schematic of how the PA practice stimulates the Fndc5 gene through the transcription complex PGC1-alpha/Err-alpha. And this in turn, BDNF, a master regulator of cell survival, differentiation and plasticity in the brain. Thus, an improvement in cognitive function, learning and memory is achieved (Wrann et al., 2013).

Secondly, the PA practice improves the microstructure of the white matter of the brain, increasing the speed and efficiency of neuronal activity (Chaddock-Heyman et al., 2014). In addition, it promotes angiogenesis, neurogenesis and synaptogenesis, which are phenomena that improve capillary density, cerebral vascularization, or the number of neurons or the quality of synaptic connections, affecting cognition (Adkins, Boychuk, Remple & Kleim, 2006). The biological maturity can also determine the relationship between, for example, the level of physical fitness and AP (Haapala, 2013). This means that more mature young people could have a more developed neuromuscular system, and therefore achieve better scores in physical and cognitive tests in parallel way (Ardoy et al., 2014, Esteban-Cornejo et al., 2014). Goldstein (1987) showed that adolescents with a more mature skeleton achieved a higher CP compared to those with less skeletal maturity (Haapala, 2013). On the other hand, improvements in speed-agility and coordination could cause preactivation of the neocerebellum and dorsolateral prefrontal cortex (Diamond, 2000), leading to improvements in CP (Budde et al., 2008; Kwak et al., 2009). Therefore, improvements in these variables could favour the neuromotor system, improve the conduction velocity of the nerve impulse, and influence the speed of brain processing (Esteban-Cornejo et al., 2014, Torrijos-Niño, Martínez-Vizcaíno, Pardo-Guijarro, García-Prieto, Arias-Palencia & Sánchez-López, 2014).

Additionally, a greater practice of PA can motivate students to use more interest in school, show more attention and better behavior in class. In addition to increasing self-esteem and reducing stress and anxiety, it can improve school performance (Torrijos-Niño et al., 2014; Tremblay, Inman & Willms, 2000). To all the above we must add that: 1) The PA practice increases the levels of cerebral neurotransmitters such as serotonin and endorphins, producing a feeling of happiness, well-being and relaxation (Lojovich, 2010); and 2) if PA is practised in groups, it increases motivation, self-efficacy and prosocial behaviors, facilitating decision-making, and relationships among mates (Agbuga et al., 2012; Davis et al., 2015; Jaakkola et al., 2012, Marker et al., 2015, Santos et al., 2016). Therefore, the combination of all the previous improvements can favour the psychological health and cognition of adolescents.

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OBJETIVOS

General

Analizar la influencia de la actividad física y la condición física en variables de bienestar psicológico y la cognición de los adolescentes. Para todo ello, se han llevado a cabo estudios de revisión sistemática, asociación, e intervención en Educación Secundaria.

Específicos

- Analizar el nivel de atracción hacia la actividad física y el rendimiento académico en adolescentes, así como la asociación entre dicha atracción y las calificaciones en las asignaturas de Matemáticas, Lengua y Educación Física en función del sexo, tras ajustar por edad e índice de masa corporal (**Paper I**).
- Analizar la asociación del desplazamiento activo con indicadores de salud psicológica como felicidad, bienestar, angustia psicológica o imagen corporal, y de rendimiento académico en Matemáticas, Lengua, Educación Física y rendimiento académico general —promedio de Matemáticas, Lengua y Educación Física— en adolescentes (**Papers II** y **III**).
- Revisar y analizar críticamente la literatura científica a través de una revisión sistemática, para conocer la relación entre los diferentes componentes de la condición física y el rendimiento cognitivo y académico en adolescentes, teniendo en cuenta las posibles covariables (**Paper IV**).
- Conocer la asociación entre condición física y rendimiento académico en adolescentes. Así como identificar los puntos de corte para la capacidad cardiorrespiratoria, velocidad-agilidad o fuerza muscular como posibles predictores de rendimiento académico. Especial importancia de la infuencia de covariables como edad, fatness o nivel socioeducativo de las familias (**Papers V** y **VI**).
- Analizar el efecto del programa C-HIIT monitorizado, de 12 semanas de duración durante las clases de Educación Física, en la creatividad e inteligencia emocional de los adolescentes (**Paper VII**).
- Analizar el efecto del programa C-HIIT monitorizado, de 12 semanas de

duración durante las clases de Educación Física, sobre variables de rendimiento cognitivo como memoria, atención selectiva, concentración, cálculo matemático y razonamiento lingüístico en adolescentes (**Paper VIII**).

AIMS

Overall

To analyse the influence of physical activity and physical condition on variables of psychological well-being and adolescent cognition. For all this, studies of systematic review, association, and intervention in Secondary Education have been carried out.

Specifics

- To analyse the level of attraction to physical activity and academic performance in adolescents, as well as the association between this attraction and the grades in the subjects of Mathematics, Language and Physical Education according to sex, after adjusting for age and BMI (**Paper I**).
- To analyse the association of active commuting with psychological health indicators such as happiness, well-being, psychological distress or body image, and academic performance in Mathematics, Language, Physical Education and general academic performance —Average Mathematics, Language and Physical Education— in adolescents (**Papers II** and **III**).
- To review and critically analyse the scientific literature through a systematic review, to know the relationship between the different components of physical fitness and cognitive and academic performance in adolescents, taking into account the confounders (**Paper IV**).
- To know the association between physical fitness and academic performance in adolescents. As well as identifying the cutting points for cardiorespiratory capacity, speed-agility or muscular strength as possible predictors of academic performance. Special importance of the influence of confounders such as age, fatness or socio-educational level of families (**Papers V** and **VI**).
- To analyse the effect of the monitored C-HIIT program, of 12 weeks duration during Physical Education classes, on creativity and emotional intelligence in adolescents (**Paper VII**).
- To analyse the effect of the monitored C-HIIT program, of 12 weeks duration during Physical Education classes, on variables of cognitive performance such as memory, selective attention, concentration, mathematical calculation and

linguistic reasoning in adolescents (**Paper VIII**).

MATERIAL Y MÉTODOS

La sección de material y métodos de la presente memoria de Tesis se resume en la siguiente tabla que incluye la información metodológica más relevante de los artículos que componen la memoria de Tesis (Tabla 1):

Tabla 1. Tabla resumen de las metodologías utilizadas en los diferentes artículos que componen esta Tesis Doctoral.

Artículo	Diseño	Participantes	Procedimiento	Variables	Análisis estadístico
I. Influence of level of attraction to physical activity on academic performance of adolescents.	Transversal.	Un total de 1009 alumnos de educación secundaria (579 chicas).	El nombre de cada participante fue codificado. La cumplimentación del cuestionario y las medidas de peso y talla se llevaron a cabo durante las clases de EF. Se solicitó a los centros educativos la calificación numérica en Matemáticas, Lengua y EF (segundo trimestre).	Atracción hacia la AF (Rose et al., 2009): Factor 1: disfrute con la AF y deportes. Factor 2: disfrute con la AF. Factor 3: disfrute con la AF vigorosa. Factor 4: importancia del ejercicio físico. RA en Matemáticas, Lengua y EF. Covariables: Edad e IMC.	Análisis de regresión lineal independiente para chicos y chicas, y separadamente para cada asignatura y ajustado por edad e IMC. Para estudiar si los adolescentes con baja vs. alta atracción hacia la AF (respuesta = 1-3 vs. respuesta = 4-5) tenían también mejor RA se realizaron análisis ANCOVA con edad e IMC como covariables.
II. Influence of active commuting on happiness, well-being, psychological distressand body shape in adolescents.	Transversal.	Un total de 1012 alumnos de educación secundaria (582 chicas).	El nombre de cada participante fue codificado. La cumplimentación de los cuestionarios y las medidas de peso y talla se llevaron a cabo durante las clases de EF. Los participantes se clasificaron como inactivos (≤15 minutos al día de desplazamiento activo) y activos (>15 minutos al día).	Cuestionario sobre desplazamiento activo. Felicidad subjetiva (Subjective Happiness Scale). Bienestar y angustia psicológica (General Well-Being): Factor 1: Bienestar psicológico. Factor 2: Angustia psicológica. Imagen corporal (Body Shape Questionnaire, BSQ-49). Covariables: Edad, IMC, sexo, estudios de la madre.	Se realizaron análisis de regresión lineal y ANCOVA para estudiar la asociación del tiempo activo para ir al centro educativo (categorías: inactivos frente a activos) con las variables de bienestar psicológico, ajustando por edad, IMC y sexo. Los análisis se repitieron incluyendo en el modelo los estudios de la madre.
III. Active commuting to school influences on academic performance of Spanish adolescent girls.	Transversal.	Un total de 1006 alumnos de educación secundaria (578 chicas).	Los cuestionarios y las medidas de peso y talla se cumplimentaron durante las clases de EF. Se solicitó a los Centros la calificación en Matemáticas, Lengua y EF. Los adolescentes se clasificaron en	Cuestionario sobre desplazamiento activo. RA en Matemáticas, Lengua y EF. Covariables: Edad e IMC.	Se realizaron análisis de regresión lineal y ANCOVA ajustados por edad e IMC. La variable independiente fue el número de trayectos de ida o vuelta semanales andando durante > a 15 minutos. Se

			inactivos (empleaban transporte motorizado o realizaban <5 trayectos/semana andando durante más de 15 minutos), y activos (realizaban ≥ de cinco trayectos/semana andando más de 15 minutos).		clasificaron en inactivos y activos. Los valores oscilaban entre cero y 10 trayectos. Se tomó la cifra de 15 minutos en base a lo establecido en estudios previos (Martínez-Gómez et al., 2011).
IV. Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015.	Revisión sistemática. Estructura en base a otras revisiones previas y la guía PRISMA.	21 estudios fueron incluídos en la revisión. 10 fueron transversales, 4 longitudinales con cohortes, 1 fue transversal y longitudinal con cohortes, y 6 fueron de intervención.	4 bases de datos fueron revisadas, desde enero del 2005 a enero del 2015 (PubMed, SportDiscus, Web of Science, and ProQuest). Adicionalmente, se revisaron las referencias de los artículos seleccionados.	Se realizó la búsqueda en las anteriores bases de datos usando los siguientes términos: (1) Physical fitness (physical education, physical fitness, cardiovascular, aerobic, musculoskeletal, strength, speed, agility, ability, coordination, flexibility). (2) Academic performance (cognitive performance, academic performance, academic attainment, academic achievement, academic outcomes). (3) Adolescent (adolescent, teenagers, children, childhood).	Porcentajes y frecuencias.
V. Associations of physical fitness with academic performance in teenagers.	Transversal.	2272 adolescentes (chicas = 1117).	El nombre de cada participante fue codificado. La cumplimentación de los test físicos se llevó a cabo durante las clases de EF. Se solicitó a los centros educativos la calificación numérica en Matemáticas, Lengua y EF. El RA se recodificó como bajo (<7 puntos), y alto (≥7 puntos).	Condición física (cardiorrespiratria, velocidad-agilidad y fuerza), medida con la batería ALPHA-Fitness®. RA en Matemáticas, Lengua y EF. Covariables: Edad, nivel socioeducativo de las familias mediante los estudios de la madre e IMC.	Student's t-test para muestras independientes en variables continuas, y $\chi 2$ para las categóricas. Regresión logística binaria y ANCOVA controlando por covariables. Rendimiento diagnóstico con curvas ROC, Areas bajo la curva y puntos de corte para predecir alto o bajo rendimiento académico en función de cada test de condición física analizado.

VI. Association between different components of physical fitness and academic performance in adolescents, taking into account the social-educational status and fatness.	Transversal.	1164 adolescentes (chicas = 602).	El nombre de cada participante fue codificado. La cumplimentación de los test físicos se llevó a cabo durante las clases de EF. Se solicitó a los centros educativos la calificación numérica en Matemáticas, Lengua y EF.	Condición física (cardiorrespiratria, velocidad-agilidad y fuerza), medida con la batería ALPHA-Fitness®. RA en Matemáticas, Lengua y EF. Covariables: Sexo, edad, nivel educativo de las madres, y tipo de población (rural o urbana).	ANOVA de un factor para variables continuas y $\chi 2$ para variables categóricas. Regresión lineal ajustada por las diferentes covariables (en diferentes pasos).
VII. The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school.	Estudio cuantitativo aleatorizado.	184 adolescentes de 12–16 años (chicas = 86).	GC (n = 94) que llevó a cabo estiramientos estáticos, y GE (n = 90) que realizó 16 minutos de C-HIIT al comienzo de las clases de EF (dos días/semana), durante 12 semanas. Para controlar la intensidad, se usó un sistema de monitorización grupal de la frecuencia cardíaca: Seego Realtracksystems® (Spain). Cada participante debía mantener la intensidad por encima del 85% de su FCmax (rango≈165-185 ppm) durante al menos el 80% de los 16 minutos de cada sesión.	C-HIIT Creatividad (test CREA) Inteligencia emocional (TEIQue-SF): Factor 1: Bienestar Factor 2: auto-control Factor 3: Emocionabilidad Factor 4: Sociabilidad Covariables: Edad e IMC.	Student's t-test para muestras independientes en variables continuas, y $\chi 2$ test para categóricas. Correlación de spearman. ANCOVA de medidas repetidas [dos tiempo (pre, post)] x [dos grupo (GC, GE)] x [dos Nivel de AF (inactivos, activos)]. Inactivos (< 5 días/semana realizando al menos 1h de MVPA) Activos (≥5 días/semana de MVPA). Análisis post-hoc se ajustó por Bonferroni. Tamaño del efecto con la d de Cohen.
VIII. 24 sessions of Monitored Cooperative High-Intensity	Estudio cuantitativo aleatorizado.	184 adolescentes de 12–16 años (chicas = 86).	GC (n = 94) que llevó a cabo estiramientos estáticos, y GE (n = 90) que realizó 16 minutos de C-HIIT al comienzo de las	C-HIIT Memoria Atención. Concentración	Student's t-test para muestras independientes en variables continuas, y $\chi 2$ test para categóricas. Correlación de

Interval Training Improves Attention-Concentration and Mathematical Calculation in Secondary School.		clases de EF (dos días/semana), durante 12 semanas. Para controlar la intensidad del ejercicio, se usó un sistema de monitorización grupal de la frecuencia cardíaca: Seego Realtracksystems® (Spain).	Cálculo matemático Razonamiento lingüístico Covariables: Edad, IMC, y los valores pre de las variables dependientes en las que había diferencias previas.	spearman. ANCOVA de medidas repetidas [dos tiempo (pre, post)] x [dos grupo (GC, GE)] x [dos Nivel de AF (inactivos, activos)]. Análisis post-hoc se ajustó por Bonferroni. Tamaño del efecto con la d de Cohen.

AF: Actividad física. EF: Educación Física. IMC: Índice de masa corporal. RA: Rendimiento académico. ANCOVA: Análisis de covarianza. ROC: Receiver Operating Characteristic. GC: Grupo control. GE: Grupo experimental. C-HIIT: entrenamiento interválico de alta intensidad cooperativo. FCmax: Frecuencia cardíaca máxima. Ppm: Pulsaciones por minuto. MVPA: Actividad física de moderada a vigorosa.

MATERIAL AND METHODS

Material and methods section is summarised in the next table (Table 1), including the more important information of every paper that takes part of this PhD Thesis:

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

Paper	Design	Participants	Procedure	Variables	Statistical analysis
I. Influence of level of attraction to physical activity on academic performance of adolescents.	Cross-sectional	A total of 1009 high school students (579 girls).	The name of each participant was coded. The questionnaire and the measurements of weight and height were carried out during PE classes. The schools were asked for the numerical grade in Math, Language and PE (second quarter).	Attraction to PA (Rose et al., 2009): Factor 1: enjoy with PA and sports. Factor 2: enjoy with PA. Factor 3: enjoy with vigorous PA. Factor 4: importance of PA. AP in Math, Language and PE. Confounders: Age and BMI	Independent linear regression analysis for boys and girls, and separately for each subject, and adjusted for age and BMI. To study if adolescents with low vs. high attraction to PA (response = 1-3 vs. response = 4-5) had also better AP, ANCOVA analyses were used with age and BMI as confounders.
II. Influence of active commuting on happiness, well-being, psychological distressand body shape in adolescents.	Cross-sectional	A total of 1012 high school students (582 girls).	The name of each participant was coded. The questionnaires and the measurements of weight and height were carried out during PE classes. Participants were classified as inactive (≤15 minutes per day of active displacement) and active (> 15 minutes per day).	Questionnaire on active commuting. Subjective Happiness Scale. Wellbeing and psychological distress (General Well-Being): Factor 1: Psychological well-being Factor 2: Psychological distress. Body image (Body Shape Questionnaire, BSQ-49). Confounders: Age, BMI, sex, maternal education level.	Linear regression and ANCOVA analyses were performed to study the association of active commuting time to go to the educational center (categories: inactive vs. active) with psychological well-being variables, adjusting for age, BMI and sex. The analyses were repeated including in the model the maternal education level.
III. Active commuting to school influences on academic performance of Spanish adolescent girls.	Cross-sectional	A total of 1006 high school students (578 girls).	The questionnaires and weight and height measurements were completed during PE classes. The Centers were asked for the marks in Math, Language and PE. The adolescents were classified as inactive (they used motorized transport or performed <5 travels/week walking for more than 15 minutes), and active (they performed ≥ five travels/week	Questionnaire on active commuting. AP in Math, Language and PE. Confounders: Age and BMI. Linear regression and ANCOVA analyses were performed, adjusted for age and BMI.	The independent variable was the number of weekly travel walking for > 15 minutes. They were classified as inactive and active. The values ranged from 0 to 10 travels. The amount of 15 minutes was taken based on what was established in previous studies (Martínez-Gómez et al., 2011).

			walking more than 15 minutes).		
IV. Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015.	Systematic review. Structure based on other previous reviews and the PRISMA guide.	21 studies were included in the review. 10 were transverse, 4 longitudinal with cohorts, 1 was transversal and longitudinal with cohorts, and 6 were intervention.	4 databases were reviewed, from January 2005 to January 2015 (PubMed, SportDiscus, Web of Science, and ProQuest). Additionally, the references of the selected articles were reviewed.	The search in the previous databases was carried out using the following terms: (1) Physical fitness (physical education, physical fitness, cardiovascular, aerobic, musculoskeletal, strength, speed, agility, ability, coordination, flexibility). (2) Academic performance (cognitive performance, academic performance, academic attainment, academic achievement, academic outcomes). (3) Adolescent (adolescent, teenagers, children, childhood).	Percentages and frequencies.
V. Associations of physical fitness with academic performance in teenagers.	Cross-sectional	2272 adolescents (girls = 1117).	The name of each participant was coded. The assessment of physical fitness tests was carried out during PE classes. The schools were asked for the numerical marks in Math, Language and PE. The AP was recoded as low (<7 points), and high (≥7 points).	Physical fitness (cardiorespiratory capacity, speed-agility and muscular strength), measured with the ALPHA-Fitness® battery. AP in Math, Language and PE. Confounders: Age, socio-educational level of families through the maternal education level and BMI.	Student's t-test for independent samples in continuous variables, and χ^2 for categorical variables. Binary logistic regression and ANCOVA controlling by confounders. Diagnostic performance with ROC curves, areas under the curve and cut points to predict high or low AP depending on each test of physical fitness analysed.
VI. Association between different components of physical fitness and academic performance in adolescents, taking into account the social-educational status and fatness.	Cross-sectional	1164 adolescents (girls = 602).	The name of each participant was coded. The assessment of physical fitness tests was carried out during PE classes. The schools were asked for the numerical marks in Math, Language and PE.	Physical fitness (cardiorespiratory capacity, speed-agility and muscular strength), measured with the ALPHA-Fitness® battery. AP in Math, Language and PE. Confounders: Sex, age, maternal education level, and type of population (rural or urban).	One-way ANOVA for continuous variables and χ^2 for categorical variables. Linear regression adjusted for the different confounders (in different steps).

VII. The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school.	Quantitative randomized study.	184 adolescents aged 12-16 (girls = 86).	CG (n = 94) that carried out static stretching, and EG (n = 90) that performed 16 minutes of C-HIIT at the beginning of PE classes (two days/week), for 12 weeks. To control the intensity, a heart rate monitoring system was used: Seego Realtracksystems® (Spain). Each participant had to maintain the intensity above 85% of his HRmax (range≈165-185 bpm) for at least 80% of the 16 minutes of each session.	C-HIIT Creativity (CREA test) Emotional intelligence (TEIQue-SF): Factor 1: Wellness Factor 2: self-control Factor 3: Emotionality Factor 4: Sociability Confounders: Age and BMI.	Student's t-test for independent samples in continuous variables, and $\chi 2$ test for categorical variables. Spearman correlation. ANCOVA of repeated measures [two time (pre, post)] x [two group (CG, EG)] x [two Level of PA (inactive, active)]. Inactive (<5 days/week performing at least 1 h of MVPA) and actives (≥5 days/week of MVPA). Post-hoc analysis was adjusted by Bonferroni. Effect size with Cohen's d.
VIII. 24 sessions of Monitored Cooperative High-Intensity Interval Training Improves Attention-Concentration and Mathematical Calculation in Secondary School.	Quantitative randomized study	184 adolescents aged 12–16 (girls = 86).	CG (n = 94) that carried out static stretching, and EG (n = 90) that performed 16 minutes of C-HIIT at the beginning of PE classes (two days/week), for 12 weeks. To control exercise intensity, a heart rate monitoring system was used: Seego Realtracksystems® (Spain).	C-HIIT Memory Attention Concentration Mathematical calculation Linguistic reasoning Confounders: Age, BMI, and the pre values of the dependent variables in which there were previous differences.	Student's t-test for independent samples in continuous variables, and $\chi 2$ test for categorical variables. Spearman correlation. ANCOVA of repeated measures [two time (pre, post)] x [two group (CG, EG)] x [two Level of PA (inactive, active)]. Post-hoc analysis was adjusted by Bonferroni. Effect size with with Cohen's d.

PA: Physical activity. PE: Physical Education. BMI: Body mass index. AP: Academic performance. ANCOVA: Analysis of covariance. ROC: Receiver Operating Characteristic. CG: Control group. EG: Experimental group. C-HIIT: cooperative high-intensity interval training. HRmax: Maximum heart rate. Bpm: Beat per minute. MVPA: Moderate to vigorous physical activity

RESULTADOS Y DISCUSIÓN

Los resultados y discusión se presentan en la forma en que han sido previamente publicados/sometidos en revistas científicas. Adicionalmente, en la siguiente tabla se ofrece un resumen de los principales resultados obtenidos en cada uno de los estudios realizados (Tabla 2):

Tabla 2. Resumen de los resultados obtenidos en los diferentes artículos que componen la presente Tesis.

Artículo	Resultados
I. Influence of level of attraction to physical activity on academic performance of adolescents.	Los resultados muestran que los chicos tienen una mayor atracción hacia la AF que las chicas, y que en ambos sexos todos los factores de atracción hacia la AF están asociados positivamente con mejores calificaciones en la asignatura de EF. Los análisis mostraron que el disfrute con la AF vigorosa es el principal factor de atracción que se relaciona, en chicas, con mejores calificaciones en Matemáticas y Lengua. En chicos, el disfrute con juegos y deportes, y con la práctica de AF vigorosa no influyen en su RA, sin embargo aquellos que dan más importancia al ejercicio físico obtienen peores calificaciones en Lengua y Matemáticas.
II. Influence of active commuting on happiness, well-being, psychological distressand body shape in adolescents.	El desplazamiento activo influye sobre la felicidad y el bienestar psicológico de los/las adolescentes. En concreto, emplear más de 15 minutos al día de desplazamiento activo al Centro educativo contribuye a la mejora del bienestar en la adolescencia.
III. Active commuting to school influences on academic performance of Spanish adolescent girls.	Los resultados mostraron que las chicas que realizan un mayor número de desplazamientos activos semanales de más de 15 minutos, tenían un mayor rendimiento académico en Matemáticas, en EF, y mayor RA general. En chicos, ninguna asociación resultó significativa. Desplazarse al instituto andando, al menos cinco trayectos semanales de más de 15 minutos, se relaciona con mayores calificaciones en Matemáticas en las chicas adolescentes.
IV. Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015.	Ocho estudios mostraron asociación entre el nivel de condición física y el RC, y 11 respecto al RA. La capacidad cardiorrespiratria, velocidad-agilidad, coordinación motora, y la habilidad perceptivo-motora son las medidas de condición física mayormente asociadas con RC y RA. Sin embargo, los hallazgos con respecto a la fuerza y flexibilidad no son claros. Finalmente, el 62% de los estudios analizados usaron covariables. Las más usadas fueron el nivel socioeconómico, el fatness, el estado puberal, el sexo, y la edad.
V. Associations of physical fitness with academic performance in teenagers.	Chicos y chicas por encima de 3.60 y 6.25 paliers en el test de capacidad cardiorrespiratoria (Course Navette), respectivamente, mostraron una mayor probabilidad de obtener un alto RA (≥7 puntos) en Matemáticas + Lengua (OR=1.715 y 2.441, respectivamente). Solo las chicas con una puntuación por debajo de 12.67 segundos en el test de velocidad-agilidad, tuvieron una probabilidad 1.45 veces mayor de conseguir mejor RA (≥7 puntos) en Matemáticas + Lengua (OR=0.682). Finalmente, solo las chicas con una fuerza de salto horizontal mayor a 123cm tuvieron una mayor probabilidad de conseguir alto RA (≥7 puntos) en Matemáticas+Lengua (OR=2.129). Por tanto, las chicas con alta condición física cardiorrespiratoria, velocidad-agilidad, y fuerza de salto; así como los chicos con mayor capacidad cardiorrespiratoria, mostraron mejor RA tras tener en cuenta las covariables edad, estudios de la madre, e IMC.
VI. Association between different components of physical fitness and academic performance in adolescents, taking into account the social-	La capacidad aeróbica se asoció con el RA, tras ajustar por sexo, edad, población, y nivel educativo de la madre. La habilidad motora se asoció con todas las variables de RA, excepto con Lengua. Estas asociaciones se mantuvieron e incluso aumentaron tras ajustar por fatness, sobre todo por el porcentaje de grasa corporal.

educational status and fatness.	
VII. The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school.	El GE incrementó significativamente la puntuación en los factores de bienestar y sociabilidad tras el programa C-HIIT. Más específicamente, los adolescentes inactivos (< 5 días/semana realizando al menos 1h de MVPA) del GE mostraron mejoras significativas en comparación con el GC en creatividad, bienestar y sociabilidad. Sin embargo, no encontramos cambios en los adolescentes físicamente activos (≥5 días/semana de MVPA).
VIII. 24 sessions of Monitored Cooperative High-Intensity Interval Training Improves Attention-Concentration and Mathematical Calculation in Secondary School.	El GE aumentó en un 14.2% la atención selectiva, un 8.41% la concentración, y un 15.5% el cálculo matemático con resecto al GC tras un programa C-HIIT de 12 semanas de duración. Estas mejoras son especialmente significativas en los participantes inactivos. Sin embargo, no se obtuvieron diferencias en las variables de memoria y de razonamiento lingüístico.

AF: Actividad física. EF: Educación Física. IMC: Índice de masa corporal. RA: Rendimiento académico. RC: Rendimiento cognitivo. GC: Grupo control. GE: Grupo experimental. OR: odds ratio. C-HIIT: entrenamiento interválico de alta intensidad cooperativo. MVPA: Actividad física de moderada a vigorosa.

RESULTS AND DISCUSSION

The results and discussion are presented in the same way that have been previously published or submitted to scientific journals. Additionally, the main results of every paper are presented in the next table (Table 2).

Table 2. Summary table of the results obtained in the current Thesis.

Paper	Results
I. Influence of level of attraction to physical activity on academic performance of adolescents.	The results show that boys have a greater attraction to PA than girls, and that in both sexes all the factors of attraction to PA are positively associated with better grades in PE. The analyses showed that the enjoyment with vigorous PA is the main factor of attraction that is related, in girls, with better grades in Math and Language. In boys, the enjoyment with games and sports, and the practice of vigorous PA do not influence their AP, however those who give more importance to physical exercise get worse grades in Language and Math.
II. Influence of active commuting on happiness, well-being, psychological distress and body shape in adolescents.	Active commuting influences the happiness and psychological well-being of adolescents. To perform more than 15 minutes per day of active commuting to the educational center contributes to the improvement of psychological health in adolescence.
III. Active commuting to school influences on academic performance of Spanish adolescent girls.	The results showed that girls who perform a greater number of weekly active travels of more than 15 minutes, had a higher AP in Math, in PE, and higher overall AP. In boys, no association was significant. Commuting to educational center by walking, at least five weekly active travels of more than 15 minutes, is related to higher scores in Math in adolescent girls.
IV. Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015.	Eight studies showed an association between fitness level and CP, and 11 with regard to AP. Cardiorespiratory capacity, speed-agility, motor coordination, and perceptual-motor ability are the measures of physical fitness mostly associated with CP and AP. However, the findings regarding strength and flexibility are not clear. Finally, 62% of the studies analyzed used confounders. The most used were socioeconomic status, fatness, pubertal status, sex, and age.
V. Associations of physical fitness with academic performance in teenagers.	Boys and girls over 3.60 and 6.25 paliers in the cardiorespiratory fitness test (Course Navette), respectively, showed a higher probability of obtaining a high AP (≥7 points) in Math + Language (OR = 1.715 and 2.441, respectively). Only girls with a score below 12.67 seconds in the speed-agility test had a 1.45 times higher probability of getting better AP (≥7 points) in Math + Language (OR = 0.682). Finally, only girls with a standing long jump test greater than 123cm had a higher probability of achieving high AP (≥7 points) in Math + Language (OR = 2.129). Therefore, girls with high cardiorespiratory fitness, speed-agility, and muscular strength; as well as the boys with greater cardiorespiratory capacity, showed better AP after taking into account the confounders age, maternal education level, and BMI.
VI. Association between different components of physical fitness and academic performance in adolescents, taking into account the social-educational status and fatness.	Cardiorespiratory capacity was positively associated with AP, after adjusting for sex, age, population, and maternal education level. Motor ability was associated with all AP variables, except with Language. These associations were maintained and even increased after adjusting for fatness, especially due to the percentage of body fat.
VII. The effect of cooperative high-intensity interval training on creativity and emotional	The EG significantly increased the score on the well-being and sociability factors after the C-HIIT program. More specifically, inactive adolescents (<5 days/week performing at least 1h of MVPA) from the EG showed significant

intelligence in secondary school.	improvements in creativity, well-being and sociability, compared to CG. However, we did not find changes in physically active adolescents (≥5 days/week of MVPA).
VIII. 24 sessions of Monitored Cooperative High-Intensity Interval Training Improves Attention-Concentration and Mathematical Calculation in Secondary School.	The EG increased selective attention by 14.2%, concentration by 8.41%, and mathematical calculation by 15.5% with regard to CG after a 12-week C-HIIT program. These improvements are especially significant in inactive participants. However, no differences were found in memory and linguistic reasoning.

PA: Physical activity. PE: Physical Education. CP: Cognitive performance. AP: Academic performance. BMI: Body mass index CG: Control group. EG: Experimental group. OR: odds ratio. C-HIIT: Cooperative high intensity interval training. MVPA: Moderate to vigorous physical activity.

I

Influence of level of attraction to physical activity on academic performance of adolescents

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ORIGINAL

Influencia del nivel de atracción hacia la actividad física en el rendimiento académico de los adolescentes

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PALABRAS CLAVE
Matemáticas;
Lengua;
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Actividad física;
Rendimiento académico;
Educación secundaria

Resumen El objetivo fue conocer el nivel de atracción hacia la actividad física y el rendimiento académico, así como la asociación entre dicha atracción y las calificaciones en las asignaturas de Matemáticas, Lengua y Educación Física en función del sexo, tras ajustar por edad e índice de masa corporal, en una muestra de 1009 adolescentes españoles (n chicas = 579) entre 12-18 años. Se usó el *Children's Attraction to Physical Activity Questionnaire* y la calificación de las asignaturas. Los análisis mostraron que el disfrute con la actividad física vigorosa es el principal factor de atracción que se relaciona, en chicas, con mejores calificaciones en Matemáticas y Lengua. En chicos, el disfrute con juegos y deportes, y con la práctica de actividad física vigorosa no influyen en su rendimiento académico, sin embargo aquellos que dan más importancia al ejercicio físico obtienen peores calificaciones en Lengua y Matemáticas. Se sugiere, por tanto, que a la conocida relación entre actividad física y rendimiento académico es necesario añadir que los factores de la atracción hacia la actividad física pueden relacionarse en buena medida con diferentes resultados de rendimiento académico en función del sexo.

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KEYWORDS
Maths;
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Influence of level of attraction to physical activity on academic performance of adolescents

Abstract The aim of this study was to examine the relationship between student level of attraction to physical activity and academic performance, and the association between attraction to physical activity and grades in the subjects of Maths, Spanish Language, and Physical Education according to gender, after adjusting for age and body mass index, in a sample of Spanish adolescents. The study included 1009 12-18 year-old students (579 girls).t. The Children's Attraction to Physical Activity questionnaire and numeric marks in the subjects were used. Analyses showed that enjoyment with vigorous physical activity is the main attraction factor related to higher grades in Maths and Spanish Language among girls. Among boys, enjoyment of games and sports, and vigorous physical activity is observed to have no impact on academic performance. However, lower grades were observed in Maths and Spanish Language among boys who give great importance to physical activity. Therefore, it is suggested that the well-known physical activity-academic performance relationship must take into account physical activity-attraction factors, as they may well have some impact on academic performance according to gender.

La práctica frecuente de actividad física (AF) es un hábito fundamental para el mantenimiento de las funciones vitales y forma parte esencial del bienestar físico y de un estilo de vida saludable (Bagby & Adams, 2007; Fogel, Raymond, Miltenberger & Koehler, 2010). La AF en jóvenes se asocia con incrementos de la capacidad antioxidante de la sangre (Carlsohn, Rohn, Mayer & Schweigert, 2010), mayor mineralización del hueso (Pitukcheewanont, Punyasavatsut & Feuille, 2010) y mejora de la autoestima (Biddle & Asare, 2011), además es un importante predictor de la morbimortalidad por todas las causas en los adultos (Kodama et al., 2009).

Aunque en menor medida, también se han hallado asociaciones entre la práctica continuada de AF y parámetros relacionados con la capacidad cognitiva del niño, debido al incremento de los niveles del factor neurotrófico derivado del cerebro que ayuda a la supervivencia de las neuronas y fomenta su crecimiento (Ardoy et al., 2014, Noakes & Spedding, 2012). Además, la AF mejora la plasticidad sináptica y actúa como un agente neuroprotector ya que aumenta la circulación sanguínea cerebral y mejora la función neuroeléctrica (Hillman, Erickson & Kramer, 2008). Como consecuencia de esas adaptaciones fisiológicas, se produce una mayor atención selectiva, una inhibición de respuestas inapropiadas, mayor flexibilidad en el pensamiento y una mejor capacidad de mantenimiento de información en la memoria que pueden contribuir a una mejora del rendimiento académico (RA) (Chaddock et al., 2012).

El RA hace referencia al éxito de un alumno en el centro educativo, medido por el promedio de calificaciones o a través de test estandarizados de rendimiento (Diamond, 2013). También se ha comprobado que el rendimiento puede estar mediatizado por el bienestar emocional (Jiménez-Morales & López-Zafra, 2009), la autopercepción de competencia y el establecimiento de metas, así como por el uso de estrategias y actividades relacionadas con el estudio por parte de los alumnos (Caso-Niebla & Hernández-Guzmán, 2007). Según el reciente Informe PISA, llevado a cabo durante el año 2012 (Ministerio de Educación, Cultura y Deporte, 2013), los adolescentes españoles se encuentran por debajo de la media de la Organización para la Cooperación y el Desarrollo Económico (OCDE) respecto a los resultados de RA. Dentro de España, Andalucía es una de las comunidades autónomas con índices de RA más bajos, junto a Murcia, Extremadura o Baleares. Algunos autores han formulado propuestas que implican la necesidad de una mayor estimulación cognitiva durante la adolescencia debido a que aún se mantiene un alto grado de plasticidad cerebral, considerada imprescindible para lograr aprendizajes significativos (Martínez-Gómez et al., 2011). Una forma de estimular la función cognitiva es a través de la práctica habitual de AF (Ardoy et al., 2014).

Se ha comprobado que el aumento de la fuerza muscular, de la capacidad aeróbica y la cantidad de AF semanal se relacionan con una mayor competencia cognitiva tanto en niños como en adolescentes (Bass, Brown, Laurson & Coleman, 2013; Chaddock et al., 2012; Coe, Pivarnik, Womack, Reeves & Malina, 2006; Haapala, 2013; So, 2012; St-Louis-Deschênes & Ellemberg, 2013). Sin embargo, esta asociación no es siempre significativa (Daley & Ryan, 2000), hallándose también resultados similares de rendimiento cognitivo en alumnos con distinto nivel de condición física (Ruiz et al., 2010). También en el contexto educativo los resultados son contradictorios. Mientras hay quien defiende que el incremento de la frecuencia semanal de clases de Educación Física (EF) no afecta al RA en Matemáticas y Lengua (Ahamed et al., 2007), otras investigaciones apuntan a que tanto la frecuencia como la intensidad de las clases de EF están asociadas con el rendimiento cognitivo del alumnado (Ardoy et al., 2014; Ericsson, 2008). A pesar de los beneficios descritos, estudios recientes demuestran que la práctica de AF ha sufrido un descenso progresivo en los jóvenes españoles especialmente entre los 12 y 18 años

(Chillón et al., 2009; Pavón & Moreno, 2008). Esta disminución parece estar motivada por una falta de atracción hacia la AF, que ha quedado eclipsada de forma creciente por hábitos sedentarios relacionados principalmente con el consumo de TV y videojuegos (Cantón, Mayor & Pallarés, 1995; Moreno, Cervelló & Martínez, 2007; Pavón & Moreno, 2008).

La atracción hacia la AF se ha definido como la intención o deseo de una persona por involucrarse en la realización de tareas que impliquen esfuerzo físico o movimiento de cierta intensidad a través de juegos o deportes (Rose, Larkin, Hands, Howard & Parker, 2009). Algunos autores han revelado que los chicos tienen más atracción hacia la AF y la practican durante mayor tiempo que las chicas, y como consecuencia, dan más importancia al ejercicio físico (Martínez-Baena et al., 2012; Ruiz & Sherman, 2005). Sin embargo, otros estudios no hallaron diferencias entre sexos y mostraron que chicos y chicas obtenían resultados similares en el disfrute con los juegos y deportes, con la AF y con la AF vigorosa (Brustad, 1993, 1996). Lo anterior es especialmente relevante debido a que las experiencias de AF vividas durante la infancia constituyen la base para la atracción hacia la AF durante la adolescencia e influyen para ser físicamente activo en la edad adulta (Rose et al., 2009; Thompson, Humbert & Mirwaldit, 2003).

Aunque los principales motivos que determinan la práctica habitual de AF son el disfrute, la salud y las relaciones sociales (Frederick-Recascino & Schuster-Smith, 2003; Moreno et al., 2007), la atracción hacia la AF es considerada un factor determinante, ya que incita a acrecentar la práctica físico-deportiva y a que se mantenga en el tiempo, y genera una adherencia hacia su práctica (Cantón et al., 1995). Conocer el nivel de atracción hacia la AF de los adolescentes españoles es, por tanto, un aspecto a tener en cuenta en la educación, ya que podría reconducir los niveles de práctica de AF, estimular su función cognitiva y contribuir a un mayor incremento del RA en los adolescentes.

Las calificaciones de las asignaturas de Matemáticas, Lengua —como asignaturas cognitivas— y EF —como referente de la actitud del niño hacia la AF— son un fiel reflejo del RA general del niño (Diamond, 2013). Aunque se ha constatado una relación entre la AF y el RA, no hemos hallado estudios científicos que asocien directamente la atracción hacia la AF —como estimulante para el mantenimiento de la práctica habitual de la AF— y el RA en adolescentes, así como las posibles diferencias entre jóvenes de diferente sexo. Por tanto, el objetivo del presente estudio fue conocer el nivel de atracción hacia la AF y de RA, así como la asociación entre dicha atracción y las calificaciones en las asignaturas de Matemáticas, Lengua y EF en función del sexo, tras ajustar por edad e índice de masa corporal (IMC), en una muestra de adolescentes españoles.

Método

Participantes

Un total de 1009 alumnos de educación secundaria de entre 12 y 18 años (57.4% chicas) pertenecientes a 6 institutos de la provincia de Jaén (Andalucía, España) participaron en el presente estudio observacional (transversal). Tres centros estaban ubicados en zona rural y 3 en zona urbana, con menos de 10000 habitantes, y más de 10000 habitantes respectivamente (Camarero, 2009). La muestra fue de conveniencia.

Todos los adolescentes de los centros fueron invitados a participar en el estudio. La participación fue del 92%, de un total de 1085 estudiantes. La muestra se redujo a 1009, ya que hubo adolescentes que no obtuvieron el consentimiento informado de los padres o no rellenaron correctamente el cuestionario. Las características sociométricas, nivel de atracción hacia la AF, y RA se presentan en la tabla 1.

Tabla 1 Características sociométricas, nivel de atracción hacia la actividad física (escala: 1-5) y rendimiento académico por sexo de los participantes (escala: 1-10 puntos)

	Todos (n = 1009)		Chicos (n = 430)		Chicas (n = 579)		*p*
	Media	*DT*	Media	*DT*	Media	*DT*	
Edad	14.53	1.64	14.58	1.66	14.49	1.62	.369
Peso (kg)	57.89	12.64	62.28	14.38	54.62	10.00	**< .001**
Talla (m)	1.65	.09	1.69	.09	1.61	.07	**< .001**
IMC (kg/m^2)	21.18	3.52	21.52	3.89	20.92	3.20	**< .01**
Atracción hacia la actividad física (cuestionario Children's Attraction to Physical Activity Questionnaire *[CAPA])*							
F1. Disfrute con juegos y deportes	4.06	.91	4.29	.83	3.88	.94	**< .001**
F2. Disfrute con la AF	4.17	.76	4.28	.72	4.09	.78	**< .001**
F3. Disfrute con la AF vigorosa	3.73	.93	4.04	.79	3.50	.95	**< .001**
F4. Importancia del ejercicio físico	3.87	.87	4.15	.79	3.65	.86	**< .001**
Total: (F1 + F2 + F3 + F4)/4	3.96	.79	4.19	.70	3.78	.80	**< .001**
Rendimiento académico (RA)							
RA en Matemáticas	6.14	2.19	6.02	2.26	6.23	2.13	.124
RA en Lengua	6.41	1.99	6.01	2.04	6.70	1.91	**< .001**
RA en Educación Física	7.52	1.44	7.60	1.39	7.47	1.47	.170

Las cifras resaltadas en negrita significan que son estadísticamente significativas.

Instrumentos

Para conocer el nivel de atracción hacia la AF se empleó la adaptación realizada por Rose et al. (2009) del *Children's Attraction to Physical Activity Questionnaire (CAPA)* (Brustad, 1993, 1996). Para este estudio se empleó la versión de 4 dimensiones que incluía solo 18 ítems de los 25 originales después de dejar excluidos los ítems negativos (versión recomendada por Rose et al., 2009). La estructura factorial es la siguiente: factor 1: disfrute con la AF y deportes (4 ítems, p. ej. «desearía poder practicar más juegos y deportes»); factor 2: disfrute con la AF (5 ítems, p. ej. «disfruto con la práctica de ejercicio físico»); factor 3: disfrute con la AF vigorosa (5 ítems, p.ej. «creo que me sentiré realmente bien después de una práctica deportiva intensa»); y factor 4: importancia del ejercicio físico (4 ítems, p.ej. «creo que es muy importante mantener una buena forma física»).

Las respuestas se puntúan mediante una escala tipo Likert cuyos valores oscilan desde 1 *(nunca)* hasta 5 *(siempre)*. Los índices de fiabilidad obtenidos en cada una de las dimensiones por medio del estadístico α de Cronbach fueron: factor 1 = .89, factor 2 = .81, factor 3 = .80, y factor 4 = .69. (α total = .940). Para obtener las medidas de peso y altura se empleó báscula digital ASIMED modelo Elegant tipo B –clase III–, y tallímetro portátil SECA 214 respectivamente. Las medidas de peso permitieron una discriminación de hasta 50 g, y de hasta 1 mm las de altura. Ambas medidas se realizaron descalzo y con ropa ligera.

Procedimiento

Una descripción verbal y escrita de la naturaleza y el propósito del estudio fue dada a los adolescentes, padres, y tutores legales, los cuales dieron su consentimiento. Se contó también con la autorización de los directores de los centros y profesores de EF. El nombre de cada alumno participante fue codificado para asegurar el anonimato y confidencialidad. Cada alumno completó el cuestionario CAPA sobre atracción hacia la AF y una ficha informativa de características sociodemográficas.

La cumplimentación del cuestionario y las medidas de peso y talla se llevaron a cabo durante las clases de EF con la supervisión de los investigadores. Para conocer el RA de los adolescentes se solicitó a los centros educativos la calificación numérica en Matemáticas, Lengua y EF de la evaluación trimestral previa a la cumplimentación del cuestionario (segundo trimestre). El estudio fue aprobado por la Comisión de Bioética de la Universidad de Jaén. En el diseño se han tenido en cuenta la normativa legal vigente española que regula la investigación clínica en humanos (Real Decreto 561/1993 sobre ensayos clínicos), así como los principios fundamentales establecidos en la Declaración de Helsinki (revisión de 2008).

Análisis de datos

Los parámetros se muestran como media, desviación típica y error estándar. Para la comparación de edad, peso, talla, IMC, factores del cuestionario CAPA, y calificaciones en Matemáticas, Lengua y EF con el sexo (masculino, femenino) se empleó la prueba *T* de *Student* para muestras independientes. Se realizaron análisis de regresión lineal para estudiar la asociación entre la atracción general hacia la AF –promedio de factores– y cada factor del cuestionario CAPA con el RA en Matemáticas, Lengua, y EF, de forma independiente para chicos y chicas. Los análisis se realizaron separadamente para cada asignatura y se ajustaron (covariables) por edad e IMC. Se usa el IMC por las evidencias de su relación con respecto al RA (Sardinha, Marques, Martins, Palmeira & Minderico, 2014). Para estudiar si los adolescentes con baja vs. alta atracción hacia la AF (respuesta = 1-3 vs. respuesta = 4-5) tenían también mejor RA se realizaron 3 análisis de covarianza (ANCOVA). Se introdujo la atracción general hacia la AF como factor fijo, las calificaciones de Matemáticas, Lengua y EF como variables dependientes, y la edad e IMC como covariables. Para todos los resultados se empleó un nivel de confianza del 95% ($p < .05$). Todos los cálculos se realizaron con el programa estadístico SPSS, v. 19.0 para WINDOWS (SPSS Inc., Chicago, EE. UU.).

Resultados

Los resultados de las variables de estudio diferenciadas por sexo (véase tabla 1) mostraron que los chicos tenían una mayor atracción hacia la AF que las chicas en los 4 factores (todos $p < .001$). Las chicas tenían un mejor RA en Lengua ($p < .001$); sin embargo, los resultados académicos en las asignaturas de Matemáticas y EF eran similares en chicos y chicas ($p > .05$).

Análisis de regresión lineal

Los resultados del análisis de regresión lineal que muestra la asociación entre la atracción general hacia la AF –promedio de factores– y cada factor del cuestionario CAPA, con la calificación en Matemáticas se presentan en la tabla 2. Los chicos que tenían una mayor atracción general hacia la AF obtuvieron calificaciones más bajas en Matemáticas ($\beta = -.318 \pm .150$; $r = -.099$, $p = .035$). El disfrute con la AF vigorosa se asociaba positivamente con la calificación de Matemáticas en chicas ($\beta = .264 \pm .092$; $r = .118$, $p = .004$), mientras que en chicos, aquellos que daban una mayor importancia al ejercicio físico tenían peores calificaciones ($\beta = -.319 \pm .134$, $r = -.112$, $p = .018$). Se observó también que la edad se asociaba negativamente con la calificación de Matemáticas tanto en chicos como en chicas, esto es, a mayor edad menor calificación en Matemáticas ($p < .001$). El IMC no se asociaba significativamente con la calificación de Matemáticas de los adolescentes estudiados.

Los resultados del análisis de regresión lineal que muestra la asociación entre la atracción general hacia la AF –promedio de factores– y cada factor del cuestionario CAPA con la calificación en Lengua se presentan en la tabla 3. Las chicas que tenían una mayor atracción general hacia la AF tenían significativamente mejores calificaciones en Lengua ($\beta = .298 \pm .099$; $r = .125$, $p = .003$), sin embargo, en chicos no se halló asociación entre la atracción general hacia la AF y las calificaciones en dicha materia. De una forma más específica, el disfrute con juegos y deportes ($\beta = .251 \pm .085$; $r = .123$, $p = .003$), el disfrute con la AF ($\beta = .305 \pm .101$; $r = .124$, $p = .003$), y el disfrute con

Tabla 2 Asociación entre atracción general hacia la actividad física −promedio de factores− y cada factor del cuestionario CAPA con la calificación en Matemáticas tras ajustar por edad e IMC

	Matemáticas							
	Chicos (430)				Chicas (579)			
	β	EE	*r*	*p*	β	*EE*	*r*	*p*
Edad	−.321	.067	−.235	< .001	−.217	.056	−.165	< .001
IMC	−.006	.028	−.010	.845	−.034	.028	−.051	.222
Disfrute con juegos y deportes	−.201	.128	−.074	.117	.167	.095	.073	.079
Edad	−.326	.067	−.239	< .001	−.225	.055	−.171	< .001
IMC	−.005	.028	−.008	.868	−.033	.028	−.050	.230
Disfrute con la AF	−.269	.148	−.086	.069	.173	.113	.063	.126
Edad	−.315	.067	−.231	< .001	−.216	.055	−.164	< .001
IMC	.001	.028	.001	.984	−.042	.028	−.062	.134
Disfrute con la AF vigorosa	−.248	.134	−.087	.065	.264	.092	.118	**.004**
Edad	.326	.067	−.239	< .001	−.227	.055	−.173	< .001
IMC	.008	.028	−.014	.772	−.032	.028	−.048	.245
Importancia del ejercicio físico	−.319	.134	−.112	**.018**	.105	.102	.043	.305
Edad	−.322	.067	−.237	< .001	−.217	.055	−.165	< .001
IMC	−.005	.028	−.008	.868	−.035	.028	−.053	.205
Atracción general hacia la AF	−.318	.150	−.099	**.035**	.183	.110	.084	.064

AF: actividad física; CAPA: *Children's Attraction to Physical Activity Questionnaire*; EE: error estándar; IMC: índice de masa corporal (kg/m^2).
En negrita p < .05 para factores de CAPA.

Tabla 3 Asociación entre atracción general hacia la actividad física −promedio de factores− y cada factor del cuestionario CAPA con la calificación en Lengua tras ajustar por edad e IMC

	Lengua							
	Chicos (430)				Chicas (579)			
	β	*EE*	*r*	*p*	β	*EE*	*r*	*p*
Edad	−.172	.061	−.140	.005	−.136	.050	−.115	.007
IMC	−.030	.026	−.057	.252	−.029	.025	−.048	.252
Disfrute con juegos y deportes	−.121	.118	−.049	.306	.251	.085	.123	**.003**
Edad	−.175	.061	−.142	.005	−.145	.049	−.123	.004
IMC	−.029	.026	−.056	.259	−.028	.025	−.047	.261
Disfrute con la AF	−.166	.136	−.059	.221	.305	.101	.124	**.003**
Edad	−.168	.061	−.137	.006	−.145	.049	−.124	.003
IMC	−.026	.026	−.050	.316	−.035	.025	−.059	.162
Disfrute con la AF vigorosa	−.157	.123	−.061	.203	.251	.083	.125	.003
Edad	−.177	.061	−.144	.004	−.149	.050	−.127	.003
IMC	−.033	.026	−.064	.200	−.026	.025	−.044	.294
Importancia del ejercicio físico	−.299	.123	−.116	**.015**	.172	.092	.078	.063
Edad	−.173	.061	−.141	.005	−.139	.050	−.118	.005
IMC	−.030	.026	−.057	.255	−.030	.025	−.050	.228
Atracción general hacia la AF	−.228	.138	−.079	.099	.298	.099	.125	**.003**

AF: actividad física; CAPA: *Children's Attraction to Physical Activity Questionnaire*; EE: error estándar; IMC: índice de masa corporal (kg/m^2).
En negrita p < .05 para factores de CAPA.

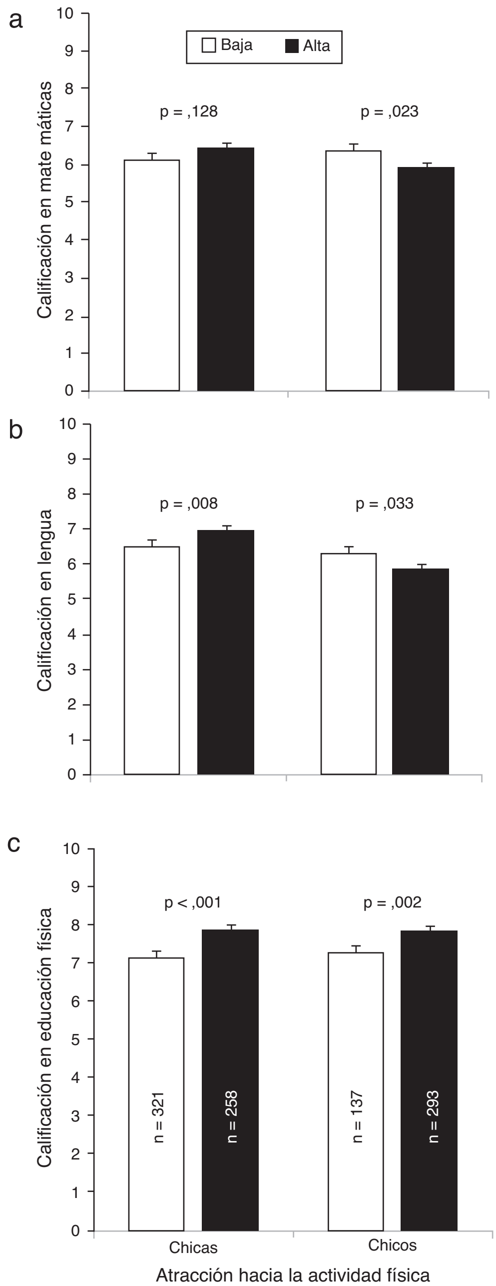

Figura 1 Asociación de la atracción hacia la actividad física con resultados de la calificación en las asignaturas de Matemáticas (a), Lengua (b) y Educación Física (c). Se introdujo la atracción general hacia la AF (baja vs. alta) como factor fijo y las calificaciones de Matemáticas, Lengua y EF como variables dependientes, y la edad e IMC como covariables.

la AF vigorosa ($\beta = .251 \pm .083$; $r = .125$, $p = .003$), se asociaban positivamente con la calificación de Lengua en chicas, mientras que en chicos, aquellos que daban una mayor importancia al ejercicio físico tenían menores calificaciones ($\beta = -.299 \pm .123$, $r = -.116$, $p = .015$). Se observó también que la edad se asociaba negativamente con la calificación de Lengua tanto en chicos como en chicas, esto es, a mayor edad menor calificación en Lengua ($p = .005$). El IMC no se asociaba significativamente con la calificación de Lengua de los adolescentes estudiados.

Los resultados del análisis de regresión lineal que muestra la asociación entre la atracción general hacia la AF –promedio de factores– y cada factor del cuestionario CAPA con la calificación en EF se presentan en la tabla 4. Las chicas y los chicos que tenían una mayor atracción general hacia la AF tenían significativamente mejores calificaciones en EF ($\beta = .483 \pm .074$; $r = .262$, $p < .001$; y $\beta = .305 \pm .093$; $r = .155$, $p = .001$, respectivamente). Tanto en chicos como en chicas los 4 factores de atracción hacia la AF se asociaban positivamente con la calificación en EF (todas las asociaciones $p < .03$). Se constató también que el IMC se asociaba negativamente con la calificación de EF tanto en chicos como en chicas, esto es, a mayor IMC menor calificación en EF ($p < .02$). La edad no se asociaba significativamente con la calificación de EF de los adolescentes estudiados ($p > .05$).

Análisis de covarianza

Los resultados del análisis ANCOVA que estudia si los adolescentes con baja atracción hacia la AF vs. alta tenían diferentes calificaciones en Matemáticas, Lengua y EF se muestran en la figura 1. En la asignatura de Matemáticas no se hallaron diferencias de notas entre las chicas con alta o baja atracción hacia la AF ($p = .128$), sin embargo, los chicos con baja atracción obtuvieron significativamente mejores calificaciones ($p = .023$, fig. 1a). En la asignatura de Lengua, chicas y chicos presentaron diferencias significativas de calificación. Mientras las chicas con una alta atracción hacia la AF obtenían mejores notas que las que mostraron baja atracción ($p = .008$), en chicos se obtuvo el efecto contrario ($p = .033$, fig. 1b). En EF, chicas y chicos con una alta atracción hacia la AF tenían calificaciones significativamente superiores ($p < .001$; $p = .002$, respectivamente, fig. 1c).

Discusión

El presente trabajo ha estudiado el nivel de atracción hacia la AF y de RA en una muestra de adolescentes españoles, así como la asociación entre dicha atracción y las calificaciones en las asignaturas de Matemáticas, Lengua y EF en función del sexo, tras ajustar por edad e IMC. Los resultados muestran que los chicos tienen una mayor atracción hacia la AF que las chicas, y que en ambos sexos todos los factores de atracción hacia la AF están asociados positivamente con mejores calificaciones en la asignatura de EF. También se ha comprobado que las chicas que disfrutan más con la AF vigorosa tienen mejores calificaciones en Matemáticas y Lengua; sin embargo, en estas mismas asignaturas, los chicos que le dan más importancia al ejercicio físico son los que presentan peores calificaciones.

Finalmente, mientras en chicas una alta atracción general hacia la AF se asocia con más alto RA en Lengua y EF, en chicos se relaciona de forma negativa con los resultados de Matemáticas y Lengua. Estas evidencias muestran que los factores de atracción hacia la AF podrían influir de forma diferente en el RA de los adolescentes, y por tanto, las medidas y recomendaciones dirigidas hacia el disfrute e interés por la práctica de AF deberían adaptarse según el sexo.

Nuestros resultados difieren con los hallados por Hagger, Cale & Almond (1997) que no encontraron diferencias entre

Tabla 4 Asociación entre atracción general hacia la actividad física –promedio de factores– y cada factor del cuestionario CAPA con la calificación en Educación Física tras ajustar por edad e IMC

	Educación Física							
	Chicos (430)				Chicas (579)			
	β	*EE*	*r*	*p*	β	*EE*	*r*	*p*
Edad	.002	.041	.002	.968	−.050	.037	−.056	.179
IMC	−.041	.018	−.115	.021	−.043	.019	−.094	.020
Disfrute con juegos y deportes	.259	.079	.155	**.001**	.416	.064	.265	**<.001**
Edad	.007	.041	.008	.870	−.074	.038	−.082	.049
IMC	−.042	.018	−.119	.017	−.042	.019	−.091	.028
Disfrute con la AF	.297	.092	.154	**.001**	.377	.077	.199	**<.001**
Edad	−.004	.041	−.005	.920	−.069	.037	−.076	.065
IMC	−.048	.018	−.134	.007	−.053	.019	−.116	.005
Disfrute con la AF vigorosa	.246	.083	.141	**.003**	.386	.062	.250	**<.001**
Edad	.004	.042	.005	.925	−.063	.038	−.070	.092
IMC	−.041	.018	−.116	.021	−.040	.019	−.087	.035
Importancia del ejercicio físico	.193	.084	.110	**.022**	.388	.069	.228	**<.001**
Edad	.003	.041	.003	.950	−.056	.037	−.062	.131
IMC	−.043	.018	−.120	.016	−.046	.019	−.100	.014
Atracción general hacia la AF	.305	.093	.155	**.001**	.483	.074	.262	**<.001**

AF: actividad física; CAPA: *Children's Attraction to Physical Activity Questionnaire*; EE: error estándar; IMC: índice de masa corporal (kg/m^2).
En negrita p < .05 para factores de CAPA.

sexo respecto a la atracción hacia la AF, sin embargo, coincidimos con la mayoría de las investigaciones previas que atribuyeron a los chicos una mayor importancia al ejercicio físico (Ruiz & Sherman, 2005), y a las chicas un menor interés por la AF y el abandono más prematuro de su práctica (Brustad, 1993, 1996; Martínez-Baena et al., 2012).

Para algunos autores, estas diferencias de sexo son debidas a que las chicas presentan una mayor prioridad hacia los estudios, una mayor desgana y pereza a la hora de practicar ejercicio físico, o a que reciben una inadecuada transferencia de actitudes y hábitos de vida saludables por parte de madres y padres (Berge, Wall, Larson, Loth & Neumark-Sztainer, 2013; Hernando, Oliva & Pertegal, 2012; Martínez-Baena et al., 2012; Palou, Ponseti, Gili, Borrás & Vidal, 2005). La solución pasaría, por tanto, por aumentar la atracción de estas chicas hacia la AF durante la adolescencia y crear estrategias que les hagan acrecentar la práctica de ejercicio y nivel de condición física, como por ejemplo, realizar AF extraescolar, usar activamente el recreo, practicar deporte con los padres o ir al centro educativo de manera activa (Basch, 2011; Nelson & Gordon-Larson, 2006).

Esta investigación ha mostrado diferencias de RA en función de la atracción a la AF de los adolescentes. Mientras los chicos con una mayor atracción hacia la AF obtienen peor RA en Lengua y Matemáticas, las chicas con alta atracción consiguen mejores calificaciones académicas. Los anteriores resultados en las chicas son similares a los obtenidos por Martínez-Gómez et al. (2011) y Kwak et al. (2009) que hallaron una asociación positiva respecto al RA en chicas adolescentes que practicaban más AF y más AF vigorosa respectivamente; o Coe et al. (2006), que confirmaron esta asociación positiva entre AF vigorosa y RA pero sin llegar a diferenciar por sexo.

Además, estudios previos han demostrado la asociación positiva de la atracción hacia la AF con la motivación hacia la práctica físico-deportiva y, como consecuencia, con la posterior adherencia a un determinado tipo de AF y/o deporte (Cantón et al., 1995; Cervelló, Escartí & Guzmán, 2007; Jiménez, Moreno, Leyton & Claver, 2015; Sánchez-Oliva, Leo, Amado, Pulido-González & García-Calvo, 2015). Esta adherencia está determinada principalmente por el disfrute con la AF, la búsqueda de un buen estado de salud y la necesidad de establecer relaciones sociales (Frederick-Recascino & Schuster-Smith, 2003; Moreno et al., 2007). Sin embargo, hasta ahora no se conocía la existencia de una relación directa entre la atracción y el RA en asignaturas concretas. Evidencias científicas demuestran que los niños y adolescentes que practican más AF y tienen una mayor condición física, plasmada en mayor fuerza muscular y capacidad aeróbica, también obtienen un mayor RA en Matemáticas y Lengua (Bass et al., 2013; Chaddock et al., 2012; Coe et al., 2006; Haapala, 2013; So, 2012; St-Louis-Deschênes & Ellemberg, 2013), debido a que la AF aporta al cuerpo humano beneficios directamente relacionados con el aumento de la capacidad cognitiva y el RA (Chaddock et al., 2012; Hillman et al., 2008; Noakes & Spedding, 2012).

Estas evidencias determinan que el disfrute derivado de la práctica habitual de AF, y especialmente del ejercicio de alta intensidad, son aspectos claros a tener en cuenta a la hora de predecir el RA en las chicas. Los factores de atracción hacia la AF han puesto de manifiesto la relevancia de acometer actividades educativas motivantes destinadas a favorecer el disfrute por el movimiento y el esfuerzo como acción combinada con las recomendaciones relacionadas con el mero ejercicio físico. Por ejemplo, para algunos autores practicar ejercicio físico diario de intensidad moderada con una duración de entre 10 y 50 min (St-Louis-Deschênes & Ellemberg, 2013), o el mero hecho de desplazarse al instituto andando (Martínez-Gómez et al., 2011), bastaría para aumentar el RA o el rendimiento cognitivo respectivamente.

Sin embargo, en chicos existe una mayor controversia. Nosotros hemos constatado que, al contrario que en las chicas, los chicos que dan mayor importancia al ejercicio físico y tienen una alta atracción general hacia la AF obtienen mejores calificaciones en EF pero peores en Matemáticas y Lengua.

La atención a estos factores de atracción es fundamental ya que aunque el aumentar el número de sesiones de EF en el instituto mejora el rendimiento cognitivo de los adolescentes (Ardoy et al., 2014), o que la AF vigorosa se asocia positivamente con un mejor RA en chicos (So, 2012), parece que una excesiva importancia al ejercicio físico podría eclipsar o relegar a un segundo término la atención y dedicación necesaria para el desarrollo de las capacidades cognitivas y los aprendizajes de las disciplinas como Matemáticas o Lengua. Se evidencia por tanto, que el RA en chicos está determinado en menor medida que en las chicas por los factores de atracción hacia la AF, y que un exceso de importancia hacia la práctica de ejercicio físico puede contribuir al detrimento de resultados académicos en las asignaturas de Matemáticas y Lengua.

Finalmente, y como en cualquier estudio, existen algunas limitaciones metodológicas y procedimentales que han de ser reconocidas. Por ejemplo, las derivadas de un estudio transversal del cual no se pueden establecer relaciones de causalidad, y las inherentes al empleo de un autoinforme para obtener la información sobre atracción hacia la AF. Se confía en que los participantes responderán a las diferentes medidas con la mayor honestidad; sin embargo, cabe la posibilidad de que los encuestados respondan de un modo que preserve la imagen más positiva de sí mismos.

También que en algunos casos los adolescentes podrían haber contestado erróneamente de forma deliberada o sin mala intención. Consideramos que estos errores se han reducido notablemente por el hecho de que los cuestionarios eran anónimos y se ha utilizado una codificación para asegurar el anonimato y confidencialidad de los participantes y respuestas emitidas. Por tanto, es importante tener presente que el grado de atracción hacia la AF de quienes se prestaron a colaborar puede no reflejar o ser totalmente representativo de aquellos otros que no lo hicieron. Por ello, se ha de ser cauto a la hora de generalizar los resultados obtenidos.

En conclusión, el grado de atracción hacia la AF influye en el RA de los adolescentes y distingue diferencias importantes en función del sexo. Aunque los chicos tienen una mayor atracción general hacia la AF que las chicas, en ambos sexos todos los factores de atracción hacia la AF están asociados positivamente con mejores calificaciones en la asignatura de EF. El disfrute con la AF vigorosa es el principal factor de atracción que se relaciona, en chicas, con mejores calificaciones en Matemáticas y Lengua. Se evidencia, por tanto, que además de la ya conocida relación entre AF y RA es necesario tener en cuenta los factores de la atracción hacia la AF, ya que en buena medida pueden predecir diferentes resultados de RA en función del sexo. Son necesarios más estudios, para profundizar en las causas de estos hallazgos.

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II

Influence of active commuting on happiness, well-being, psychological distress and body shape in adolescents

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Original breve

Influencia del desplazamiento activo sobre la felicidad, el bienestar, la angustia psicológica y la imagen corporal en adolescentes

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R E S U M E N

Objetivo: Analizar la asociación entre el desplazamiento activo y los indicadores de salud psicológica en una muestra de 1012 adolescentes.
Método: El desplazamiento activo se evaluó mediante cuestionario. La felicidad con la *Subjective Happiness Scale*, el bienestar y la angustia psicológica con el *General Well-Being*, y la imagen corporal con la versión breve del *Body Shape Questionnaire*.
Resultados: Los/las adolescentes que emplean más de 15 minutos al día en desplazamiento activo tenían niveles más altos de felicidad subjetiva (p = 0,032) y bienestar psicológico (p = 0,036), así como niveles más bajos de angustia psicológica (p = 0,021) que los/las que emplean 15 o menos minutos al día. No se hallaron diferencias significativas en la imagen corporal entre los/las adolescentes menos y más activos/as (p = 0,163).
Conclusión: Desplazarse de manera activa al instituto, durante más de 15 minutos al día, es una conducta recomendable que se asocia con un mayor nivel de felicidad y bienestar en la adolescencia.

Influence of active commuting on happiness, well-being, psychological distress and body shape in adolescents

Keywords:
Motor activity
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A B S T R A C T

Objective: To analyse the association between active commuting to secondary school and indicators of psychological health in a sample of 1012 adolescents.
Method: Active commuting was assessed through a questionnaire, subjective happiness with the Subjective Happiness Scale, well-being and psychological distress with the General Well-Being Scale, and body shape was assessed using the short version of the Body Shape Questionnaire.
Results: Adolescents who spent more than 15 minutes per day actively commuting to secondary school had higher levels of subjective happiness (p = 0.032) and psychological well-being (p = 0.021) and lower levels of psychological distress (p = 0.021) than adolescents who spent 15 minutes or less per day. There were no differences in body shape between less and more active adolescents (p >0.05).
Conclusion: Active commuting to secondary school for more of 15 minutes per day is recommended because it is associated with higher levels of happiness and well-being in adolescents.

Introducción

El desplazamiento activo es la acción de dirigirse al centro educativo por medio de transportes que conlleven un gasto energético, como andar o ir en bicicleta. Estudios recientes han apostado por el desplazamiento activo diario para ayudar a contrarrestar los bajos niveles actuales de actividad física en la adolescencia[1]. Además, se ha descrito que el desplazamiento activo puede aportar multitud de beneficios fisiológicos saludables[2]. Sin embargo, la relación entre desplazamiento activo y salud psicológica aún no está lo suficientemente establecida[3–6].

La salud psicológica es un estado mental compuesto por múltiples componentes, entre los que se encuentran la felicidad subjetiva, el bienestar psicológico y la propia imagen corporal[7]. Durante la adolescencia, una buena salud psicológica puede prevenir futuros problemas de salud e incluso actuar como predictor de la mortalidad[8]. Sin embargo, la mayoría de los estudios que

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Tabla 1
Características de los participantes

	Todos (n = 1012)		Chicos (n = 430)		Chicas (n = 582)		
	Media	IC95% (%)	Media	IC95% (%)	Media	IC95% (%)	p
Edad (años)	14,42	14,32-14,53	14,47	14,31-14,63	14,38	14,25-14,52	0,430
Peso (kg)	59,11	58,29-59,94	63,30	61,88-64,71	56,02	55,11-56,93	<0,001
Talla (m)	1,64	1,63-1,65	1,69	1,68-1,7	1,61	1,6-1,61	<0,001
IMC (kg/m[2])	21,80	21,56-22,05	22,03	21,64-22,42	21,64	21,33-21,94	0,118
Desplazamiento activo (minutos/día)	15,46	14,73-16,18	15,21	14,17-16,24	15,64	14,64-16,63	0,565
Felicidad (u.a.)	5,29	5,22-5,37	5,28	5,16-5,39	5,30	5,21-5,39	0,771
Bienestar psicológico (u.a.)	4,27	4,21-4,32	4,33	4,25-4,41	4,22	4,15-4,29	0,043
Angustia psicológica (u.a.)	2,73	2,67-2,78	2,66	2,56-2,75	2,78	2,7-2,85	0,041
Imagen corporal (u.a.)	1,87	1,81-1,94	1,74	1,64-1,83	1,97	1,89-2,06	<0,001
Nivel de estudios de la madre							
Sin estudios, n (%)	31 (3,1)		10 (2,3)		21 (3,6)		
Primaria, n (%)	537 (53,1)		237 (55,2)		303 (52)		
Secundaria, n (%)	159 (15,7)		57 (13,2)		100 (17,1)		0,725
Bachillerato/FP, n (%)	130 (12,8)		57 (13,2)		73 (12,5)		
Universidad, n (%)	155 (15,3)		69 (16,1)		85 (14,8)		
Desplazamiento no activo: coche, moto o autobús, n (%)	330 (32,6)		142 (33)		188 (32,3)		0,809
Desplazamiento activo: andando o en bicicleta, n (%)	682 (67,4)		288 (67)		394 (67,7)		
≤ 15 minutos/día desplazamiento activo, n (%)	712 (70,4)		302 (70,2)		410 (70,4)		0,941
>15 minutos/día desplazamiento activo, n (%)	300 (29,6)		128 (29,8)		172 (29,6)		

FP: formación profesional; IC95%: intervalo de confianza del 95%; IMC: índice de masa corporal; u.a.: unidades arbitrarias.

han relacionado la práctica de actividad física con una mejor salud psicológica se han centrado en la actividad física de intensidad vigorosa[7], y en muy pocos casos respecto al ejercicio físico de intensidad moderada.

El objetivo del presente estudio fue analizar la asociación del tiempo medio diario invertido en la ida y vuelta activa al centro educativo con indicadores de salud psicológica en adolescentes.

Método

Participantes

Participaron en este estudio transversal 1012 adolescentes de seis centros de educación secundaria de Andalucía.

Variables e instrumentos

Para evaluar el desplazamiento activo se usó un cuestionario que implicaba un autorregistro, durante una semana, del modo y el tiempo empleado para ir y volver del instituto[1]. Los participantes se clasificaron como inactivos (≤15 minutos al día de desplazamiento activo) y activos (>15 minutos al día)[2]. Para obtener las medidas de peso y talla se empleó una báscula digital ASIMED® modelo Elegant (Barcelona), y un tallímetro portátil SECA® 214 (SECA Ltd., Hamburgo), respectivamente. Se calculó el índice de masa corporal (IMC, en kg/m^2).

El nivel de estudios de la madre es un buen indicador del nivel socioeconómico de las familias[2,9]. Se obtuvo mediante un cuestionario que autocumplimentaron los/las adolescentes (véase la escala en la tabla 1).

La felicidad subjetiva se evaluó mediante la *Subjective Happiness Scale*[10]. Los participantes contestaron cuatro preguntas y la variable «felicidad» se corresponde con la media de las puntuaciones directas de estos ítems. El alfa de Cronbach fue de 0,795.

El bienestar y la angustia psicológica se evaluaron mediante la adaptación del cuestionario *General Well-Being*[11]. Los participantes respondieron a 20 preguntas, de las cuales 10 evalúan el bienestar psicológico y el resto la angustia psicológica. El alfa de Cronbach fue de 0,845 y 0,886, respectivamente.

Para evaluar la imagen corporal, los/las adolescentes respondieron a los 10 ítems del *Body Shape Questionnaire (BSQ-49)* adaptado de la versión original[12]. El alfa de Cronbach fue de 0,920.

Todos los resultados de consistencia interna descritos anteriormente corresponden a datos de este estudio.

Procedimiento

Se obtuvo el consentimiento informado de los/las responsables legales de los adolescentes. El nombre de cada participante fue codificado para asegurar la confidencialidad. El estudio fue aprobado por la Comisión de Bioética de la Universidad de Jaén. Además, se tuvieron en cuenta la Ley de Investigación Biomédica (2007), la Ley de Protección de Datos Personales (Ley Orgánica 15/1999) y los principios fundamentales de la Declaración de Helsinki (rev. 2013).

Análisis de datos

Se comprobaron la normalidad y la homocedasticidad de las variables mediante el test de Kolmogorov y la prueba de Levene, respectivamente. Las diferencias entre sexos se analizaron mediante las pruebas *t* de Student y ji al cuadrado. Se realizaron análisis de regresión lineal y ANCOVA para estudiar la asociación del tiempo activo para ir al centro educativo (categorías: inactivos frente a activos) con indicadores de salud psicológica en adolescentes, ajustando por edad, IMC y sexo. Los análisis se repitieron incluyendo en el modelo los estudios de la madre. Se empleó un nivel de confianza del 95%. Los cálculos se realizaron con SPSS v. 19,0 para Windows (SPSS Inc., Chicago).

Resultados

Los participantes tenían una edad promedio de 14,42 años y un IMC de 21,80 kg/m^2. El 42,5% eran chicos (n = 430) y el 57,5% eran chicas (n = 582). La muestra fue por conveniencia (tabla 1).

Tabla 2
Asociación entre el desplazamiento activo al instituto (expresado en promedio de minutos diarios) y variables psicológicas, tras ajustar por edad, IMC y sexo. Se presentan dos modelos: sin y con estudios de la madre

	Felicidad subjetiva			Bienestar psicológico			Angustia psicológica			Imagen corporal		
	β	EE	p	β	EE	p	β	EE	p	β	EE	p
Edad (años)	-0,026	0,022	0,244	-0,048	0,016	0,003	0,064	0,018	<0,001	-0,014	0,019	0,451
IMC (kg/m²)	-0,016	0,010	0,104	-0,001	0,007	0,855	0,011	0,008	0,163	0,072	0,008	<0,001
Sexo	-0,011	0,076	0,890	0,119	0,054	0,027	-0,136	0,060	0,024	-0,263	0,065	<0,001
Desplazamiento activo (min/día)	0,008	0,004	0,020	0,010	0,002	<0,001	-0,006	0,003	0,026	0,001	0,003	0,782
Edad (años)	-0,007	0,033	0,823	-0,060	0,023	0,009	0,046	0,024	0,053	0,020	0,029	0,487
IMC (kg/m²)	-0,008	0,013	0,558	0,004	0,009	0,629	<0,001	0,010	0,965	0,057	0,012	<0,001
Sexo	0,213	0,110	0,053	0,235	0,076	0,002	-0,237	0,080	0,003	-0,287	0,096	0,003
Estudios de la madre	0,098	0,046	0,032	0,048	0,032	0,127	-0,032	0,033	0,339	-0,044	0,040	0,271
Desplazamiento activo (min/día)	0,107	0,066	0,062	0,084	0,034	0,103	-0,003	0,004	0,309	0,006	0,005	0,189

β: beta no estandarizada; EE: error estándar; IMC: índice de masa corporal.

Los resultados del análisis de regresión se presentan en la tabla 2. Los/las adolescentes que empleaban más minutos al día en desplazamiento activo tenían mejores niveles de felicidad subjetiva (β = 0,008, p = 0,020) y bienestar (β = 0,010, p <0,001), y una menor angustia psicológica (β = -0,006, p = 0,026), independientemente de la edad, el IMC y el sexo. Los resultados del ANCOVA mostraron que los/las adolescentes que emplean más de 15 minutos al día en desplazamiento activo tenían mayor felicidad (p = 0,032, intervalo de confianza del 95% [IC95%]: 5,28-5,55) y bienestar (p = 0,036, IC95%: 4,26-4,45), y una menor angustia (p = 0,021, IC95%: 2,51-2,73), que los/las adolescentes que emplean ≤15 minutos al día. Al incluir el nivel de estudios de la madre en ambos análisis, la asociación y las diferencias perdieron la significación estadística (todos p >0,05; datos no mostrados para el ANCOVA). No se halló asociación ni diferencias significativas en ninguno de los análisis respecto a la imagen corporal (p >0,05).

Discusión

El presente estudio ha revelado que el desplazamiento activo se asocia positivamente con la felicidad y el bienestar, y negativamente con la angustia psicológica. Lo anterior concuerda solo en parte con estudios similares en población adulta. Mientras en algunas investigaciones el desplazamiento activo era percibido como más relajante y emocionante que el motorizado[4], y se asociaba con una mejor calidad de vida y salud psicológica[3], en otros estudios no se halló asociación[5] o incluso el desplazamiento activo perjudicaba la salud psicológica[6].

La mayoría de los estudios que han asociado la actividad física con variables psicológicas han asumido una intensidad vigorosa del ejercicio físico como factor indispensable para obtener efectos positivos[7]. Sin embargo, consideramos, de modo similar a lo hallado por Bertheussen et al.[13], que una actividad física moderada, como el desplazamiento activo, también podría aportar efectos positivos psicológicos en los/las jóvenes.

En cuanto a la duración del ejercicio, el presente estudio muestra que los/las adolescentes que invierten más de 15 minutos al día en desplazamiento activo muestran cotas más altas de felicidad y bienestar. De manera similar a lo que muestran nuestros resultados, Wen et al.[14] y Martínez-Gómez et al.[2] señalaron que 15 minutos al día de actividad física moderada son suficientes para obtener beneficios en salud, y que las chicas adolescentes que empleaban más de 15 minutos al día en desplazamiento activo mostraban un mejor rendimiento cognitivo, respectivamente. Las causas de estos hallazgos no pueden explicarse a partir del presente estudio. Sin embargo, es posible que la liberación de endorfinas, asociada a una actividad física más prolongada en el tiempo, actúe directamente sobre el cerebro produciendo sensación de felicidad, bienestar y relajación[15].

Por otro lado, este estudio también ha revelado que la asociación entre el desplazamiento activo y las variables psicológicas desaparece cuando se incluye una variable socioeconómica como el nivel educativo de la madre. Algunos estudios previos también han controlado esta variable, pero no han comprobado el modelo con y sin ella, y por tanto no pueden hacerse comparaciones[2,9]. No obstante, es posible especular que los/las adolescentes cuyas madres tienen un mayor nivel educativo podrían recibir estilos educativos parentales más proclives a estimular el bienestar y la felicidad.

El presente estudio tiene como principales limitaciones el carácter autoinformado de los cuestionarios y no haber controlado el nivel de actividad física general, aparte del desplazamiento activo. Se concluye que un tiempo superior a 15 minutos al día empleado en desplazarse activamente al instituto se asocia con mayores niveles de felicidad y bienestar, y menor angustia psicológica, en adolescentes. Se sugiere fomentar desde el contexto educativo y familiar el desplazamiento activo de los/las jóvenes.

Editora responsable del artículo

Glòria Pérez.

Declaración de transparencia

El/la autor/a principal (garante responsable del manuscrito) afirma que este manuscrito es un reporte honesto, preciso y transparente del estudio que se remite a Gaceta Sanitaria, que no se han omitido aspectos importantes del estudio, y que las discrepancias del estudio según lo previsto (y, si son relevantes, registradas) se han explicado.

¿Qué se sabe sobre el tema?

Los beneficios psicológicos del desplazamiento activo han sido poco estudiados y se han centrado en adultos. Un propicio estado de salud psicológica durante la adolescencia puede favorecer las relaciones sociales y predecir la mortalidad. No hay estudios sobre la influencia del desplazamiento activo en la salud psicológica de adolescentes.

¿Qué añade el estudio realizado a la literatura?

El desplazamiento activo influye sobre la felicidad y el bienestar psicológico de los/las adolescentes. Emplear más de 15 minutos al día de desplazamiento activo contribuye a la mejora de la salud psicológica en la adolescencia. Por sus beneficios fisiológicos y psicológicos, se sugiere crear rutas seguras y programas de fomento y control del desplazamiento activo, involucrando a las instituciones de salud pública, las instituciones educativas y las familias.

Contribuciones de autoría

A. Ruiz-Ariza y E.J. Martínez-López dirigieron el diseño y la realización del estudio, el tratamiento de los datos y su interpretación, así como la redacción y la revisión crítica del manuscrito. M.J. de la Torre-Cruz y M.T. Redecillas-Peiró participaron en el diseño y la realización del estudio, el tratamiento de los datos y su interpretación, así como en la redacción del manuscrito. Todas las personas firmantes han aprobado la versión final del texto.

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Conflictos de intereses

Ninguno.

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III

Active commuting to school influences on academic performance of Spanish adolescent girls

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El desplazamiento activo al Centro educativo influye en el rendimiento académico de las adolescentes españolas

Active commuting to school influences on academic performance of Spanish adolescent girls

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Resumen. El desplazamiento activo se define como la acción de dirigirse al Centro educativo por medio de transportes que conlleven gasto metabólico, como andar o usar la bicicleta. El tiempo medio diario de desplazamiento activo en adolescentes es de 18 minutos, y podría incrementar un 13% la actividad física total diaria. El desplazamiento activo se ha asociado a una mejor salud y rendimiento cognitivo. Sin embargo, los estudios que analizan la asociación entre desplazamiento activo y rendimiento académico son muy escasos. El objetivo fue analizar el grado de asociación del desplazamiento activo con el rendimiento académico en Matemáticas, Lengua, Educación Física y con el rendimiento académico general —promedio de Matemáticas, Lengua y Educación Física— en adolescentes. En el presente estudio transversal participaron 1.006 adolescentes españoles. El modo de desplazamiento se evaluó mediante cuestionario y para el rendimiento académico se solicitó a los institutos las calificaciones numéricas. Los adolescentes se clasificaron en inactivos (empleaban transporte motorizado o realizaban menos de cinco trayectos/semana andando durante más de 15 minutos), y activos (realizaban e» cinco trayectos/semana andando más de 15 minutos). Se realizaron análisis de regresión lineal y ANCOVA ajustados por edad e Índice de Masa Corporal. Los resultados mostraron que las chicas que realizan un mayor número de desplazamientos activos semanales tenían un mayor rendimiento académico en Matemáticas (β=0,041±0,019, p=0,036), en Educación Física (β=0,029±0,013, p=0,029), y mayor rendimiento académico general (β=0,031±0,014, p=0,027). En chicos, ninguna asociación resultó significativa (todos p>0,05). Se concluye que desplazarse al instituto andando, al menos cinco trayectos semanales de más de 15 minutos, se relaciona con mayores calificaciones en Matemáticas en las chicas adolescentes. Fomentar el desplazamiento activo, desde el ámbito escolar y familiar puede ser potencialmente relevante para mejorar el rendimiento académico en chicas españolas de Educación Secundaria.
Palabras clave: Caminar, asignaturas, cognición, educación, rendimiento cognitivo.

Abstract. Active commuting is defined as the action of going to school using a means of transportation that implies energy consumption, such as walking or cycling. Daily average time of active commuting in adolescents is 18 minutes, and this time could increase the total daily physical activity account by 13%. Active commuting has been associated with better health and cognitive performance. However, studies examining the association between active commuting and academic performance are scarce. Based on the above statements, the aim was to analyse the association between active commuting to school and academic performance in Maths, Spanish Language, Physical Education and general academic performance —mean of Math, Language and Physical Education— in adolescents. 1,006 Spanish youths participated in the present cross-sectional study. We used a weekly questionnaire to assess active commuting, whereas we requested academic marks in order to track academic performance. Adolescents were classified as inactive (using passive transport or walking 15' or more less than five times a week) and active (walking 15' or more at least six times a week). Linear regression and ANCOVA analyses adjusted by age and body mass index were performed. Our results showed that girls who carry out a higher number of weekly active trips to school had higher Maths and Physical Education marks (β=0,041±0,019, p=0,036; β=0,029±0,013, p=0,029, respectively), and better general academic performance (β=0,031±0,014, p=0,027). There were no associations in boys (all p>0,05). Commuting actively to school for more than 15' a day at least five times a week is associated with better Math performance in adolescent girls. Promotion of active commuting from both school staff and families could be potentially relevant to improve academic performance in Spanish Secondary school girls.
Key words: Walking, subjects, cognition, education, cognitive performance.

Introducción

La práctica habitual de actividad física (AF) se asocia con una mejora muscular, ósea, y cardiovascular (Gracia-Marco et al., 2011), contribuyendo además a un mayor nivel de bienestar psicológico (Padilla-Moledo et al., 2012). En jóvenes, las recomendaciones actuales sobre estilo de vida saludable aconsejan realizar al menos 60 minutos diarios de AF a una intensidad de moderada a vigorosa (Oja, Bull, Fogelholm, y Martin, 2010). Sin embargo, la mayoría de niños no alcanza estos mínimos, y durante la adolescencia los minutos de práctica de AF saludable disminuyen dramáticamente (Chillón et al., 2009; Ramos, Jiménez-Iglesias, Rivera, y Moreno, 2016). Algunos autores han sugerido que fomentar el desplazamiento activo al colegio podría ayudar a compensar este déficit de AF diaria (Chillón et al., 2011; Segura-Díaz, Herrador-Colmenero, Martínez-Téllez, y Chillón, 2015; Villa-González, Ruiz, y Chillón, 2016) y contrarrestar, en parte, los nocivos efectos derivados de los actuales estilos de vida sedentarios (Aires et al., 2011).

El desplazamiento activo se define como la acción de dirigirse al Centro educativo por medio de transportes que conlleven gasto metabólico tales como andar o usar la bicicleta (Chillón et al., 2011; Mandic et al., 2015; Segura-Díaz et al., 2015). Mendoza et al. (2011), concluyeron que el tiempo medio diario empleado en el desplazamiento activo al Centro educativo en adolescentes estadounidenses es de 18 minutos, y podría incrementar un 13% la AF total practicada durante el día (Smith et al., 2012). En otro estudio con adolescentes holandeses, Van Dijk, De Groot, Van Acker, Savelberg, y Kirschner (2014), hallaron que el desplazamiento activo constituía el 28% del total de práctica de AF semanal. Se ha comprobado, que los jóvenes que se desplazan de forma activa al Centro educativo presentan niveles más bajos de sobrepeso y obesidad (Bere, Oenema, Prins, Seiler, y Brug, 2011), mayor felicidad y bienestar (Ruiz-Ariza, De la Torre-Cruz, Redecillas-Peiró, y Martínez-López, 2015), y un mayor nivel de condición física (Chillón et al., 2011; Villa-González, Ruiz, y Chillón, 2015). Sin embargo, la asociación entre el desplazamiento activo y parámetros relacionados con la cognición en adolescentes ha sido poco estudiada y las relaciones no son tan evidentes (Martínez-Gómez et al., 2011; Van Dijk et al., 2014).

Algunos autores han informado que la práctica de AF produce beneficios a nivel cognitivo tanto si se realiza a alta (Ardoy et al., 2014) como a moderada intensidad (Backes, Horvath, y Kazial, 2015; Martínez-Gómez et al., 2011). La AF mejora la circulación sanguínea cerebral y la plasticidad sináptica (Hillman, Erickson, y Kramer, 2008), ayuda a la supervivencia de las neuronas y fomenta su crecimiento (Ardoy et al., 2014). Estas adaptaciones fisiológicas mejoran tanto la memoria como la capacidad de aprendizaje (Wrann et al., 2013), y en definitiva la función cognitiva, uno de los factores considerados clave en el rendimiento académico (RA) (Hillman et al., 2009; Mora-Corral, 2010).

El RA hace referencia al éxito de un alumno en el Centro Educativo medido a partir de las calificaciones en las diferentes asignaturas (Ruiz-Ariza, Ruiz, de la Torre-Cruz, Latorre-Román, y Martínez-López, 2016). Se ha comprobado que el RA puede estar mediatizado por la valoración de los profesores hacia las actitudes de los alumnos, así como

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el interés, la participación y la asistencia a clase de los mismos (Gutiérrez y López, 2012). Las estrategias de autoeficacia y autorregulación del aprendizaje, las estrategias de apoyo, de organización y comprensión, así como las metas de aprendizaje, también contribuyen a la explicación del RA (Valle et al., 2009). Además, puede estar influenciado por otras variables de índole afectivo-emocional (Cueli, González-Castro, Álvarez, García, y González-Pienda, 2014) o socioeconómico (Castillo et al., 2011). Sin embargo, para algunos autores, la capacidad cognitiva es uno de los factores más determinantes en el éxito académico (Laidra, Pullman, y Allik, 2007; Mora-Corral, 2010).

Romeo y McEwen (2006) sugirieron la necesidad de una mayor estimulación cognitiva durante la adolescencia debido a que aún se mantiene un alto grado de plasticidad cerebral, indispensable para poder lograr aprendizajes significativos. Dicha estimulación es determinante para la mejora del RA y podría ser favorecida por la AF diaria y sistemática que implica el desplazamiento activo al instituto (Martínez-Gómez et al., 2011; Stock et al., 2012). De hecho, aparte de la Educación Física (EF) escolar, el RA mejoraría significativamente a partir de 17 minutos de ejercicio de moderado a vigoroso al día en chicos y 12 minutos en chicas (Booth et al., 2014).

Martínez-Gómez et al. (2011), hallaron que las adolescentes españolas que realizaban desplazamiento activo al instituto tenían mejores índices de rendimiento cognitivo, medido a través de un cuestionario estandarizado de inteligencia y habilidades básicas de aprendizaje. Stock et al. (2012), en una muestra de 10380 adolescentes daneses, comprobaron que los jóvenes con una percepción más alta de su RA se desplazaban de forma activa en mayor medida que aquellos con una percepción más baja. No obstante, los estudios que analizan la asociación del desplazamiento activo al Centro educativo con el RA son muy escasos (Domazet et al., 2016; Haapala et al., 2014). Van Dijk et al., (2014), han asociado recientemente el desplazamiento activo y el RA en adolescentes, analizando las posibles diferencias en función del sexo. Estos autores hallaron una asociación muy débil entre ambas variables, encontrando solo relación entre el desplazamiento activo y los niveles de atención mediante el test d2 en chicas. Este último estudio es muy relevante debido a que fue llevado a cabo en Holanda, una población con características de desarrollo similares a la española, pero que sin embargo se encuentra entre los principales países del mundo con mayor tasa de éxito escolar (PISA, 2012).

En base a lo expuesto anteriormente, el objetivo del presente estudio fue analizar la asociación entre el desplazamiento activo al instituto y las calificaciones en las asignaturas de Matemáticas, Lengua y EF en una muestra de jóvenes españoles.

Metodología

Diseño y participantes

Se trata de un estudio transversal cuantitativo. Se empleó como covariables la edad y el IMC de los adolescentes. Durante el curso académico 2013-2014 se tomó una muestra inicial de 1224 adolescentes, pertenecientes a 12 institutos de Educación Secundaria de la provincia de Jaén (España) (7 urbanos e»10000 habitantes, y 5 rurales <10000 habitantes). Fueron excluidos aquellos alumnos que contestaron de forma incompleta o no mostraron autorización parental. Se excluyeron del estudio aquellos participantes que manifestaron emplear la bicicleta como medio de transporte activo, debido a que el número de alumnos que usaban este medio era insignificante. La muestra final de estudio estuvo formada por un total de 1006 estudiantes de Educación Secundaria.

Instrumentos

Rendimiento Académico

La calificación en las asignaturas de Matemáticas y Lengua —como variables con mayor poder explicativo de RA (Miñano, Gilar y Castejón, 2012; Ruiz-Ariza et al., 2016) – y las notas de EF —como referente de la actitud del niño hacia la AF—, fueron las variables dependientes analizadas en este estudio. Se solicitó a los Centros Educativos las calificaciones correspondientes a la evaluación trimestral previa a la cumplimentación del cuestionario (escala 1-10). Para obtener la medida de RA general se realizó un promedio de las calificaciones de las tres asignaturas.

Cuestionario de modo de desplazamiento al instituto

Se evaluó mediante un cuestionario que registró el modo, tiempo, y cantidad de desplazamientos semanales empleados para ir y volver del Centro educativo (Chillón et al., 2009; 2011). La variable independiente fue el número de trayectos de ida o vuelta semanales que cada alumno realizaba andando durante un tiempo superior a 15 minutos. Los adolescentes se clasificaron en inactivos y activos: inactivos (empleaban transporte motorizado o realizaban menos de cinco trayectos/semana andando) y activos (realizaban e» cinco trayectos andando —superiores a 15 minutos— durante la semana). Los valores oscilaban entre cero y 10 trayectos. Se tomó la cifra de 15 minutos en base a lo establecido en los estudios de Martínez-Gómez et al. (2011) y Ruiz-Ariza et al. (2015) [Figura 1].

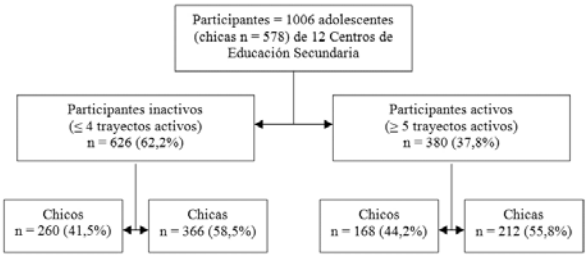

Figura 1.
Flujo de participantes en función del número semanal de trayectos y del sexo.

Covariables

Se consideró como variable de confusión la edad debido a que está inversamente relacionada con la práctica de AF y con el RA durante la adolescencia (Esteban-Cornejo, Tejero-Gonzalez, Sallis, y Veiga, 2015; Ruiz-Ariza et al., 2016). Muchos estudios han considerado también que el IMC ejerce una alta influencia tanto en la cantidad de práctica de AF como en el RA durante la adolescencia (Ruiz-Ariza et al., 2016; Sardinha et al., 2014). El IMC se calculó mediante la fórmula = peso (kg) / talla (m^2). Para obtener las medidas de peso y talla se empleó una báscula digital ASIMED modelo Elegant® tipo B —clase III—, y un tallímetro portátil SECA® 214 (SECA Ltd., Hamburgo, Alemania), respectivamente. Ambas medidas se realizaron descalzos y con ropa ligera.

Procedimiento

Se contactó vía correo postal con los Centros educativos y se contó con la autorización de los directores y profesores de EF. Se informó a padres y tutores legales de los alumnos sobre la naturaleza y el propósito del estudio. Todos dieron su consentimiento escrito para la participación de sus hijos en este estudio. El nombre de cada participante se codificó para asegurar el anonimato y confidencialidad de las respuestas emitidas. Varios investigadores debidamente formados se desplazaron a los Centros educativos. El registro de datos se llevó a cabo dentro de la clase de Educación Física. Un cuestionario sociodemográfico de datos personales como la edad y el sexo, y el cuestionario sobre desplazamiento activo al Centro educativo fueron administrados de forma individual. La duración de la toma de datos fue de 40 minutos.

Normativa legal y comité de bioética

El estudio fue aprobado por la Comisión de Bioética de la Universidad de Jaén. En el diseño se han tenido en cuenta la normativa legal vigente española que regula la investigación clínica en humanos (Real Decreto 561/1993 sobre ensayos clínicos), la ley de protección de datos de carácter personal (Ley Orgánica 15/1999), así como los principios fundamentales establecidos en la Declaración de Helsinki (revisión de 2013).

Análisis estadístico

Los parámetros se muestran como media, desviación típica y error estándar. Las diferencias descriptivas entre sexo se analizaron mediante la prueba t de Student para variables continuas y el test ÷² para variables categóricas. Se realizaron análisis de regresión lineal para estudiar la asociación del número de transportes semanales considerados activos (variable independiente) con el RA en las diferentes asignaturas (variables dependientes). Además, para estudiar si los adolescentes considerados activos tenían a su vez un mejor RA que los jóvenes inactivos se realizó análisis de covarianza ANCOVA. Se introdujeron las calificaciones de cada asignatura como variables dependientes y la clasificación dicotomizada en función del número de trayectos de más de 15 minutos (activos vs. no activos) como factor fijo. La muestra fue segmentada por sexo para todos los análisis debido a que previamente se había hallado interacción entre sexos y medidas de RA ($p < 0,05$). Todos los análisis se realizaron separadamente para cada asignatura y se ajustaron por edad e IMC, ya que se halló correlación entre edad e IMC con respecto al RA (ambas $p < 0,01$). Para todos los análisis se empleó un nivel de confianza del 95%. Los cálculos se realizaron con el programa estadístico SPSS, v. 19,0 para WINDOWS (SPSS Inc., Chicago).

Tabla 1.
Características sociométricas, trayectos activos semanales y rendimiento académico diferenciado por sexo

	Todos (n = 1006)		Chicos (n = 428)		Chicas (n = 578)		P
	Media	DT	Media	DT	Media	DT	
Edad (años)	14,43	1,69	14,47	1,74	14,39	1,66	0,431
Peso (kg)	59,09	13,37	63,22	14,9	56,04	11,19	<0,001
Talla (m)	1,64	0,09	1,69	0,09	1,61	0,07	<0,001
IMC (kg/m²)	21,80	3,92	22,01	4,12	21,65	3,75	0,149
RA en Matemáticas	6,16	2,14	5,98	2,20	6,29	2,08	0,023
RA en Lengua	6,33	1,97	5,87	1,99	6,67	1,88	<0,001
RA en Educación Física	7,44	1,48	7,36	1,53	7,51	1,43	0,117
RA General: (Mat+Len+EF)/3	6,64	1,54	6,40	1,55	6,82	1,52	<0,001
Tiempo promedio de desplazamiento activo (minutos/día)	18,30	1,14	18,45	1,11	18,25	1,16	0,620
Trayectos semanales totales >15 minutos	5,74	4,50	5,69	4,47	5,78	4,53	0,764
Trayectos de >15 minutos, 5 o más veces/semana (n (%))	380 (37,8)		168 (39,2)		212 (36,7)		0,913

IMC: índice de masa corporal; RA: rendimiento académico; DT: desviación típica. P para la comparación de sexos (t de Student para variables continuas, y el test ?² para variables categóricas). Trayectos activos semanales (escala: 0 – 10, trayectos > 15 minutos) y rendimiento académico (escala: 0 – 10 puntos).

Tabla 2.
Asociación entre el número de trayectos de ida o vuelta al centro educativo > 15 minutos andando (escala: 0 – 10 trayectos), y el rendimiento académico en Matemáticas, Lengua, Educación Física y rendimiento general, en adolescentes españoles de 12-17 años.

	Chicos (428)				Chicas (578)			
	Matemáticas							
	β	EE	r	P	β	EE	r	P
Edad	-0,249	0,063	-0,195	<0,001	-0,113	0,053	-0,089	0,035
IMC	-0,020	0,026	-0,038	0,437	-0,033	0,023	-0,061	0,151
Trayectos semanales activos	0,011	0,024	0,022	0,642	0,041	0,019	0,089	0,036
	Lengua							
	β	EE	r	P	β	EE	r	P
Edad	-0,185	0,057	-0,159	0,001	-0,102	0,048	-0,089	0,036
IMC	-0,031	0,024	-0,064	0,193	-0,036	0,021	-0,072	0,087
Trayectos semanales activos	0,006	0,022	0,014	0,767	0,024	0,018	0,057	0,179
	Educación Física							
	β	EE	r	P	β	EE	r	P
Edad	-0,028	0,044	-0,032	0,521	-0,008	0,037	-0,009	0,824
IMC	-0,052	0,018	-0,142	0,004	-0,049	0,016	-0,129	0,002
Trayectos semanales activos	0,003	0,017	.0,008	0,872	0,029	0,013	0,092	0,029
	Rendimiento Académico General							
	β	EE	r	P	β	EE	r	P
Edad	-0,154	0,044	-0,171	0,001	-0,074	0,039	-0,080	0,057
IMC	-0,034	0,018	-0,092	0,060	-0,039	0,017	-0,098	0,020
Trayectos semanales activos	0,007	0,017	0,019	0,687	0,031	0,014	0,093	0,027

EE: Error estándar. IMC: Índice de masa corporal (Kg/m²). Los análisis fueron ajustados por edad e índice de masa corporal.

Resultados

Los participantes tenían una edad promedio de 14,43 ± 1,69 años (rango: 12-17 años) y un IMC de 21,80 ± 3,92 kg/m². El 42,5% fueron chicos (n=428) y el 57,5% chicas (n=578). El 37,7% de los 1006 participantes realizaba 5 o más trayectos semanales de más de 15 minutos. Las características sociométricas, nivel de RA, y desplazamiento activo se presentan en la Tabla 1. Los resultados mostraron que las chicas tenían mejores calificaciones en Matemáticas ($p = 0,023$) y en Lengua ($p < 0,001$), y un mayor RA general que los chicos ($p < 0,001$). El número de trayectos y el tiempo promedio empleado durante la semana fue similar en chicos y chicas ($p > 0,05$) [ver tabla 1].

Los resultados del análisis de regresión lineal que muestra la asociación entre el número de desplazamientos activos al instituto (trayectos andando superiores a 15 minutos) y el RA en Matemáticas, Lengua, EF, y RA general se presentan en la tabla 2. Las chicas que realizaban más trayectos activos semanales tenían significativamente mejores calificaciones en Matemáticas (β= 0,041 ± 0,019, $p = 0,036$), y EF (β= 0,029 ± 0,013, $p = 0,029$), así como un mayor RA general (β= 0,031 ± 0,014; $p = 0,027$). Sin embargo, las anteriores asociaciones no se encontraron en los chicos (todos $p > 0,05$). En la asignatura de Lengua no se halló asociación respecto al número de trayectos activos en ninguno de los dos sexos ($p > 0,05$). Se observó también que la edad se asociaba negativamente con la calificación de Matemáticas (β= -0,249 ± 0,063, $p < 0,001$ en chicos, y β= -0,113 ± 0,053, $p = 0,035$ en chicas) y Lengua (β = -0,185 ± 0,057, $p = 0,001$ en chicos, y β = -0,102 ± 0,048, $p = 0,036$ en chicas), y con el RA general solo en chicos, esto es, a mayor edad menor RA (β = -0,154 ± 0,044, $p = 0,001$). El IMC se asoció negativamente con la calificación de EF en ambos sexos (β = -0,052 ± 0,018, $p < 0,004$ en chicos, y β = -0,049 ± 0,016, $p = 0,002$ en chicas), y con el RA general en chicas (β = -0,039 ± 0,017, $p = 0,020$).

Los resultados del análisis ANCOVA que estudia si los adolescentes activos (>5 trayectos semanales de más de 15 minutos) tenían mejor calificación en Matemáticas, Lengua, EF, y RA general que los inactivos (empleaban transporte motorizado o realizaban menos de cinco trayectos/semana andando), se muestran en la figura 2. Los resultados mostraron que las chicas activas obtenían significativamente mejores calificaciones en Matemáticas ($p = 0,027$) y en EF ($p = 0,005$), así como un mejor RA general ($p = 0,008$) que las inactivas. Los resultados mostraron también que no existen diferencias entre chicos activos e inactivos en ninguna de las variables estudiadas —Matemáticas, Lengua, EF, y RA general— (todas $p > 0,05$). En la asignatura de Lengua los resultados de chicos y chicas en función del grado de AF semanal fueron similares ($p > 0,05$).

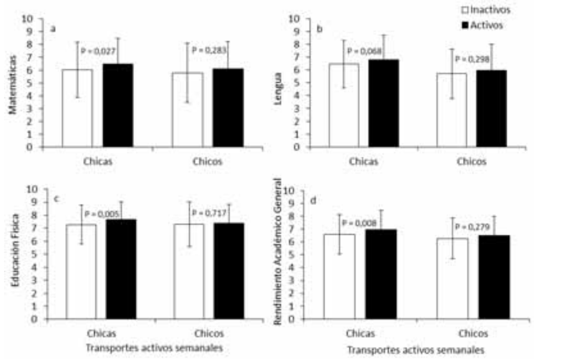

Figura 2. Asociación entre niveles de transporte al centro educativo (inactivos vs. activos) con la calificación en las asignaturas de Matemáticas (a), Lengua (b), Educación Física (c), y rendimiento académico general (d) en adolescentes españoles de 12 – 17 años. El trasporte escolar se clasificó como inactivos (empleaban transporte motorizado o menos de cinco trayectos andando/semana) vs. activos (= cinco trayectos andando/semana = 15 minutos). Todos los análisis fueron ajustados por edad e IMC. Resultados expresados como media y desviación estándar.

Discusión

El presente trabajo ha estudiado la relación del desplazamiento activo al instituto respecto a las calificaciones en las asignaturas de Matemáticas, Lengua y EF, así como en RA general en base al promedio de las tres, en una muestra de jóvenes españoles. Los resultados muestran que los adolescentes activos realizaban un promedio de 18 minutos al día de desplazamiento andando al Centro educativo, sin haber diferencias significativas por sexo. Las chicas que realizan más trayectos activos semanales obtienen significativamente mejores calificaciones en Matemáticas y EF, así como mejor RA general. Sin embargo, en chicos no se han hallado diferencias de RA en función del tipo de desplazamiento al instituto.

Nuestros resultados muestran que las chicas que realizan más trayectos activos semanales obtienen mejores calificaciones en Matemáticas, pero no en Lengua. Estos son similares a los hallados por Martínez-

Gómez et al. (2011), que mostraron que las chicas adolescentes que invierten más de 15 minutos al día en desplazamiento activo al Centro educativo, presentan niveles más altos de rendimiento cognitivo. Además, mientras algunas investigaciones no han hallado asociación entre desplazamiento activo y RA (Van Dijk et al., 2014), otros autores han concluido que desplazarse de forma activa al instituto se asocia con mejores calificaciones en Matemáticas, pero no incluyen resultados con respecto a Lengua —tiempo de desplazamiento no reportado— (Domazet et al., 2016). Esta divergencia entre Matemáticas y Lengua, podría deberse a que una mayor AF influye en la codificación simbólica, mejora los recursos atencionales, y el procesamiento durante las tareas aritméticas (Moore, Drollette, Scudder, Bharij, y Hillman, 2014). Mientras que la influencia de la AF sobre el lenguaje está aún menos explorada (Ardoy et al., 2014).

Nosotros hemos observado que el desplazamiento activo ejerce además un efecto diferencial en función del sexo, ya que afecta al RA en Matemáticas, EF y al RA general en chicas pero no en chicos. Estos resultados son similares a los obtenidos por Martínez-Gómez et al. (2011) y Van Dijk et al. (2014), que hallaron asociación positiva entre el desplazamiento activo al Centro educativo y el rendimiento cognitivo solo en chicas. Algo similar ocurre con los resultados de asociación que Kwak et al. (2009), hallaron entre AF y RA en adolescentes suecas, y con los de Ruiz-Ariza et al. (2016), en adolescentes españolas. Para estos autores el RA podría verse incrementado en chicas por la práctica de AF o por el simple disfrute con esta práctica, respectivamente, pero solo si se llevaba a cabo a una intensidad alta o vigorosa.

Aunque el efecto del ejercicio vigoroso está ampliamente contrastado (Kwak et al., 2009; Ruiz-Ariza et al., 2016; So, 2012), nuestros hallazgos y los obtenidos por Hillman et al. (2009), Martínez-Gómez et al. (2011), Stock et al. (2012), Van Dijk et al. (2014), y Domazet et al. (2016), demuestran que el desplazamiento activo al Centro educativo, a pesar de estar considerado como de intensidad leve o moderada, influye también positivamente sobre el rendimiento cognitivo y RA. Por tanto, la influencia de la intensidad del ejercicio físico sobre el RA es un factor más a estudiar, ya que podría tener efectos distintivos en las funciones cerebrales (Liu et al., 2009; Martínez-Gómez et al., 2011; Reigal, Borrego, Juárez, y Hernández-Mendo, 2016).

Las causas por las que se obtiene diferente efecto sobre el RA en chicos y chicas no pueden ser explicadas a partir del presente estudio. Sin embargo, existen dos posibles razonamientos. Por un lado, el estrés ocasionado por los cambios biológicos y psicológicos de la adolescencia puede provocar problemas de ansiedad o depresión, sobre todo en chicas (Rudolph, 2002). Estos problemas tienen un efecto negativo sobre el RA a corto y largo plazo (Suhrcke y de Paz-Nieves, 2011). Se ha demostrado que la práctica de AF incrementa el factor neurotrófico derivado del cerebro (BDNF) (Ruiz-Ariza, Grao-Cruces, de Loureiro, y Martínez-López, 2016; Wrann et al., 2013), que es determinante en el aumento de las funciones cognitivas (Hillman et al., 2009) y en la prevención de la depresión en chicas (Autry, Adachi, Cheng, y Monteggia, 2009). En este caso, el desplazamiento activo al Centro educativo podría aumentar el BDNF, reducir el estrés, la ansiedad y la depresión, así como mejorar el RA. Por otro lado, el desplazamiento activo podría aumentar la producción y circulación del factor de crecimiento insulínico I (IGF-1). Este IGF-1 interactúa con el estrógeno femenino promoviendo la supervivencia neuronal y la neuroprotección (Van Dijk et al., 2014). Por último, el efecto diferencial del sexo podría encontrarse en la asociación entre las habilidades sociales y el RA. Algunos estudios han informado que el desplazamiento activo al Centro educativo favorece el contacto social entre vecinos y mejora las habilidades sociales (Giles-Corti, Foster, Shilton, y Falconer, 2010). Durlak, Weissberg, Dymnicki, Taylor, y Schellinger (2011), asociaron las anteriores mejoras con un aumento de los resultados académicos. Sin embargo, aunque las chicas podrían mostrar mejores habilidades sociales que los chicos (Garaigordobil y Durá, 2006), no tenemos evidencia de que las chicas del presente estudio se hayan visto afectadas por los beneficios sociales del desplazamiento activo en mayor medida que los chicos, y por tanto, obtengan mejor RA.

El presente estudio presenta un alto grado de similitud con resultados previos que han puesto el foco en distintos tipos de AF en jóvenes y su relación con el rendimiento cognitivo y académico. Haapala et al. (2014), en jóvenes finlandeses, y Ruiz et al. (2010), en adolescentes españoles, mostraron que la AF extraescolar no perjudica al tiempo de estudio y al tiempo dedicado a la realización de tareas escolares, sino que esta AF influye positivamente en el rendimiento cognitivo en adolescentes. Por tanto, realizar un desplazamiento de forma activa al Centro educativo podría contribuir a alcanzar los niveles semanales necesarios de AF para influir positivamente en el RA en los jóvenes.

Existen algunas limitaciones que han de ser reconocidas. Por ejemplo, que al tratarse de un estudio transversal no permite establecer relaciones de causalidad. El cuestionario se encuentra en fase de validación, por lo que aún no podemos afirmar que sea válido y fiable. Las respuestas del mismo son auto informadas por los adolescentes que en algunos casos podrían haber sido contestadas erróneamente de forma deliberada o sin mala intención. Además, no se incluyen otras importantes covariables como el estatus socioeconómico familiar. Aunque estos errores podrían haberse visto reducidos ya que se ha utilizado la codificación para asegurar el anonimato y confidencialidad de los participantes y respuestas emitidas. Otras fortalezas pueden ser la amplia muestra utilizada incluyendo chicos y chicas, y el análisis de la relación entre variables hasta el momento muy poco estudiadas.

Conclusiones

Se concluye que desplazarse al instituto andando, al menos cinco trayectos semanales superiores a 15 minutos/día, se relaciona con calificaciones más altas en Matemáticas, Educación Física y RA general en chicas adolescentes españolas. Fomentar el desplazamiento activo, especialmente en las chicas, desde el ámbito escolar, y familiar puede ser potencialmente relevante para mejorar el RA.

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IV

Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015

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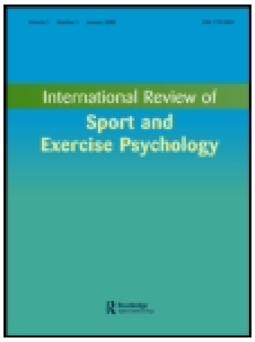

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Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015

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ABSTRACT

Background: The aim of this systematic review was to investigate the association of different components of physical fitness on cognitive performance (CP) and academic performance (AP) in adolescents, taking into account potential confounders.
Method: Studies were identified in four databases (Pubmed, SportDiscus, Web of Science, and ProQuest) from January 2005 through to January 2015. A total of 21 articles met the inclusion criteria. *Results*: 8 studies showed association between physical fitness and CP, and 11 studies with AP. Cardiorespiratory fitness, speed-agility, motor coordination, and perceptual-motor skill are the highest measures associated with CP and AP. However, the findings on strength and flexibility are unclear. Finally, 62% of the 21 studies used confounders. The most controlled confounder were socioeconomic status, fatness, pubertal status, sex, and age.
Conclusion: Fitness is associated with higher CP and AP. More research is needed in order to understand the causes of the differential effect of physical fitness components on CP and AP.

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physical fitness; cognitive performance; academic performance; confounder; adolescents; systematic review

Introduction

Physical fitness refers to the full range of physical qualities of cardiorespiratory fitness (CRF), muscular strength, speed-agility, coordination, flexibility, or body composition (Castro-Piñero et al., 2010; Ruiz et al., 2009). Substantial data have demonstrated the role of physical fitness for improving the musculoskeletal system (Ortega, Ruiz, Castillo, & Sjöström, 2008), preventing psychological risk factors (including depression, anxiety, and psychological stress) (Caputo & Simon, 2013; Lavie, Milani, O'Keefe, & Lavie, 2011), decreasing the risk of cardiometabolic diseases (Ortega et al., 2008), and reducing the risk of all-causes of premature mortality (Ortega, Silventoinen, Tynelius, & Rasmussen, 2012). Furthermore, in recent years a growing number of studies have also shown the relationship between physical fitness and cognitive performance (CP) and academic performance (AP) in children (Castelli, Hillman, Buck, & Erwin, 2007; Haapala, 2013; Torrijos-Niño et al., 2014) and adolescents (Ardoy et al., 2014; Chen, Fox, Ku, & Taun, 2013; Coe, Peterson, Blair, Schutten, & Peddie, 2013).

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CP is affected by the inhibitory control and executive functions, which are the factors responsible for the maintenance of information in working memory, planning and mental organisation, selective attention, and behaviour control (Diamond, 2013; Haapala, 2013). Physical fitness could optimise the above functions because it promotes an increase of cerebral blood flow and synaptic plasticity (Pareja-Galeano et al., 2013), and an increase in the brain-derived neurotrophic factor (BDNF) levels that support the survival and growth of neurons (Noakes & Spedding, 2012; Wrann et al., 2013). These physiological adaptations could improve learning ability (Chaddock-Heyman et al., 2014a; Wrann et al., 2013) and may have a positive influence on subsequent AP (Chaddock-Heyman et al., 2014a; Tomporowski, McCullick, Pendleton, & Pesce, 2015).

AP refers to adolescents' success in secondary school, measured by grade point averages or by the child meeting standardised performance tests (Haapala, 2013). In addition to CP, other factors such as teachers' assessment of student attitudes, interest, participation, and attendance in class can influence on AP (Gutiérrez & López, 2012). Likewise, AP may be mediated by other socioeconomic variables, such as education level and occupation of parents (Castillo et al., 2011), family influence, sociocultural context, teacher opinion (Keeley & Fox, 2009), duration of breastfeeding (Victora et al., 2015), general emotional well-being of the child (Morales & López-Zafra, 2009), self-perception of competence, and setting goals and study strategies for young people (Caso-Niebla & Hernández-Guzmán, 2007). Therefore, to study the association of physical fitness with cognition, it is essential to separate CP from AP. In addition, it is necessary to know the differential result compared to other variables, such as age, sex, BMI and socioeconomic status (SES), as these could influence the results of association due to their importance during adolescence. In fact, the main limitation of the current research is that there is no consensus about the most influential confounders on the association between physical fitness and AP (Esteban-Cornejo et al., 2014a).

Longitudinal and cross-sectional studies that analyse the relationship of different components of physical fitness with CP and AP have proliferated over the last decade (Aberg et al., 2009; Castelli et al., 2007; Esteban-Cornejo et al., 2014a; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011; Wittberg, Northrup, & Cottrel, 2008). However, the results are inconclusive, and we are not aware of any review that has specifically compared the influence of each physical fitness component—CRF, muscular strength, speed-agility, motor coordination, flexibility, or body composition—with CP and AP in adolescents.

On the other hand, previous reviews have studied the association of physical activity (PA) with CP and AP in children and adolescents and have produced divergent results (Chaddock-Heyman, Hillman, Cohen, & Kramer, 2014b; Esteban-Cornejo, Tejero-Gonzalez, Sallis, & Veiga, 2015a; Fedewa & Ahn, 2011; Haapala, 2013; Rasberry et al., 2011; Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012; Tomporowski, Davis, Miller, & Naglieri, 2008). Possible causes are that most of the evidence comes from studies that do not recognise the multifactorial nature of the PA (Esteban-Cornejo et al., 2015a; Haapala, 2013). PA in adolescents is a very wide term that can refer equally to participation in sports (Bradley, Keane, & Crawford, 2013), PE classes (Ardoy et al., 2014), extracurricular PA (Esteban-Cornejo et al., 2014b), active commuting to school (Martínez-Gómez et al., 2011), moderate to vigorous physical activity (MVPA) (Syväoja, Tammelin, Ahonen, Kankaanpää, & Kantomaa, 2014; Van Dijk, De Groot, Savelberg, Van Acker, & Kirschner, 2014), or physical fitness (Haapala, 2013).

The question of this study is the following: '*Do the components of physical fitness influence on CP and AP in secondary school adolescents?*' This review focuses on adolescence because this is a key stage for consolidating healthy lifestyles and increasing physical fitness (Martínez-Gómez et al., 2011; Ortega et al., 2008). Furthermore, during this period there is a higher grade of brain plasticity (Romeo & McEwen, 2006) that is decisive for stimulating cognitive function (Ardoy et al., 2014). Understanding low/high physical fitness as a predictor of CP and AP could clarify the debate about the potential of physical fitness on cognition and decisions about the level of integration in education systems.

Therefore, the objective of the present systematic review was to investigate the associations of different components of physical fitness with CP and AP in adolescents. Additionally, this paper also reviewed potential mediators and moderators (i.e., socioeconomic variables, fatness or sex) that could influence the relationship of physical fitness with CP and AP.

Method

The study was designed following the structure and recommendation of other systematic reviews (Castro-Piñero et al., 2010; Esteban-Cornejo et al., 2015a; Ruiz et al., 2009) and the treatment used by PRISMA guidance for reports and studies (Moher, Liberati, Tetzlaff, & Altman, 2009).

Search limits

A comprehensive search of 4 databases of literature (PubMed, SportDiscus, Web of Science, and ProQuest) from January 2005 through to January 2015 was undertaken. Additionally, reference lists of the selected papers were reviewed. The principal categories of search terms were identified and used in different combinations:

(1) Physical fitness (physical education, physical fitness, cardiovascular, aerobic, musculoskeletal, strength, speed, agility, ability, coordination, flexibility).
(2) Academic performance (cognitive performance, academic performance, academic attainment, academic achievement, academic outcomes).
(3) Adolescent (adolescent, teenagers, children, childhood).

Table 1 shows the main terms used in the search for each category.

Selection criteria

The relevant papers selected for inclusion in the review were checked against the following criteria:

(1) The study was a full text report published in a peer-reviewed journal.
(2) The study population was a healthy community-based population.
(3) The study included papers written in English, with a population of high-school adolescents between 13 and 18 years of age.
(4) The study used a cross-sectional, longitudinal, or interventional design.
(5) There were no exclusion criteria with regard to ethnic origin.

Table 1. Search strategy in databases.

Database	Search Strategy	Limits	Filter
PubMed	('physical education' OR 'physical fitness') AND ('cognitive performance' OR 'academic performance' OR academic attainment OR academic achievement OR academic outcomes) AND (adolescents OR teenager OR children OR childhood)	• Publication date 2005/01/01–2015/01/31 • Humans • Adolescent: 13–18 years • English language	146 items filtered
SportDiscus (EBSCO)	TX ('physical fitness' OR fitness OR 'physical education') and TX ('cognitive performance' OR 'academic performance' OR 'academic attainment' OR 'academic achievement' OR 'academic outcomes') and TX (adolescent* OR children OR childhood OR teenager*)	• Publication date 2005/01/01–2015/01/31 • Humans • Peer-reviewed • English language • Research article	448 items filtered
Web of Science	('physical education' OR 'physical fitness') AND ('cognitive performance' OR 'academic performance' OR academic attainment OR academic achievement OR academic outcomes) AND (adolescent OR teenager OR children OR childhood)	• Publication date 2005/01/01–2015/01/31 • English language • Article or review	238 items filtered
PRoQuest ERIC	(ab('physical fitness' OR 'physical education' OR 'fitness')) AND (ab,ti(cognitive performance OR academic performance OR academic attainment OR academic achievement OR academic outcomes)) AND (ab,ti (adolescent OR children OR childhood OR teenager))	• Publication date 2005/01/01–2015/01/31 • Peer-reviewed • English language • Journal article	44 items filtered

Data extraction and reliability

Information on author, title, aim, sample size, age, study year, country, design, physical fitness measurement, CP and AP measurement, confounders, and main results/conclusions was extracted from all studies. The search process was carried out by three independent reviewers (ARA, AGC, EJML). The reviewers read every title and all the abstracts, and a consensus meeting was arranged to resolve any differences between them. The results of the most recent reviews were summarised first, then studies that were potentially relevant for the selected topics were screened for retrieval.

Quality assessment and level of evidence

The quality assessment of the question was carried out on the basis of other standardised assessment lists (Castro-Piñero et al., 2010; Ruiz et al., 2009) and on our selection criteria. The list included 6 items (A-F) on peer-reviewed journal, population, measurements, design, confounders, and report of the results. Each item was rated as '2' (fully reported), '1' (moderately reported) or '0' (not reported or unclear). For all studies, a total quality score was calculated by counting the number of positive items (a total score between 0 and 12). Three levels of evidence were constructed. Studies were defined as of high quality (HQ) if they had a total score of 9 or higher. A total score of 5 to 8 was defined as of medium quality (MQ), and a score of less than 5 was defined as low quality (LQ) (see Table 2).

Table 2. List of included studies with quality scores.

Authors and variables	A	B	C	D	E	F	Total score	Quality level
Planinsec and Pisot (2006). Motor coordination and intelligence level	2	2	2	1	2	0	**9**	**HQ**
Budde et al. (2008). Coordinative exercise and attentional performance	2	2	2	2	2	1	**11**	**HQ**
Aberg et al. (2009). CRF and cognition	2	2	2	1	2	2	**11**	**HQ**
Kwak et al. (2009). Fitness and AP	2	2	1	1	2	2	**10**	**HQ**
Stroth et al. (2009). Fitness, acute exercise and executive control	2	2	1	1	2	0	**8**	**MQ**
Travlos (2010). High intensity PE classes and CP	2	2	1	1	2	0	**8**	**MQ**
Welk et al. (2010). Fitness and AP	2	2	1	2	2	1	**10**	**HQ**
Ruiz et al. (2010). PA, fitness, weight status, and CP	2	2	2	2	2	2	**12**	**HQ**
Morales et al. (2011). PA, perceptual-motor performance and AP	2	2	1	1	2	0	**8**	**MQ**
London and Castrechini (2011). Fitness and AP	2	2	2	1	2	0	**9**	**HQ**
Chen et al. (2013). Fitness and AP	2	2	2	2	2	1	**11**	**HQ**
Kantomaa et al. (2013). PA, obesity, motor function and AP	2	2	1	1	2	2	**10**	**HQ**
Bass et al. (2013). Fitness and AP	2	2	1	1	2	1	**9**	**HQ**
Coe et al. (2013). Fitness, AP and SES	2	2	2	1	2	0	**9**	**HQ**
Hogan et al. (2013). Fitness, acute aerobic exercise and CP	2	2	1	2	2	0	**9**	**HQ**
Ardoy et al. (2014). PE class, fitness and, CP and AP	2	2	2	1	2	1	**10**	**HQ**
Bezold et al. (2014). Fitness and AP	2	2	1	2	2	2	**11**	**HQ**
Janak et al. (2014). Fitness and AP	2	2	1	2	2	1	**10**	**HQ**
Esteban-Cornejo et al. (2014a). Fitness and AP	2	2	2	2	2	2	**12**	**HQ**
Sardinha et al. (2014). Fitness, fatness and AP	2	2	2	1	2	1	**10**	**HQ**
Soga et al. (2015). Executive function and acute moderate aerobic exercise	2	2	1	1	2	0	**8**	**MQ**

Note: Rating for total score: high quality (HQ) = 9–12; medium quality (MQ) = 5–8; low quality (LQ) = 0–4. CRF = Cardiorespiratory Fitness. AP = Academic Performance. CP = Cognitive Performance. PA = Physical Activity. PE = Physical Education. A: The study was a full text report published in a peer-reviewed journal. B: The study population was healthy. C: The selected physical fitness, cognitive and AP outcomes were clearly described. D: Population was of high-school adolescents between 13 and 18 years of age. E: The study had a cross-sectional, longitudinal or interventional design. F: Data was adjusted for confounders.

Results

General findings

The flow of search results through the systematic review process is shown in Figure 1. After removal of duplicates and those excluded at title or abstract level, a total of 88 papers were retrieved. These potential studies were reviewed according to the selection criteria, on the basis of which, a total of 67 articles were excluded. Finally, 21 articles were included in the systematic review.

A detailed analysis of these studies showed that 10 were cross-sectional (48%) (Bass, Brown, Laurson, & Coleman, 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kwak et al., 2009; Morales, González, Guerra, Virgili, & Unnithan, 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010; Sardinha, Marques, Martins, Palmeira, & Minderico, 2014; Welk et al., 2010), 4 were longitudinal with cohorts (19%) (Bezold et al., 2014; Chen et al., 2013; Kantomaa et al., 2013; London & Castrechini, 2011), 1 was cross-sectional and longitudinal with cohort (5%) (Aberg et al., 2009), and 6 were intervention studies (29%) (Ardoy et al., 2014; Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Hogan et al., 2013; Soga, Shishido, & Nagatomi, 2015; Stroth et al., 2009; Travlos, 2010). Ardoy et al. (2014), Budde et al. (2008), Soga et al. (2015), used a group-randomised controlled trial. However, Hogan et al. (2013), Stroth et al. (2009); and Travlos, 2010 used a non-randomised controlled trial. With regard to quality assessment, 17 papers were of high quality and 4 of medium quality (Table 2). This review includes

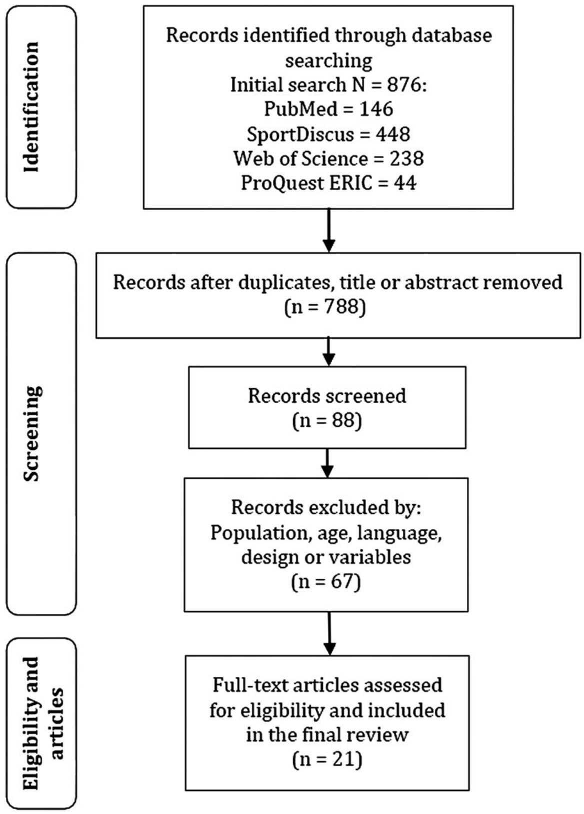

Figure 1. Flow of articles through the search process.

data from 3,910,791 individuals, and the sample size of the studies varied from 30 (Hogan et al., 2013) to 2,550,144 (Janak et al., 2014) participants. The samples were from 10 different countries: 1 study was conducted in Slovenia (Planinsec & Pisot, 2006), 3 in Germany (Budde et al., 2008; Hogan et al., 2013; Stroth et al., 2009), 2 in Sweden (Aberg et al., 2009; Kwak et al., 2009), 1 in Greece (Travlos, 2010), 6 in the USA (Bass et al., 2013; Bezold et al., 2014; Coe et al., 2013; Janak et al., 2014; London & Castrechini, 2011; Welk et al., 2010), 4 in Spain (Ardoy et al., 2014; Esteban-Cornejo et al., 2014a; Morales et al., 2011; Ruiz et al., 2010), 1 in Taiwan (Chen et al., 2013), 1 in Finland (Kantomaa et al., 2013), 1 in Portugal (Sardinha et al., 2014), and 1 in Japan (Soga et al., 2015). Detailed information about all the studies is presented in Table 3.

Physical fitness, cognitive performance, and academic performance measurement

Physical fitness measures used in each study are shown in Table 3: 20 studies used objective measures to assess physical fitness, and only 1 study used another measure (parent-reported motor function) (Kantomaa et al., 2013); 17 studies assessed CRF (Aberg et al., 2009; Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Hogan et al., 2013; Janak et al., 2014; Kwak

Table 3. Characteristics of the analysed studies ($N = 21$).

Authors and variables	Study design / Confounders / Duration	Sample / age/ Country	Physical fitness measures	CP and AP measures	Results
Planinsec and Pisot (2006). Motor coordination and intelligence level	Cross-sectional / Nothing / —	550 / 13.1 years / Slovenia	Motor coordination across eight tests: (a) coordination of movement in rhythm (tests: drumming with the hands, drumming with the hands and feet); (b) hand-eye coordination (test: match juggling); (c) whole-body coordination (tests: polygon backward, climbing and descending); (d) performance of complex coordination movements (tests: running while changing directions, running around two stands with obstacles, running, rolling, crawling).	Intelligence was carried out with test TN-20. This test is intended to measure fluid intelligence, i.e., the general neurophysiologic capacity of the central nervous system for information processing.	Results showed differences between the above- and below-average intelligence groups in: drumming with the hands, drumming with the hands and feet, match juggling, polygon backward running while changing directions, running around two stands with obstacles, and running, rolling, and crawling. In all these tests the above-average intelligence group achieved better results ($p < .05$). There were no significant differences between above- and below-average intelligence groups in the motor coordination test of climbing and descending ($p > .05$).
Budde et al. (2008). Coordinative exercise and attentional performance	Interventional / Heart rate / 10 min	115 / 13–16 years / Germany	Two groups: Experimental group: 10 min of coordinative exercises, within these exercises different bilateral coordinative abilities were stressed within short periods of time: for example, the ability to balance, to react, to adjust, and to differentiate. Control group: 10 min of a normal sport lesson at a moderate intensity without any specific coordinative request.	Neuropsychological performance assessed in the areas of attention and concentration using the d2-test.	Coordinative exercise was more effective in completing the concentration and attention task ($p < .01$). With the heart rate being the same in both groups, authors assume that the coordinative character of the exercise might be responsible for the significant differences. Results were achieved with students who practise sport every day (25–30 h per week). Consequently these results support the demand for more acute coordinative exercise in schools.

Aberg et al. (2009). CRF and cognition	Cross-sectional and longitudinal / conscription year, conscription test centre, father's education, and mother's education / 3 years	1,221,727 Swedish male subjects / 15–18 years / Sweden	CRF measured by ergometer cycling. Isometric muscle strength was measured by knee extension, elbow flexion, and handgrip.	Cognitive tests: logical performance test, verbal test of synonyms and opposites, test of visuospatial/ geometric perception, and technical/ mechanical skills including mathematical/physics problems. Performance on all 4 tests was combined to obtain a global intelligence (general cognitive ability).	CRF, not muscular strength, at age 18 years is associated with CP. Associations between CRF and CP remained even after adjusting for relevant confounders. Change in CRF between ages 15 and 18 years predicted global intelligence at age 18 years. Similar results were obtained for logical, verbal, visuospatial, and technical scores. Moreover, CRF during early adulthood predicted SES and educational attainment later in life (all $p < .05$).
Kwak et al. (2009). Fitness and AP	Cross-sectional / CRF, mother's education for SES, family structure, parental monitoring, sex, pubertal phase, and sum of skinfolds / —	232 / 15–16 years / Sweden	Aerobic PA was measured with an accelerometer. The average minutes per day spent in light (<3 METs), moderate (3–6 METs), and vigorous (>6 METs) PA.	AP was assessed through 17 school subjects (Swedish, English, Biology, Chemistry, Physics, Mathematics, Social Sciences, History, Geography, Religion, PE, Health, and 5 additional subjects of preference). The sum of grades for the 17 subjects was used.	After controlling for confounding factors, AP was associated with vigorous PA in girls (ß = 0.30, $p < .01$), which remained after inclusion of CRF (ß = 0.23, $p < .05$). In boys, AP was associated with pubertal phase (ß = 0.25, $p < .05$). After inclusion of CRF, it was only associated with CRF (ß = 0.25, $p < .05$).
Stroth et al. (2009). Fitness, acute exercise, and executive control	Interventional (controlled cross-over study) / Nothing / 20 min	35 higher- and lower-fit adolescents / 13–14 years / Germany	20 min of acute aerobic exercise and 20 min of rest, sitting on the cycling ergometer for 20 min in both conditions to keep them as similar as possible.	Eriksen flanker task with event-related potential recordings.	Results provide additional evidence for the beneficial effects of fitness on cognition across the human lifespan. While fitness was associated with reliable effects ($p < .05$), acute exercise did not affect event-related potentials in comparison to rest. This suggests that the long-term effects of PA are more robust than short-term effects after a single bout of exercise.

(*Continued*)

Table 3. Continued.

Authors and variables	Study design / Confounders / Duration	Sample / age/ Country	Physical fitness measures	CP and AP measures	Results
Travlos (2010). High intensity PE classes and CP	Interventional / Nothing / 4 PE classes	48 / 13–15 years / Greece	Intervention task: an interval aerobic run was employed to increase PA during four PE classes that met at different times during the school day.	A 2-min mathematics task	The intense interval aerobic run significantly affected numeric speed and accuracy of simple addition problems (all $p < .05$). Students who attended the 1st, 3rd, and 5th hour of the daily classes had significantly higher AP, while the AP of students who attended the 6th-hour PE class was decreased.
Welk et al. (2010). Fitness and AP	Cross-sectional / SES, minority status, and school size / 2007–2008	36,835 / 6–18 years / USA	CRF (PACER) and BMI.	AP data from the Texas Education Agency (TAKS).	Mixed-model regression analyses revealed modest associations between fitness and AP after controlling for confounders. The effects of fitness on AP were positive but small. A separate logistic regression analysis indicated that higher fitness rates increased the odds of schools achieving exemplary/ recognised school status.
Ruiz et al. (2010). PA, fitness, weight status, and CP	Cross-sectional / sex, age, pubertal status, SES, family structure, CRF, strength, and BMI / 2000–2002	1820 / 13–18,5 years / Spain	Self-reported participation in physical sport activity during leisure time. CRF (PACER), muscular strength (dynamometer and standing long jump test), and BMI.	CP (Verbal, numeric and reasoning abilities, and an overall score) was measured by the Spanish version of the SRA-Test of Educational Ability.	Participation in physical sports activities during leisure time was associated with better CP ($p < .001$), independent of potential confounders (CRF and BMI). CRF was not associated with CP. Neither upper body nor lower body muscular strength was associated with CP. CP was similar across weight status categories.

Morales et al. (2011). PA, perceptual-motor performance, and AP	Cross-sectional / Nothing / —	487 / 9–16 years: 2 groups: 9–12 years and 13–16 years / Spain	Perceptual-motor skills (fine motor skills: tower of cubes; gross motor skills: target throwing).	Two subtests from BADYG to assess cognitive skills (mathematics skills and oral skills).	Tower of cubes (fine motor skills) and age were predictors of linguistic skills and mathematics skills in adolescents ($r^2 = 0.45$). thus, this study suggests that enhanced motor skills are associated with better AP.
London and Castrechini (2011). Fitness and AP	Longitudinal / Nothing / From the 2002–2003 to 2007–2008 school years	2 cohorts of students: 1325 / Grade 4–7 (9–13 years) / USA 1410 / Grade 6–9 (12–15 years) / USA	CRF (PACER), body composition, abdominal strength and endurance, trunk extensor strength and endurance, upper body strength and endurance, and flexibility.	California standardised test in mathematics and English language arts.	Comparing those who are persistently fit to those who are unfit, authors find disparities in both mathematics and English language arts test scores ($p < .05$). These AP disparities begin even before students begin fitness testing in Grade 5 and are larger for girls and Latinos. Overall fitness is a better predictor of AP than BMI. SES acts as a buffer for those who have poor fitness but strong AP.
Chen et al. (2013). Fitness and AP	Longitudinal / Sex and parents' SES (parents' occupation and education) / Data were collected on 6 occasions across 3 school years: 2008–2011	669 / 7–9th grade (14,6 years) / Taiwan	CRF (1600 boys/800 girls-meter run), sit-and-reach flexibility, bent-leg curl-ups (test abdominal muscle strength and endurance during 1 minute), and BMI.	Language, Mathematics, Science, and Social Studies.	The results showed that improvement in CRF ($p < .01$), but not muscular endurance or flexibility, is significantly related to greater AP. A weak and non-significant AP-BMI relationship was seen.

(*Continued*)

Table 3. Continued.

Authors and variables	Study design / Confounders / Duration	Sample / age/ Country	Physical fitness measures	CP and AP measures	Results
Kantomaa et al. (2013). PA, obesity, motor function, and AP	Longitudinal / Self-reported MVPA at age 16 years, CRF, self reported BMI, early academic impairment, sex, mother's highest level of education when the adolescent was 16 years old / 8 years	8.061 / 8–16 years / Finland	Parent-reported motor function (gross and fine motor skills) at age 8 years.	GPA at age 16 years, calculated as a measure of: mother tongue (in most cases Finnish or Swedish), first foreign language (started at Grade 3), second foreign language (started at Grade 7), mathematics, biology, geography, physics, chemistry, religion or ethics, history, music, visual arts, PE, crafts and home economics.	Compromised motor function in childhood predicted lower levels of PA, poor CRF, and higher levels of obesity in adolescence ($p < .01$). Furthermore, higher levels of PA were associated with a higher GPA, and obesity with a lower GPA in adolescence ($p < .01$). Compromised motor function had a negative indirect effect on GPA via lower levels of PA and obesity, but not via CRF. Thus, PA and obesity may mediate the association between childhood motor function and adolescents' AP.
Bass et al. (2013). Fitness and AP	Cross-sectional / Age and participation in the National School Lunch Programme as indicator of SES / —	838 / 13 years / USA	CRF (PACER). Muscular strength and muscular endurance were assessed using the push-up test and one-minute curl-up test, respectively. Sit and reach was used for flexibility. For body composition, BMI and body fat percentage using a bioelectrical impedance analyser were used.	The Illinois Standardised Achievement Test was used to assess AP in reading and mathematics.	The largest correlations were seen for CRF and muscular endurance (ranging from 0.12 to 0.27, all $p < .05$). Boys in the Healthy Fitness Zone for CRF or muscular endurance were 2.5–3 times more likely to pass their mathematics or reading exams. Girls in the Healthy Fitness Zone for CRF were approximately 2–4 times as likely to meet or exceed reading and mathematics test standards, controlling for SES and age.

Coe et al. (2013). Fitness, AP, and SES	Cross-sectional / Nothing / 2008	1.701 / 8–12–15 years / USA	CRF (PACER), muscular strength, muscular endurance, flexibility, and body composition).	Standardised tests for mathematics, English, and Social Studies.	There were no significant differences between fitness groups for mathematics and English in Grade 3 students. Grade 6 and Grade 9 students with high fitness scored significantly better on mathematics and Social Studies tests compared with less fit students ($p < .05$). Muscular strength and muscular endurance were associated with AP in all grades.
Hogan et al. (2013). Fitness, acute aerobic exercise, and CP	Interventional / Nothing / 20 min	30 / 14,2 years / Germany	Fitness was assessed by a continuous-graded maximal exercise test. Participants were divided into two groups according to a median split into relatively fit and unfit groups. Participants were then assigned to the study with two recording sessions, one following a 20-min bout of exercise on a stationary bike at a moderate intensity and one following a 20-min period of rest.	CP and coherence of the EEG (Eriksen flanker task with EEG recordings).	Fit participants had faster reaction times in the exercise condition in comparison with the rest condition. The results suggest that fitness and acute exercise may enhance CP by increasing functionality of the attentional system in adolescence. This study highlights the importance of intervention programmes providing PA for adolescents, which may improve attention and CP at school and in everyday life.

(*Continued*)

Table 3. Continued.

Authors and variables	Study design / Confounders / Duration	Sample / age/ Country	Physical fitness measures	CP and AP measures	Results
Ardoy et al. (2014). PE class, fitness, CP, and AP	Intervention / Sex, sexual maturation, attendance and baseline values of the dependent variable studied as covariates / 4 months	67 / 13 years / Spain	Adolescents in the CG (control group) received the usual PE sessions (55 min sessions twice per week). Adolescents in the EG1 (experimental group 1) had 4 PE sessions per week, with the same aims, contents and pedagogical strategies as the sessions taken by CG. Adolescents in the EG2 received four PE sessions per week of high intensity. The time devoted to the rest of academic subjects was the same for the three groups. Additionally, CRF (PACER), muscular strength (standing long jump test), and speed-agility (4 × 10-m shuttle run test) were assessed.	CP was assessed by the medium version of the Spanish Overall and Factorial Intelligence Test (IGF-M) (nonverbal and verbal abilities, abstract reasoning, spatial ability, verbal reasoning and numerical ability). AP was assessed by grades in mathematics, Spanish Language, Foreign Language-English, Social Sciences, Natural Sciences, Technology, Plastic-Visual Education and Music, average score from all subjects (includes PE), and average score from all subjects excluding PE.	All CP indicators improved significantly in adolescents from the EG2, compared with those from the CG and EG1 (all $p < .001$), and verbal reasoning ($p = .02$). No difference between CG and EG1 in CP. Adolescents from the EG2 had an improved average AP (a score including all the subjects) compared with the CG and the EG1 ($p < .001$). The differences were significant for mathematics ($p = .02$) and other subjects, including Technology ($p < .001$), Natural Sciences ($p < .001$), and PE ($p < .001$). AP indicators improved in most of adolescents in EG2 (average for all school subjects = 96% and = 78% when excluding PE). Additional analyses showed that improvements in speed-agility and CRF were correlated with improvements in CP. No associations were observed between changes in fitness and changes in AP.

Bezold et al. (2014). Fitness and AP	Longitudinal / Race and/or ethnicity, language spoken at home, days absent from school, place of birth, student household poverty, National School Lunch Program, and obesity status / Between 2006–2007 and 2011–2012	83,111 / K-12 (6–18 years) / USA	CRF (PACER), push up, and curl-up tests. For each student, the change in fitness was calculated for three periods: Grade 5–6, Grade 6–7, Grade 7–8.	New York State standardised assessments in English Language Arts and mathematics. Raw scores were used to calculate grade-specific percentile scores separately for mathematics and English Language Arts for each year of data (2006–2007 to 2010–2011). mathematics and English Language Arts percentiles for each student were summed, and a new grade-specific percentile was calculated based on the sum.	For girls and boys, a substantial increase in fitness from the previous year resulted in a greater improvement in academic ranking than was seen in the reference group (girls: 0.36 greater percentile point improvement, 95% CI [0.09, 0.63]; boys: 0.38 greater percentile point improvement, 95% CI [0.09, 0.66]). A substantial decrease in fitness was associated with a decrease in AP in both boys and girls. Effects of fitness on AP were stronger in high-poverty boys and girls than in low-poverty boys and girls.
Janak et al. (2014). Fitness and AP	Cross-sectional / SES, grade category stratified by sex / 2008–2009	2,550,144 / Grades 3–12 (8–18 years) / USA	CRF (PACER and the 1-mile run) and BMI	TAKS subject material included English language arts, reading, writing, mathematics, science, and social studies with content varying by grade level.	This was the first study to describe and analyse this association by geopolitical regions. The prevalence of students meeting the TAKS standard was significantly higher in the highest fitness category for BMI and CRF compared to all other categories, regardless of sex or grade category. Linear modelling suggested a 5% increase in the prevalence of students meeting healthy BMI and CRF standards would result in a 2.25% and 0.65% increase in the prevalence of students meeting the TAKS standard.

(*Continued*)

Table 3. Continued.

Authors and variables	Study design / Confounders / Duration	Sample / age/ Country	Physical fitness measures	CP and AP measures	Results
Esteban-Cornejo et al. (2014a). Fitness and AP	Cross-sectional / sex, age, city, pubertal status, maternal education, fitness, and fatness / 2011–2012	2.038 / 6–18 years / Spain	CRF (PACER). Motor ability (4 × 10-m shuttle run test). Muscular strength (z-score with handgrip strength and standing long jump test).	AP assessed through school records using 4 indicators: mathematics, Language, an average of mathematics and Language, and grade point average score.	CRF and motor ability were independently associated with all AP variables in youth, even after adjustment for fitness and fatness indicators (all $p < .001$), whereas muscular strength was not associated with AP independent of the other 2 physical fitness components. In addition, the combined adverse effects of low CRF and motor ability on AP were observed across the risk groups (p for trend < .001).
Sardinha et al. (2014). Fitness, fatness, and AP	Cross-sectional / Gender, weight status, CRF and different cohorts / 2009–2011	1531 / 12–14 years / Portugal	CRF (PACER). Participants were classified as fit and unfit. Weight status (BMI): Participants were classified into normal weight and overweight or obese, according to the International Obesity Task Force.	AP measured using the marks students, at the end of their academic year, in mathematics, language (Portuguese), foreign language (English), and sciences.	CRF and BMI were independently related with AP. Fit students, compared with unfit students had higher odds for having high AP (OR = 2.29, 95% CI [1.48, 3.55], p <0.001). Likewise, having a normal weight status was also related with high AP (OR = 3.65, 95% CI [1.82, 7.34], $p < .001$).
Soga et al. (2015). Executive function and acute moderate aerobic exercise	Interventional / Nothing / exercise session, 13.3 ± 2 min; rest session, 13 ± 2 min	55 / 15–16 years / Japan	2 experiments, both in separate sessions, with the same testing model: Experiment 1: $n = 28$; walking on a treadmill at 60% maximal heart rate. Experiment 2: $n = 27$; walking on a treadmill at 70% maximal heart rate).	A modified flanker task and a modified n-back task to assess inhibitory control and working memory before, during, and after walking on a treadmill at moderate intensity.	Reaction time for working memory increased during exercise in both experiments, while response accuracy decreased during exercise only at 70% maximal heart rate. Moderate intensity exercise had no substantial effect on inhibition control. Following cessation of the exercise, no effects were observed for either executive function assessment.

Note: CRF = Cardiorespiratory Fitness. PE = Physical Education. PA = Physical Activity. SES = Socioeconomic Status. CP = Cognitive Performance. AP = Academic Performance. BMI = Body Mass Index. MVPA = Moderate to Vigorous Physical Activity. GPA = Grade-point Average. EEG = Electroencephalogram. PACER = Progressive Aerobic Capacity Endurance Run. TAKS = Texas Essential Knowledge and Skills.

et al., 2009; London & Castrechini, 2011; Ruiz et al., 2010; Sardinha et al., 2014; Soga et al., 2015; Stroth et al., 2009; Travlos, 2010; Welk et al., 2010), 9 studied muscular strength (Aberg et al., 2009; Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; London & Castrechini, 2011; Ruiz et al., 2010), 2 speed-agility (Ardoy et al., 2014; Esteban-Cornejo et al., 2014a), 2 motor coordination (Budde et al., 2008; Planinsec & Pisot, 2006), 2 perceptual-motor skill (Kantomaa et al., 2013; Morales et al., 2011); 4 included flexibility (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; London & Castrechini, 2011), 8 added fatness (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; Janak et al., 2014; London & Castrechini, 2011; Ruiz et al., 2010; Sardinha et al., 2014; Welk et al., 2010), and 1 studied MVPA measured with accelerometers, analysing the mediation of CRF (Kwak et al., 2009). To evaluate CRF, 11 studies used the 20-m shuttle run test (PACER) (Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; London & Castrechini, 2011; Ruiz et al., 2010; Sardinha et al., 2014; Welk et al., 2010), 4 used ergometer cycling (Aberg et al., 2009; Hogan et al., 2013; Kwak et al., 2009; Stroth et al., 2009), 1 used an intense interval aerobic run (Travlos, 2010), and another used a walk on a treadmill at moderate intensity (Soga et al., 2015). To assess muscular strength, the most widely used measures were the curl up test (Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; London & Castrechini, 2011), the push up (Bass et al., 2013; Bezold et al., 2014; Coe et al., 2013), and manual dynamometer and the standing long jump test (Esteban-Cornejo et al., 2014a; Ruiz et al., 2010). Speed-agility was assessed with the 4×10-m shuttle run test (Ardoy et al., 2014; Esteban-Cornejo et al., 2014a). Motor coordination was evaluated with specific tests (Planinsec & Pisot, 2006) or with exercises of bilateral coordinative skills for short periods of time (Budde et al., 2008). Perceptual-motor skills were performed through fine and gross motor skills (Kantomaa et al., 2013; Morales et al., 2011). With regard to flexibility, the 4 studies used sit-and-reach test (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; London & Castrechini, 2011). Finally, fatness was mostly assessed on the basis of BMI (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; Janak et al., 2014; London & Castrechini, 2011; Ruiz et al., 2010; Sardinha et al., 2014; Welk et al., 2010).

A wide variety of tests of general intelligence, neuropsychology capacity, verbal capacity, visual perception, mathematical ability, inhibitory control, or working memory (Aberg et al., 2009; Ardoy et al., 2014; Budde et al., 2008; Hogan et al., 2013; Morales et al., 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010; Soga et al., 2015; Stroth et al., 2009; Travlos, 2010) were used to assess CP. Indirect tests were also used: that is, questionnaires or validated cognitive tests (Aberg et al., 2009; Ardoy et al., 2014; Budde et al., 2008; Morales et al., 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010; Travlos, 2010), and brain function direct tests, i.e., electroencephalographic (EEG) (Hogan et al., 2013; Soga et al., 2015; Stroth et al., 2009). However, AP assessment shows fewer dispersion measures, and most of the studies use average of numeric scores in different academic subjects, mainly mathematics and language scores (Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kantomaa et al., 2013; Kwak et al., 2009; London & Castrechini, 2011; Sardinha et al., 2014; Welk et al., 2010).

Physical fitness and cognitive performance

Among the 10 studies that examined the association between physical fitness and CP (Aberg et al., 2009; Ardoy et al., 2014; Budde et al., 2008; Hogan et al., 2013; Morales et al., 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010; Soga et al., 2015; Stroth et al., 2009; Travlos, 2010), 1 was a longitudinal study (Aberg et al., 2009), 6 were interventional (Ardoy et al., 2014; Budde et al., 2008; Hogan et al., 2013; Soga et al., 2015; Stroth et al., 2009; Travlos, 2010), and 3 were cross-sectional studies (Morales et al., 2011; Planinsec & Pisot, 2006; Ruiz et al., 2010). The first study showed that improvement in CRF between 15 and 18 years predicts CP at the age of 18; however, this effect was not found in the case of muscular strength (Aberg et al., 2009). Among the interventional studies, it was found that improvement in PE class intensity, through interval aerobic runs, has a positive influence on numeric speed and on solving simple mathematics problems (Travlos, 2010). Ardoy et al. came to a similar conclusion with the above effect after an increase in the intensity and number of PE classes and after improvements in speed-agility and CRF (Ardoy et al., 2014). A further 2 intervention studies showed a strong positive effect on CP after 10 minutes of coordination exercise (Budde et al., 2008) and 20 minutes of aerobic moderate exercise (Hogan et al., 2013). Nevertheless, 2 similar studies, based on 13 (Soga et al., 2015) or 20 (Stroth et al., 2009) minutes of moderate aerobic exercise, did not achieve significant effect. Finally, while 2 cross-sectional studies did show a positive relation between physical fitness and CP (Morales et al., 2011; Planinsec & Pisot, 2006), a further study did not find a significant association (Ruiz et al., 2010).

Physical fitness and academic performance

A total of 12 studies examined the association between physical fitness and AP (Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kantomaa et al., 2013; Kwak et al., 2009; London & Castrechini, 2011; Sardinha et al., 2014; Welk et al., 2010). Of these studies, 4 used a longitudinal design (Bezold et al., 2014; Chen et al., 2013; Kantomaa et al., 2013; London & Castrechini, 2011), 1 was interventional (Ardoy et al., 2014), and 7 were cross-sectional studies (Bass et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kwak et al., 2009; Sardinha et al., 2014; Welk et al., 2010). With regard to the first group of studies, London and Castrechini (2011) found that fit young people achieve better mathematics and language scores than those who are unfit. Two studies revealed that an increase in fitness from childhood has a significant influence, with better AP for adolescence (Bezold et al., 2014; Kantomaa et al., 2013). However, a separate analysis of the influence of each fitness component showed that only CRF was related with higher AP (Chen et al., 2013). With regard to the interventional study, Ardoy et al. (2014) showed that the raise of number and intensity of PE weekly classes, positively affects AP. Nevertheless, for these authors, improvements in CRF, muscular strength or speed-agility, did not lead to a significantly increased AP (Ardoy et al., 2014). Finally, 4 of the 7 cross-sectional studies revealed an association between CRF and AP after adjusting for potential confounders (Janak et al., 2014; Kwak et al., 2009; Sardinha et al., 2014; Welk et al., 2010), although in 1 of them, the association was weak (Welk et al., 2010). In another cross-sectional study, Coe et al. (2013) showed a significant association between higher fitness scores (Healthy Fitness Zone of Fitnessgram) and AP. A further study with the same design, but controlling by SES and age, showed that CRF was positively associated with AP in mathematics and reading, mostly in girls rather than boys (Bass et al., 2013). Esteban-Cornejo et al. (2014a), in another cross-sectional study, found positive associations of CRF and motor-agility with AP, although this association was not significant with regard the muscular strength.

Discussion

This systematic review has researched the association of different components of physical fitness with CP and AP in adolescents. Studies from 2005 to January 2015 were obtained from 4 databases. A total of 21 articles met the inclusion criteria: 10 studies used a cross-sectional design, 6 were intervention studies, 4 were longitudinal, and only 1 study included a double design that was cross-sectional and longitudinal. The physical fitness variables used were CRF, muscular strength, speed-agility, motor coordination, perceptual-motor skill, flexibility, and fatness. Of the 21 studies, 62% used confounders. The most controlled confounder was SES. Fatness was also widely used, measured through the sum of skinfold, BMI, or waist circumference. Pubertal status, sex, or age were also included as confounders. A majority of the studies showed a positive association of physical fitness with CP and AP. Eight studies showed association between physical fitness and CP, and only 2 studies found no association (Ruiz et al., 2010; Soga et al., 2015). A better physical fitness was associated with higher AP in 11 studies (Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kantomaa et al., 2013; Kwak et al., 2009; London & Castrechini, 2011; Sardinha et al., 2014; Welk et al., 2010), while 1 study found no relation (Ardoy et al., 2014). CRF, speed-agility, motor coordination, and perceptual-motor skill are the components that are mostly associated with CP and AP in adolescents, while the relationship with regard to muscular strength and flexibility has been less studied and the results are unclear.

These results suggest that physical fitness can be a factor with potential for cognitive and academic development during adolescence. This is especially so because physical fitness contributes to the acceleration of psychomotor development, decreases anxiety and stress, and increases self-esteem, all of which are closely related with AP (Tremblay, Inman, & Willms, 2000). Likewise, physical fitness could improve the student's behaviour in a learning context and, consequently, may increase the potential for better concentration and AP (Singh et al., 2012). Thus, developing programmes that are based on improving fitness could promote academic success for students in this age range (Coe et al., 2013). Some factors that may positively influence physical fitness levels could be motivation, adherence to PA through the use of new technologies as heart rate monitors, proposals of extracurricular PA, parental support outside the school context, and increased intensity of PE classes.

The detailed analysis of the influence of each physical fitness component has found that CRF is the most studied component and has the greatest influence on the CP and AP. To evaluate CRF, 11 studies used the 20-m shuttle run test (PACER) (Ardoy et al., 2014; Bass et al., 2013; Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; London & Castrechini, 2011; Ruiz et al., 2010; Sardinha et al., 2014; Welk et al., 2010). Most of these studies showed a positive association of CRF on

CP (Aberg et al., 2009; Hogan et al., 2013; Janak et al., 2014; Stroth et al., 2009; Travlos, 2010) and AP (Bezold et al., 2014; Chen et al., 2013; Coe et al., 2013; Janak et al., 2014; Kantomaa et al., 2013; Kwak et al., 2009; London & Castrechini, 2011; Sardinha et al., 2014; Welk et al., 2010), 2 studies found no significant effects (Ardoy et al., 2014; Ruiz et al., 2010), but none revealed a negative association. The study of Aberg et al. (2009), carried out with 1.221.727 Swedish male adolescents, established that improvements in CRF between ages 15 and 18 years predicted global intelligence at age 18. Furthermore, physically active lessons of moderate to vigorous or high intensity can provide wide benefits for CP and AP (Donnelly & Lambourne, 2011; Mullender-Wijnsma et al., 2015).

Several mechanisms have been proposed to explain the association of CRF with CP and AP. First, CRF stimulates the hippocampus Fndc5 gene expression through a PGC-1α /Errα transcriptional complex. This elevated Fndc5 gene expression, in turn, stimulates BDNF gene expression. BDNF is the master regulator of nerve cell survival, differentiation, and plasticity in the brain, which improves cognitive function (Chang & Etnier, 2015; Noakes & Spedding, 2012; Piepmeier & Etnier, 2015; Wrann et al., 2013). Second, CRF improves the microstructure of the white matter of the brain, increasing the speed and efficiency of neuronal activity (Chaddock-Heyman et al., 2014a). Third, CRF increases angiogenesis. This phenomenon improves capillary density and brain vascularisation, affecting cognition (Adkins, Boychuk, Remple, & Kleim, 2006). Finally, CRF is related with higher P3 event-related brain potential amplitude and lower P3 latency, which reflects a better ability to modulate neuroelectric indices of cognitive control (Hillman et al., 2009). These processes are involved in cognitive control, specifically in inhibition, cognitive flexibility, and working memory, which provide the basis for a better AP (Diamond, 2000; Haapala, 2013).

With regard to muscular strength, 2 cross-sectional studies showed no association with CP (Ruiz et al., 2010) and AP (Esteban-Cornejo et al., 2014a). An intervention study showed that improvements in muscular strength did not positively affect CP and AP (Ardoy et al., 2014). Neither did improvements in muscular strength between ages 15 and 18 predict intelligence at age 18 (Aberg et al., 2009). In contrast, Coe et al. (2013) reported that muscular strength was associated with AP between 8 and 15 years of age. The longitudinal study of Bezold et al. (2014) also revealed that the combined improvement of muscular strength and CRF was positively associated with AP, and a decrease in the levels of these components was associated with a decrease in AP. This disagreement in the results can be explained by several factors: (1) the possible collateral influence of improvements on other fitness components (Bezold et al., 2014), (2) using different tests to assess muscular strength (Torrijos-Niño et al., 2014), (3) the different sample sizes (Chen et al., 2013), or (4) the controlled confounders (Chen et al., 2013; Coe et al., 2013; Esteban-Cornejo et al., 2014a). Therefore, it is necessary for future studies to continue to analyse the influence of muscular strength and to determine the causes of these divergent results.

On the other hand, this systematic review has found that speed-agility can be a potential predictor of CP (Ardoy et al., 2014) and AP (Esteban-Cornejo et al., 2014a). The study by Niederer et al. (2011) showed that from the age of 5–6 years, speed-agility is associated with a better memory. Several studies have found an association of motor coordination with intelligence (Planinsec & Pisot, 2006), with concentration, and with attention (Budde et al., 2008). Positive associations of fine-motor skill with linguistic and mathematical skill have been also found (Morales et al., 2011). In addition, gross-motor development predicts a significant improvement in memory some years later (Piek, Dawson, Smith, &

Gasson, 2008). At the same time, disorders in coordination and motor skills have been associated with cognitive and learning deficits (Haapala, 2013).

Various biological and neurological mechanisms could explain the effect of speed-agility, motor coordination, and perceptual-motor skill on CP and AP. First, biological maturity may confound the relationship between motor skills and CP (Haapala, 2013), which means that more mature young people could have a more advanced neuromuscular system and, therefore, achieve better scores in motor tests. In fact, in this review some studies show the importance of pubertal maturation, adding this as a confounder (Ardoy et al., 2014; Esteban-Cornejo et al., 2014a). Second, improvements in speed-agility and coordination might lead to a pre-activation of the neocerebellum and dorsolateral prefrontal cortex (Diamond, 2000), leading to improvements in attention (Budde et al., 2008; Kwak et al., 2009). Third, high levels of speed-agility, coordination, and motor skill are highly associated with the neuromotor system. This can improve conduction speed of the nerve impulse and have an influence on the brain's processing speed (Esteban-Cornejo et al., 2014a; Torrijos-Niño et al., 2014). Fourth, these variables could improve the spinal cord function, causing synaptogenesis and an increase in the number of synapses, increasing the BDNF and the reorganisation of movement representations within the motor cortex (Adkins et al., 2006). This combined set of neural changes could positively impact on CP (Adkins et al., 2006) and, subsequently, on AP (Esteban-Cornejo et al., 2014a; Torrijos-Niño et al., 2014).

Studies that examined the association of flexibility with CP and AP used the sit-and-reach test to assess this component (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013; London & Castrechini, 2011). London and Castrechini (2011) showed that general physical fitness—including flexibility—was a better predictor of AP than obesity. However, flexibility was not independently associated with CP and AP in other studies in this review (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013). The lack of relationship of flexibility with CP and AP could be because this type of exercise does not produce sufficient stimulus on the nervous system, nor does it increase brain blood flow. Nevertheless, these findings contrast with other previous research on scholar age, which showed an association between flexibility and AP in 7961 Australian students (Dwyer, Sallis, Blizzard, Lazzarus, & Dean, 2001) and in 254,743 American students (Van Dusen et al., 2011), perhaps due to sample size, participant age, or because more flexible children could also have more CRF, speed-agility, or motor coordination, components that affect CP and AP. Future studies should consider both findings and should continue to explore the effect of flexibility at the cognitive level.

The influence of body composition on CP and AP is another interesting point in this review. Two studies found no association of fatness with CP (Ruiz et al., 2010) and AP (Chen et al., 2013). In contrast, 2 other studies showed a negative relationship between fatness and AP (Kantomaa et al., 2013; Sardinha et al., 2014). Along the same lines, it has been demonstrated that young people with a healthy diet and who do more exercise weekly achieve better AP (Shi, Tubb, Fingers, Chen, & Caffrey, 2013). Another cross-sectional study showed that independent and combined neonatal and current body composition may influence AP (Esteban-Cornejo et al., 2015b). The diversity of results regarding this association could be explained by the lack of control of some of the variables related to the characteristics of participants or by other psychosocial variables (Donnelly & Lambourne, 2011). Despite these findings, it has been shown that physical fitness is a better predictor of AP than fatness (London & Castrechini, 2011; Torrijos-Niño et al., 2014).

This systematic review has noted that 62% of the studies analysed used confounders. The confounders most used were SES through maternal education (Esteban-Cornejo et al., 2014a; Kantomaa et al., 2013; Kwak et al., 2009), educational level of both parents (Aberg et al., 2009; Chen et al., 2013; Ruiz et al., 2010), participation in the National School Lunch Programme (Bass et al., 2013; Bezold et al., 2014; Janak et al., 2014; Welk et al., 2010), and indicators of fatness, especially BMI (Bezold et al., 2014; Esteban-Cornejo et al., 2014a; Kantomaa et al., 2013; Ruiz et al., 2010; Sardinha et al., 2014). Previous studies have shown that there is an influence of SES (Coe et al., 2013; London & Castrechini, 2011) and fatness (Sardinha et al., 2014; Torrijos-Niño et al., 2014) on cognition. On the other hand, sex (Ardoy et al., 2014; Chen et al., 2013; Esteban-Cornejo et al., 2014a; Janak et al., 2014; Kantomaa et al., 2013; Kwak et al., 2009; Ruiz et al., 2010; Sardinha et al., 2014) appears as another important confounder. Although 2 studies show no differences by sex (Morales et al., 2011; Ruiz et al., 2010), other studies did find differences. The majority of studies found a higher fitness effect on AP in girls than in boys (Bass et al., 2013; Kwak et al., 2009; London & Castrechini, 2011). The sex effect in another study also suggests that the association between more time spent in PA and higher CP is more frequently found in adolescent girls than in boys (Martínez-Gómez et al., 2011). However, we are aware of only one study that associates more vigorous PA with better AP in males (So, 2012). This trend favouring girls could be explained by the dose-response effect (Martínez-Gómez et al., 2011)—that is, boys are more active than girls (Verloigne et al., 2012) and, therefore, the achieved stimulus, due to lower levels of PA, may not be sufficient to produce the same effect on CP in both sexes. Other possible confounders that could affect the association of physical fitness with CP and AP are student household poverty (Bezold et al., 2014), heart rate (Budde et al., 2008), age (Bass et al., 2013; Chen et al., 2013; Esteban-Cornejo et al., 2014a; Ruiz et al., 2010), other fatness indicators (such as sum of skinfolds, waist circumference, or neonatal body composition), pubertal status (Ardoy et al., 2014; Esteban-Cornejo et al., 2014a; Kwak et al., 2009; Ruiz et al., 2010), minority status, school size (Welk et al., 2010), early academic impairment (Kantomaa et al., 2013), time of breastfeeding (Victora et al., 2015), race and/or ethnicity, language spoken at home, days absent from school, or place of birth (Bezold et al., 2014).

The strength of this review is that it has examined the individual and combined associations for CP and AP with regard to the different components of physical fitness. The review covers a period of 10 years and includes peer-reviewed research from 10 different countries. A quality standardised assessment list was used to select the studies. The review included cross-sectional, longitudinal, and interventional studies, and potential confounders were taken into account. On the other hand, this review has also some limitations. For example, we gave equal importance to studies with small sample sizes and studies with larger samples. Other important databases, such as EMBASE, were not included in the current systematic review. Other limitations could be language bias and publication bias (as regards search restrictions and including only published studies). Nevertheless, we have not found in previous systematic reviews and reference lists any relevant study meeting the inclusion criteria of this review in a language other than English. In addition, for the introduction and discussion sections, we take into account the most relevant studies prior to 2005 and previous systematic reviews that include variables studied in this review. Likewise, the review does not include studies that focused on metabolic (i.e., overweight-obesity) or other kinds of diseases (i.e., mental, allergic, or developmental disorders). In addition, some of the effects of the association may be inconsistent due to the influence of inter-components within the same participant. For example, in studies where only a global average score of physical fitness without separate components was used (i.e., London & Castrechini, 2011), there may be a collateral effect of some of them (i.e., CRF, speed-agility, or motor coordination), on components less closely related to the CP and AP (i.e., flexibility), thus diluting the real impact of each component. However, most studies analysed in this review separate by component and do not find an independent association between flexibility and CP or AP (Bass et al., 2013; Chen et al., 2013; Coe et al., 2013). Future studies should consider these independent relationships. Finally, although we have relied on quality tools used by previous studies, the tool used to measure quality is not validated (Castro-Piñero et al., 2010; Ruiz et al., 2009).

Conclusion

The present review found a total of 21 articles that analysed the association of physical fitness with CP and AP in adolescents. Ten of these articles focused on CP and 12 on AP (one studied both CP and AP). Most studies showed a positive association of physical fitness with CP and AP: 8 studies showed an association between physical fitness and CP, whereas only 2 studies found no association. Better physical fitness was also associated with better AP in 11 studies, while only 1 study found no relationship. CRF, speed-agility, motor coordination, and perceptual-motor skill are components that are mostly associated with CP and AP in adolescents, while the relationship with regard to muscular strength and flexibility is unclear. Finally, confounders may play a key role in these associations. More research is needed to explain the differential effect of different physical fitness components on CP and AP, to clarify the role of confounders, and to determine the cut-off point in fitness for predicting better CP and AP. Programmes and combined interventions to improve fitness, CP and AP during adolescence should be promoted in political, educational, and family areas.

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V

Associations of physical fitness with academic performance in teenagers

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Associations of physical fitness with academic performance in teenagers

Verenigings van fisieke fiksheid met akademiese prestasie in tieners

short title: Physical fitness and academic performance

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Associations of physical fitness with academic performance in teenagers

Verenigings van fisieke fiksheid met akademiese prestasie in tieners

short title: Physical fitness and academic performance

Abstract

The aim was to examine the associations between physical fitness and academic performance (AP) in Spanish teenagers. It was also intended to identify the cut-off point in cardiorespiratory fitness (CRF), speed-agility (S/A), and muscular strength (MS) as predictors of AP. The sample was of 2272 teenagers aged 12-17 years. ALPHA-fitness tests were used. AP was measured with the grades in PE, and in Mathematics and Language (M&L). The associations were analyzed by binary logistic regression after controlling for age, socioeconomic status and body mass index (BMI). Males and females above 3.60 and 6.25 stages in the CRF test showed a higher likely of high average of M&L (OR=1.715 and 2.441, respectively, $p<0.009$). Only the females with S/A below 12.67 seconds had 1.45 times higher likely to achieve a high performance in M&L (OR=0.682, $p=0.034$). Finally, only the females with MS above 123cm had a higher likely to achieve a high performance in M&L (OR=2.129, $p<0.001$). In conclusion, females with high CRF, S/A and MS, and males with high CRF show better AP regardless of confounders. It is suggested to encourage young students towards a greater effort during fitness programmes, and to let parents and students know this relationship with AP.

Keywords: cardiorespiratory fitness; cognition; muscular strength; socioeconomic status; speed-agility.

Associations of physical fitness with academic performance in teenagers

Introduction

The effects of physical fitness on teenagers' health and well-being have been researched extensively over the past decade (Mcaleese *et al.,* 2016). A current line of thinking has also linked up high levels of physical fitness with better academic performance (AP) among teenagers (Aberg *et al.,* 2009; Du Toit *et al.,* 2011; Ruiz-Ariza *et al.,* 2017). AP refers to success at school as measured by an average of grades or standardized academic tests (Haapala, 2013). Recent research has proved that physical fitness may result in better cognitive performance as a result of better blood supply to the brain, increased synaptic plasticity and increased neuronal survival and growth (Ruiz-Ariza *et al.,* 2017). These physiological adaptations improve working memory (Haapala, 2013), selective attention and concentration (Diamond, 2013), all of them considered key factors in AP (Esteban-Cornejo *et al.,* 2014; Ruiz-Ariza *et al.,* 2017). Physical fitness also has a positive effect on self-esteem and behavior at school, thus improving learning capacity (Torrijos-Niño *et al.,* 2014).

The components of physical fitness that may have effect on AP, are cardiorespiratory fitness (CRF), speed-agility (S/A) and muscular strength (MS) (Diamond, 2013; Esteban-Cornejo *et al.,* 2014). The three capacities are closely related, but they have different degrees of influence on AP: whereas CRF always shows a positive association, S/A and MS are poorly known and their data lead to contradictory results (Du Toit *et al.,* 2011; Ruiz-Ariza *et al.,* 2017). The three capacities have seldom been studied together, thus firm conclusions on their effect on AP are difficult to draw (Ardoy *et al.,* 2014; Esteban-Cornejo *et al.,* 2014).

The influence of major confounders like age, the socioeconomic status of families and body mass index (BMI) adds further difficulties in the identification of the relationship between fitness and teenagers' AP (Ruiz-Ariza *et al.,* 2017). Research on multiple associations between fitness and AP has also become more intense, using a range of recodifications. Esteban-Cornejo *et al.* (2014) classified physical fitness for S/A and MS as low or high based on the 75th percentile of their sample, taking age and sex into consideration. And Torrijos-Niño *et al.* (2014) segmented by sex and divided into four categories according to CRF, S/A and MS based on the quartiles of their sample (poor=Q1, satisfactory=Q2-Q3, and good=Q4).

Certain recodifications of fitness level and adjustments of the main covariates may mediate substantially the evidence of association of fitness level with AP. Thus, the question remains: Can fitness level be used to predict teenager's AP? To our knowledge, research has not identified the cut-off points from the analysis of diagnostic performance of the measures of physical tests. Therefore, their value as predictors of AP is still unknown. Research on this issue could clarify the debate on the potential of physical fitness in school learning.

Purpose of Research

The aim of this paper was to know the associations of the measures of physical fitness as predictors of teenager's AP. It was also intended to identify the cut-off point of the measures of CRF, S/A, and MS as predictors of AP in teenagers.

Methodology

Design and participants

This cross-sectional study relies on data of 2272 teenagers aged 12-to-17 of 16 high schools of the Autonomous Community of Andalusia, Spain. The educational centers were selected for convenience. The data were collected between April and June 2014 with the informed consent of the participants' parents or legal guardians. This study was approved by the Bioethics Committee of the University of XXXX (omitted for anonymity), and it complies with the principles of the Declaration of Helsinki (2013 version, Brasil).

Instruments and procedure

Physical fitness

Physical fitness (CRF, S/A and MS) was measured with the health-related physical test battery for children and adolescents ALPHA-Fitness®. The reliability of these tests for children and adolescents has been published elsewhere (Ruiz *et al.,* 2011). CRF was measured with the 20-meter shuttle run test. S/A was measured with the 4x10-meter shuttle run test. MS was measured with the standing long jump test. S/A and MS tests were performed twice and the best record was registered. They showed an excellent intra-class correlation (ICC=0.921, 95% CI: 0.874 - 9.520, and ICC=0.911, 95% CI: 0.872 - 0.935, respectively). The S/A score was interpreted inversely, so the higher number of seconds meant a lower S/A capacity.

Academic performance

AP was recorded based on the 0-to-10 grades received in the subjects in the term immediately before the questionnaire was run. A total measure of AP was taken using the average of Mathematics and Language (M&L). Physical Education (PE) was used as control of the participants' attitude towards AP in this subject. For their instrumental nature, M&L are believed to be the subjects with the highest explanatory power of students' AP (Miñano *et al.,* 2012).

Confounding variables

The following covariates were considered for the association between the level of physical fitness and AP: 1) Age, as obtained from the schools' student records; 2) Socioeconomic level, as measured with an item on the mother's education level (Esteban-Cornejo *et al.,* 2014; Ruiz-Ariza *et al.,* 2017) (in this item, the possible answers were categorized as follows: 1=no schooling, 2=primary education, 3=secondary education, high school and vocational education, and 4=university degree); and 3) BMI, as measured by dividing weight by height squared in meters (kg/m^2). The measures were obtained with an ASIMED® type B –class III– digital scale and with a SECA® 214 portable measuring rod (accurate to 50g and 1mm, respectively). The participants were measured barefoot and wearing light clothing.

Data analysis

The data are presented as mean (SD) or percentage. The differences in continuous variables between males and females were analyzed with Student's t-test for independent samples and with a $\chi 2$ test for categorical variables. The association between high CRF, S/A and MS levels (predictor variables) and AP (outcomes) was analyzed by binary logistic regression after controlling for age, socioeconomic status and BMI. Areas under curve (AUC) were used for the different AP in teenagers with low vs. high level of fitness in each component, and they were analyzed with ANCOVA after controlling for the above confounders. AP was recoded as low (<7 points) and high (≥7 points). The variable S/A was multiplied by -1 for an inverted curve comparable with the CRF and MS results. The analyses were made separately for each fitness component and for each AP indicator. Statistical significance was set at $P<0.05$. SPSS v. 21.0 for Windows (SPSS Inc., Chicago) were used.

Results

Table 1 presents descriptive characteristics of the study sample. The fitness level was significantly higher in males than in females on all the tests ($p<0.001$ in all cases). Males received higher grades than females in PE and lower grades in M&L ($p<0.001$ in all cases).

Table 1. Descriptive Characteristics for the Study Sample by Sex

	All (n = 2272)		Males (n = 1155)		Females (n = 1117)		
	Mean	SD	Mean	SD	Mean	SD	*p value*
Anthropometric characteristics							
Age (years)	14.57	1.72	14.63	1.76	14.51	1.67	0.071
Weight (kg)	59.4	13.66	62.73	14.78	55.91	11.39	<0.001
Height (m)	1.64	0.09	1.68	0.09	1.60	0.06	<0.001
BMI (kg/m^2)	21.96	4.15	22.10	4.31	21.8	3.97	0.069
Maternal education university level (%)	20		20.8		19.3		0.599

Physical fitness							
CRF: 20-m shuttle run (stage)	5.25	2.47	6.51	2.45	3.93	1.68	<0.001
CRF: VO_2 max (mL/kg/min)	41.92	6.93	45.31	6.68	38.38	5.22	<0.001
S/A: Shuttle run 4 x 10 m (seconds)	12.33	1.32	11.63	1.1	13.07	1.12	<0.001
MS: Long jump test (cm)	153	32.95	172	30.21	133.1	22.2	<0.001
Academic performance							
AP PE (0-10)	7.38	1.47	7.49	1.47	7.27	1.46	<0.001
AP Mathematics (0-10)	5.85	2.18	5.56	2.16	6.15	2.16	<0.001
AP Language (0-10)	5.9	2.06	5.47	2.05	6.35	1.97	<0.001
Average of Mathematics and Language (0-10)	5.88	1.92	5.52	1.9	6.25	1.87	<0.001

Note. Independent samples t-test were applied for *p value*. AP = Academic performance. CRF = Cardiorespiratory fitness. S/A = Speed/Agility. MS = Muscular strength.

Figure 1 shows diagnostic performance of the three components of fitness with regard to the teenagers' AP. The AUC in CRF, S/A and MS was similar (p>0.05 in all cases) and above 0.640 both for males and females as regards the utility of these tests regarding to AP in PE. The same analysis for prediction of AP in M&L showed similar curves (p>0.05 in all cases), with a lower diagnostic utility. An AUC>0.58 was recorded for the three components of fitness in females, and close to or lower than .5 in males (0.520, 0.476 and 0.475 in CRF, S/A and MS, respectively). Table 2 shows the AUC and cut-off points of each component of physical fitness beyond which teenagers show low/high AP in PE and in M&L.

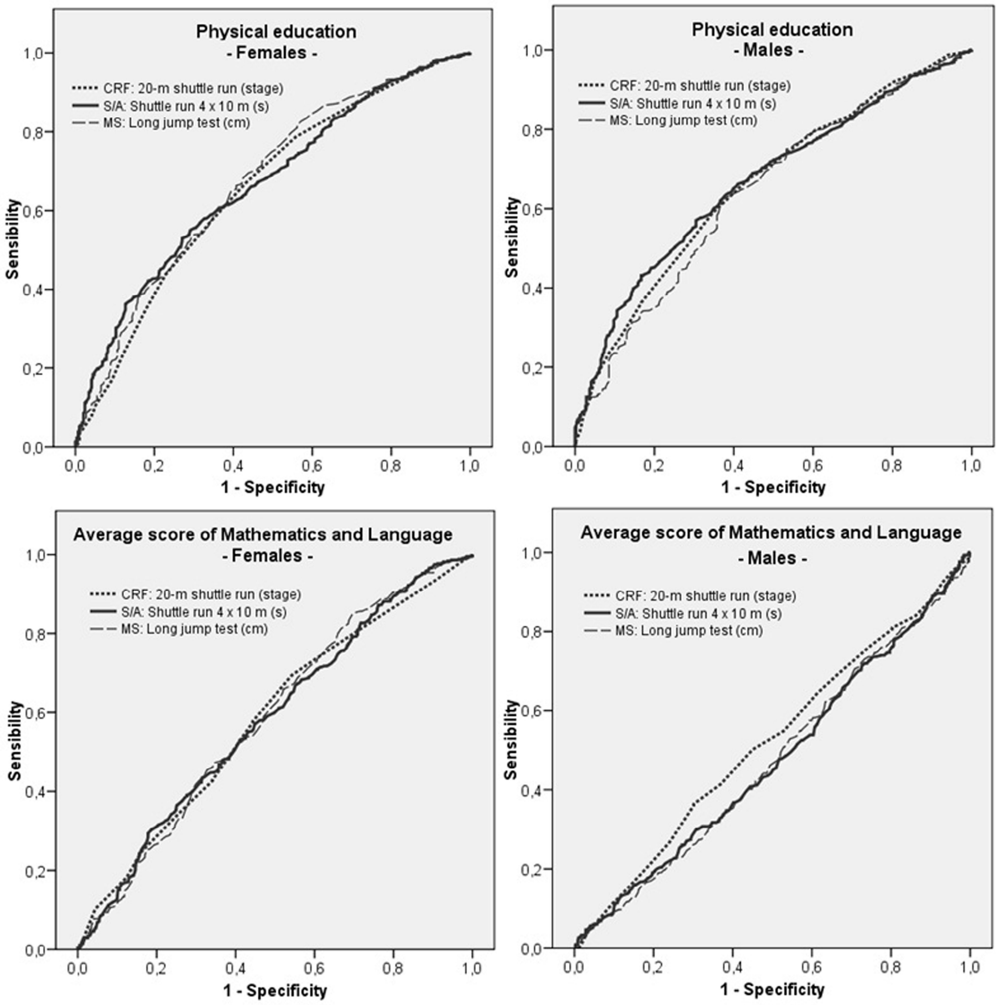

Figure 1. Diagnostic performance —ROC curves— of the three fitness components (CRF, S/A and MS) with respect to the academic performance of adolescents in PE and the average of Mathematics and Language in adolescents. AUC: Area under the curve. CRF: 20-m shuttle run (stage). S/A: Shuttle run 4 x 10 m (seconds). MS: Long jump test (cm).

Table 2. Areas under curve (AUC) and cut-off points in each test (cardiorespiratory fitness=CRF, speed and agility=S/A, and muscular strength=MS) according to which the participants show low or high academic performance in PE and the average of Mathematics and Language. The results are shown by age and sex. CRF: 20-m shuttle run (stage). S/A:

Shuttle run 4 x 10 m (seconds). MS: Long jump test (cm). > Cut-off in CRF and MS = High academic performance. < Cut-off in S/A=High academic performance

	CRF (stage)		S/A (seconds)		MS (cm)	
Years	PE	Average Mathematics and Language	PE	Average Mathematics and Language	PE	Average Mathematics and Language
Females	AUC (Cut-off)	AUC (Cut-off)	AUC (Cut-off)	AUC (Cut-off)	AUC (Cut-off)	AUC (Cut-off)
12	0.641 (4.150)	0.553 (3.750)	0.633 (12.845)	0.539 (13.13)	0.754 (113.75)	0.581 (117.75)
13	0.742 (3.500)	0.532 (3.250)	0.695 (12.985)	0.561 (12.920)	0.727 (117.75)	0.545 (118.75)
14	0.648 (4.250)	0.637 (3.750)	0.594 (12.535)	0.600 (12.555)	0.631 (128.50)	0.639 (125.75)
15	0.639 (3.750)	0.626 (3.250)	0.715 (12.845)	0.579 (12.765)	0.712 (141.25)	0.647 (129.25)
16	0.780 (3.250)	0.646 (3.250)	0.762 (12.985)	0.617 (12.845)	0.683 (131.25)	0.534 (117.75)
17	0.513 (3.750)	0.557 (4.750)	0.677 (12.450)	0.653 (12.220)	0.710 (125.75)	0.614 (120.750)
12-17	0.657 (3.85)	0.584 (3.60)	0.664 (12.79)	0.583 (12.67)	0.773 (130.00)	0.587 (123.00)
Males						
12	0.712 (5.75)	0.642 (6.75)	0.616 (12.205)	0.536 (11.98)	0.677 (157.75)	0.580 (151.70)
13	0.638 (6.25)	0.533 (5.75)	0.580 (12.07)	0.580 (12.04)	0.553 (164.50)	0.539 (166.25)
14	0.629 (7.25)	0.500 (6.25)	0.647 (11.71)	0.550 (11.87)	0.630 (159.75)	0.527 (167.25)

15	0.708	0.590	0.705	0.516	0.658	0.503
	(6.25)	(7.75)	(11.37)	(11.14)	(161.50)	(180.00)
16	0.640	0.541	0.728	0.536	0.659	0.563
	(6.25)	(7.25)	(11.93)	(11.12)	(186.75)	(180.75)
17	0.617	0.511	0.737	0.549	0.716	0.581
	(6.75)	(6.75)	(11.05)	(11.48)	(193.00)	(202.75)
12-17	0.659	0.520	0.667	0.476	0.643	0.475
	(6.25)	(6.75)	(11.59)	(11.46)	(170.00)	(174.00)

Table 3 shows the data that evidence an association between high levels of CRF, S/A and MS with regard to AP in PE and M&L. Males and females above 3.60 and 6.25 stages respectively in the CRF test, showed a higher likely of high performance both in PE (Odds ratio [OR]=3.047 and 2.625, respectively) and in M&L (OR=1.715 and 2.441, respectively), $p<0.009$ in all cases. Regarding S/A, the females and males with records under 12.79 and 11.59 seconds respectively had a 2.7 and 3.1 times higher likely to achieve a high AP in PE (OR=0.373, $\beta=-0.985$ and OR=0.320, $\beta=-1.139$, respectively, both $p<0.001$). Only the females with S/A records below 12.67 seconds had a significant 1.45 times higher likely to achieve a high performance in M&L (OR=0.682, $\beta=-0.383$, $p=0.034$). Finally, the females and the males with a MS in the long jump test above 130cm and 170cm respectively had a higher likely to achieve a high performance in PE (OR=4.649 and 2.881, respectively, both $p<0.001$), and only the females with MS records above 123cm had a higher likely to achieve a high performance in M&L (OR=2.129, $p<0.001$).

Table 3. Odds ratio (OR) and 95% CI for high levels of cardiorespiratory fitness (CRF), speed and agility (S/A) and muscular strength (MS) with respect to academic performance

indicators (PA) in PE and the average of Mathematics and Language in males and females. The analysis were carried out separately for ach component and controlled for age, socioeconomic status and BMI. CRF: 20-m shuttle run (stage). S/A: Shuttle run 4 x 10 m (seg). MS: Long jump test (cm)

		Females (1117)				Males (1155)			
		N	p	OR	95% CI	N	p	OR	95% CI
CRF									
PE	Low PA	309		1	Referent	268		1	Referent
	High PA	808	<0.001	3.047	1.919 - 4.837	887	<0.001	2.625	1.584 – 4.351
Mathematics and Language	Low PA	656		1	Referent	847		1	Referent
	High PA	461	<0.001	2.441	1.691 - 3.523	308	0.008	1.715	1.150 - 2.557
S/A									
PE	Low PA	309		1	Referent	268		1	Referent
	High PA	808	<0.001	.373	0.237 - 0.588	887	<0.001	0.320	0.196 - 0.522
Mathematics and Language	Low PA	656		1	Referent	847		1	Referent
	High PA	461	0.034	.682	0.479 - 0.971	308	0.610	0.905	0.616 - 1.329
MS									
PE	Low PA	309		1	Referent	268		1	Referent
	High PA	808	<0.001	4.649	2.954 - 7.318	887	<0.001	2.881	1.743 - 4.761
Mathematics and Language	Low PA	656		1	Referent	847		1	Referent

	High PA	461	<0.001	2.129	1.414 - 3.206	308	0.732	1.072	0.720 - 1.595

Note. S/A was interpreted inversely, so the higher number of seconds meant a lower S/A capacity.

Figure 2 shows the different AP between low and high levels of physical fitness in 12-to-17 teenagers after controlling for age, socioeconomic status and BMI. Teenagers with high CRF, S/A, and MS achieved a higher AP in PE (all $p<0.001$, figures 1a and 1b). Girls and boys with high CRF levels also showed a higher AP in M&L ($p<0.012$, figures 1c and 1d). Still, a high S/A and MS level was associated with a higher AP in M&L among females ($p=0.007$ and $p<0.001$, respectively, figure 1c), but not among males ($p>0.05$, figure 1d).

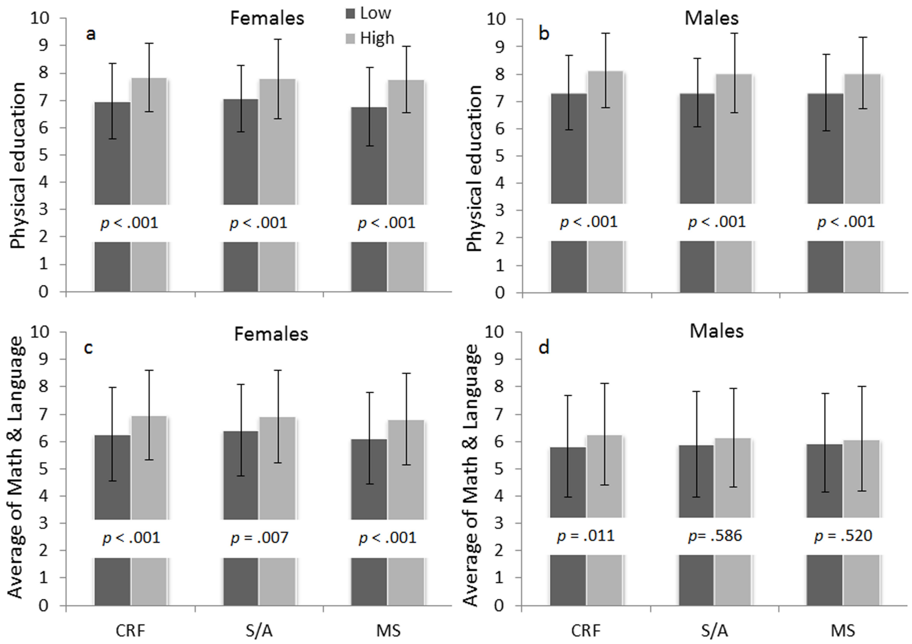

Figure 2. Influence of cardiorespiratory fitness (CRF), speed and agility (S/A) and muscular strength (MS) ––low or high fitness–– with academic performance in PE and the average of

Mathematics and Language in adolescents. The data are shown as mean and standard deviation. The analyses were adjusted by age, socioeconomic status and BMI. CRF: 20-m shuttle run (stage). S/A: Shuttle run 4 x 10 m (seconds). MS: Long jump test (cm).

Discussion

This paper intended to establish the cut-off points of the measures of physical fitness as predictor of teenager's AP. It was also aimed to establish whether the points low vs high fitness were associated with AP in PE and in M&L.

Our results show that CRF is the only capacity of physical fitness associated with a higher AP in M&L in both males and females. These results are in line with most of the specialized research results published recently (Diamond, 2013; Torrijos-Niño *et al.,* 2014). To our knowledge, scarce papers have not shown any association between increase in CRF and improvement in AP at school (Ardoy *et al.,* 2014; Ruiz-Ariza *et al.,* 2017). Some studies have identified these associations and suggest that increased CRF is associated with improved mathematical calculation skills and resolution of arithmetic problems (Moore *et al.,* 2014), as well as with a richer stock of words and meanings, which in turn results in a higher language level and language control (Scudder *et al.,* 2014). Research based on 1,221,727 Swedish male informants also showed that positive changes in CRF between the ages of 15 and 18 predict global intelligence at the age of 18 (Aberg *et al.,* 2009), but until now, these results had not been proved independently of confounders as age, socioeconomic status and BMI.

Several mechanisms may explain the association between CRF and AP at school: 1) CRF stimulates the gene encoding the brain-derived neurotrophic factor (BDNF) that is a master regulator of cell survival and a neuroprotector and improves learning memory and neuroelectric functionality (Wrann *et al.,* 2013). 2) CRF increases the level of brain neurotransmitters such as serotonin or norepinephrine, which facilitate information processing (Lojovich, 2010). And 3) CRF favors angiogenesis, a process that increases capillary density and brain vascularization, therefore influencing cognition (Adkins *et al.,* 2006). However, AP is not affected only by physiological factors. Additional explanations may be related to the following: 1) Highly motivated students may aim at maximum performance both in CRF tests and in school subjects. 2) High CRF might optimize attention and behavior in the classroom. And 3) CRF boosts self-esteem and reduces stress and anxiety, which may improve school performance (Torrijos-Niño *et al.,* 2014).

As to S/A, our results show that there is not a high prediction of AP in instrumental subjects. Still, in females this component is associated with a higher AP in the average of M&L regardless of age, socioeconomic status and BMI. These results are in line with the little research available, where S/A is also proved to be associated with AP after controlling for educational level of mothers and for fatness (Esteban-Cornejo *et al.,* 2014), and for age and family socioeconomic status (Torrijos-Niño *et al.,* 2014) in both sexes. Specifically, it has been proved that this component is associated with memory, with inhibitory control and with attention, all of which are major factors in school AP (Ruiz-Ariza *et al.,* 2017). Thus, lower levels of S/A, are often associated with cognitive and learning deficits (Haapala, 2013), and low motor activity may affect cognitive development negatively and may slow down AP (Ruiz-Ariza *et al.,* 2017).

Our data show that MS is associated with a higher AP in females regardless of age, socioeconomic level and BMI. Comparative analysis of these results is not entirely in line with the literature. While some cross-sectional studies proved MS to be associated with school AP (Bezold *et al.,* 2014; Du Toit *et al*., 2011), others did not find any relation after controlling for socioeconomic status and BMI (Chen *et al.,* 2013). MS has also been proved to lose its association with AP in M&L when it is analyzed combined with CRF and S/A (Esteban-Cornejo *et al.,* 2014). Longitudinal studies have not found any relation between MS and AP after increasing the number and the intensity of weekly PE sessions (Ardoy *et al.,* 2014). Similarly, improved MS between 15 and 18 years, did not predict global intelligence at the age of 18 (Aberg *et al.,* 2009). The controversy surrounding MS may be explained in terms of several factors: a) The collateral influence of the other fitness components, like CRF and S/A, b) the use of varied tests for measuring strength (Torrijos-Niño *et al.,* 2014), c) the various sample sizes used (Chen *et al.,* 2013), and d) the method and the controlled confounders (Ruiz-Ariza *et al.,* 2017).

Various mechanisms may explain the association of S/A and MS with AP found here: 1) Both components are related to the neuromotor system and could thus improve the speed of the nerve impulse and therefore influence positively the brain's processing speed and the cognitive functions (Esteban-Cornejo *et al.,* 2014). 2) More mature teenagers might have a more developed neuromuscular system and, therefore, score higher in the physical tests. Goldstein (1987) proved that skeletally older teenagers achieved a higher cognitive performance compared with the skeletally younger. This relation could thus be explained in part in terms of differences in genetic and of the stage of biological maturity (Haapala, 2013). 3) S/A exercises could cause synaptogenesis, and therefore increase the number of synapses and the brain-derived neurotrophic factor (BDNF) (Adkins *et al.,* 2006). And 4) High levels of S/A and MS could improve functions of the spinal cord, causing neurobiological changes that favor cognitive development (Adkins *et al.,* 2006) and school AP (Torrijos-Niño *et al.,* 2014).

Finally, our results reveal an association between S/A and MS and AP in M&L among females, but not among males. This is in line with results available in the literature (Bass *et al.,* 2013). To our knowledge, only one study associated an increase of intense physical activity with higher AP in males (So, 2012). The bias towards females here could be explained in terms of the dose-response effect (Machado-Rodrigues *et al.,* 2010): Males are more active than females (Verloigne *et al.,* 2012), and the effect caused from lower levels of physical activity may not have the same relevance in the cognition of the both sexes (Ruiz-Ariza *et al.,* 2016).

Despite the above, our findings should be taken cautiously, considering the limitation imposed by its cross-sectional design and the convenience sample used that limit the generalization of the results. Yet, this paper also has relevant strengths, as the inclusion of confounders in its data analysis, and the use of objective field tests validated for the evaluation of physical fitness.

Conclusion

In conclusion, a higher level of CRF, S/A, and MS in adolescents girls and a higher CRF in boys, are associated with greater average of M&L**,** regardless of age, socioeconomic status and BMI. It is suggested to encourage and motivate students towards a greater effort during CRF, S/A and MS programmes, it is also necessary let parents and students know this relationship between fitness and AP. Further research on promotion of physical fitness is needed for proper assessment of the quantitative and qualitative importance of the benefit for AP, its causes and the explanation for the differences found between males and females.

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VI

Association between different components of physical fitness and academic performance in adolescents, taking into account the social-educational status and fatness

Ruiz-Ariza, A., & Martínez-López, E. J. (2016).

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ASOCIACIÓN ENTRE DISTINTOS COMPONENTES DE CONDICIÓN FÍSICA Y RENDIMIENTO ACADÉMICO EN ADOLESCENTES, TENIENDO EN CUENTA EL STATUS SOCIOEDUCATIVO Y EL FATNESS

ASSOCIATION BETWEEN DIFFERENT COMPONENTS OF PHYSICAL FITNESS AND ACADEMIC PERFORMANCE IN ADOLESCENTS, TAKING INTO ACCOUNT THE SOCIAL-EDUCATIONAL STATUS AND FATNESS

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RESUMEN

El objetivo fue analizar la asociación de la condición física con el rendimiento académico (RA) en adolescentes, tras ajustar por variables socioeducativas y fatness. Participaron 1164 adolescentes de 12-18 años. Se usó la batería ALPHA-Fitness. El RA se obtuvo con las notas de Matemáticas, Lengua y Educación Física (EF). La capacidad aeróbica se asoció con el RA, tras ajustar por sexo, edad, población y nivel educativo de la madre. La habilidad motora se asoció con todas las variables de RA, excepto con Lengua. Estas asociaciones se mantuvieron e incluso aumentaron tras ajustar por fatness, sobre todo por el porcentaje de grasa corporal. Sugerimos a los profesores de EF que den más importancia al componente aeróbico y motor en sus clases, y promuevan acciones interdisciplinares con las demás asignaturas. Además, proponemos fomentar desde el ámbito educativo, político y familiar, el aumento de la condición física aeróbica y motora durante la adolescencia.

PALABRAS CLAVE: Test de condición física, nivel socioeducativo, porcentaje de grasa corporal, rendimiento escolar.

ABSTRACT

The aim was to analyze the association of physical fitness with academic performance (AP) in adolescents, after adjusting for social-educational and fatness variables. 1164 adolescents between 12-18 years participated. ALPHA-Fitness battery was used. AP was obtained with Math, Language and Physical Education (PE) marks. Aerobic capacity is associated with AP, after adjusting by sex, age, population and maternal education. Motor ability was associated with all AP variables, except with Language. Furthermore, these associations were mantained and even increased after adjusting by fatness indicators, especially by body fat percentage. We encourge PE teachers to give more importance to the aerobic and motor components during their class, and to promote interdisciplinary joint actions between the subject of PE and other subjects, as well as to promote the improvement of aerobic capacity and motor ability from educational, political and family context, during the adolescence.

***KEYWORDS**: Physical fitness test, nivel social-educational level, fatness percentage, school performance.*

1. INTRODUCCIÓN

Un adecuado nivel de condición física proporciona numerosos beneficios físicos y mentales (Walker, MacIntosh, Kozyrskyj, Becker y McGavock, 2013), reduce el riesgo de enfermedades crónicas y aumenta la longevidad (Blair y Morris, 2009). Además, una corriente científica actual lo ha relacionado con mejor rendimiento cognitivo y rendimiento académico (RA) en niños y adolescentes (Ardoy et al., 2014; Chaddock et al., 2012; Esteban-Cornejo et al., 2015; Pareja-Galeano et al., 2013).

En relación a las líneas previas, se ha comprobado que el nivel de condición física es clave para el funcionamiento cerebral en los jóvenes. Más específicamente, un mayor nivel de condición física aumenta el flujo sanguíneo cerebral y la plasticidad sináptica (Pareja-Galeano et al., 2013). Estas adaptaciones mejoran la memoria y la capacidad de aprendizaje, claves en el RA (Park y Poo, 2013). Del mismo modo, una elevada condición física, se ha asociado con mayor motivación, mejores habilidades sociales, mayor adquisición de valores, y con un mejor comportamiento de los adolescentes en el aula, lo que aumenta la concentración en las clases y el aprovechamiento de las mismas (Singh, Uijtdewilligen, Twisk, van Mechelen y Chinapaw, 2012).

A pesar de los anteriores argumentos, la evidencia respecto a la relación de la condición física con el RA sigue siendo escasa. Algunas debilidades encontradas en los estudios recientes, es la falta de diferenciación entre los diferentes componentes de la condición física con mayor influencia sobre el RA, y la falta de control de factores de confusión socioeducativos importantes, como la educación de la madre (Castelli et al., 2007; Torrijos-Niño et al., 2014). Así como otras variables que controlen el fatness –nivel de grasa corporal– (Chen, Fox, Ku y Taun, 2013; Sardinha et al., 2014; Torrijos-Niño et al., 2014). Los componentes de la condición física con posible potencial para mejorar el RA son la capacidad aeróbica, la fuerza muscular y la habilidad motora (Chaddock et al., 2012; Esteban-Cornejo et al., 2014; Sardinha et al., 2014; Torrijos-Niño et al., 2014). Estas tres cualidades físicas están altamente asociadas entre sí (Esteban-Cornejo et al., 2014; Lubans et al., 2010), pero hemos encontrado discrepancia con respecto a su relación con el RA (Aberg et al., 2009; Castelli et al., 2007; Coe et al., 2013; Sardinha et al., 2014), y solo algunas investigaciones actuales han incluido la habilidad motora (Esteban-Cornejo et al., 2014; Torrijos-Niño et al., 2014).

Pretendemos centrarnos en la adolescencia, porque es la etapa clave para consolidar hábitos de vida saludables y aumentar el nivel de condición física (Ortega et al., 2008). Además, durante este periodo existe un alto grado de plasticidad en el cerebro de los jóvenes, que es determinante para potenciar la cognición, afianzar comportamientos adecuados y favorecer el éxito laboral futuro (Ardoy et al., 2014). Comprender la relación entre cada componente de la condición física y el RA, podría orientar a los profesionales de la Educación Física (EF) y del deporte, respecto al tipo de actividad física (AF) a fomentar con el objetivo de mejorar el rendimiento escolar, pudiendo así tomar decisiones sobre su nivel de incorporación y difusión dentro de los Centros educativos y de las actividades extraescolares y familiares.

Por tanto, en base a los argumentos precedentes, el objetivo fue analizar en una muestra de adolescentes, la asociación de la capacidad aeróbica, fuerza muscular y habilidad motora con el RA en Matemáticas, Lengua y EF, con una media de Matemáticas y Lengua y una media de las tres asignaturas, tras ajustar en distintos modelos por variables socioeducativas y de fatness.

2. MÉTODO

2.1. Participantes

Un total de 1569 adolescentes de 12-18 años participaron inicialmente en el presente estudio transversal. Los participantes pertenecían a Centros de ESO de la Comunidad Autónoma de Andalucía, España. Tras eliminar los datos nulos e incompletos, se incluyeron en los análisis 1164 jóvenes (74% de la muestra original). Los datos fueron recogidos entre marzo y junio de 2014 por miembros instruidos del grupo de investigación.

2.2. Procedimiento

Antes de comenzar el estudio, los padres, directores de los Centros y profesores de EF fueron informados del propósito del mismo. Se obtuvo un consentimiento informado de los padres o tutores legales. El estudio fue aprobado por el Comité de Bioética de la Universidad de Jaén. Además, se tuvo en cuenta la Ley de Investigación Biomédica (2007), la ley de protección de datos personales (Ley Orgánica 15/1999), así como los principios fundamentales de la Declaración de Helsinki (revisión de 2013).

2.3. Variable predictora: Condición física

El nivel de condición física se evaluó siguiendo la batería de test físicos relacionados con la salud en jóvenes, ALPHA-Fitness (Ruiz et al., 2011). Todos los tests se realizaron en una sola sesión durante el tercer trimestre escolar, según el protocolo de Esteban-Cornejo et al. (2014).

La capacidad aeróbica se evaluó mediante el test de 20 m de ida y vuelta. Se realizó una vez y al final de la sesión. La puntuación fue el número de periodos completados. Los participantes debían correr entre dos líneas a 20 m de distancia, al ritmo de los pitidos de la señal sonora. El test finalizaba cuando el sujeto se detenía debido a la fatiga, o cuando no llegaba a la línea correspondiente en dos ocasiones consecutivas. Los participantes fueron constantemente animados durante la prueba (Esteban-Cornejo et al., 2014). El número de periodos se transformó en el consumo máximo de oxígeno (VO_2 max, mL/kg/min) a través de la ecuación de Lèger (Lèger, Mercier, Gadoury y Lambert, 1988).

La fuerza muscular se obtuvo través de la prueba de prensión manual y del salto de longitud a dos piernas. Para la prueba de prensión manual, se usó un dinamómetro con mango ajustable (TKK 5101 Grip D; Takey, Tokyo, Japan) (Esteban-Cornejo et al., 2014). El test se realizó dos veces para cada mano, y se registró la máxima puntuación en kilogramos. La puntuación media de la mano derecha e izquierda fue calculada. El test de salto de longitud a dos piernas también se evaluó dos veces. Se realizó con los pies detrás de la línea, con una apertura de piernas aproximadamente a la anchura de los hombros. La distancia más larga fue registrada en centímetros (Esteban-Cornejo et al., 2014). Una única puntuación z de fuerza muscular fue computada entre los dos test musculares. La puntuación individual de cada test se estandarizó de la siguiente manera: z-valor estandarizado = (valor-media)/DT. La puntuación z total de fuerza muscular se calculó con la media de las dos puntuaciones individuales (Esteban-Cornejo et al., 2014).
La habilidad motora se evaluó con el test de ida y vuelta 4x10 m de velocidad de movimiento, agilidad y coordinación. Los participantes realizaron 4 carreras de ida y vuelta a máxima velocidad en una distancia de 10 m. El test se repitió dos veces y se registró la más rápida en segundos (Esteban-Cornejo et al., 2014). Es importante indicar, que la puntuación obtenida en esta prueba debe ser interpretada de forma inversa, es decir, a más segundos empleados en completarla, menor habilidad motora.

2.4. Variable dependiente: Rendimiento académico

El RA se evaluó a través de las calificaciones en Matemáticas, Lengua, EF, una puntuación media de Matemáticas y Lengua, y otra puntuación media de Matemáticas, Lengua y EF. Usamos las calificaciones de las asignaturas instrumentales porque son consideradas las variables con mayor poder explicativo del RA (Ruiz-Ariza et al., 2016). Además, hay evidencias previa de que la condición física influye en estas asignaturas (Esteban-Cornejo et al., 2014; Moore et al., 2014; Scudder et al., 2014; Torrijos-Niño et al., 2014). Asimismo, usamos la nota de EF como marcador de la actitud de los adolescentes hacia la AF.

2.5. *Variables de confusion controladas*

El nivel socioeducativo tiene una fuerte asociación con el RA (Coe et al., 2013; Torrijos-Niño et al., 2014), por consiguiente se controló, y fue evaluado a través del nivel educativo de la madre (Esteban-Cornejo et al., 2014), con las siguientes opciones: Sin estudios, educación primaria, educación secundaria, educación universitaria. La educación materna se preguntó directamente a las madres usando un cuestionario (Torrijos-Niño et al., 2014). Además, se tuvo en cuenta el sexo y la edad (Ruiz-Ariza et al., 2016), y el tipo de población –rural o urbana- como determinante social.

El fatness fue evaluado siguiendo los procedimientos estandarizados (Esteban-Cornejo et al., 2014). Para el peso se usó una báscula digital ASIMED tipo B clase-III (Spain) y para la altura se usó un tallímetro portátil SECA 214 (SECA Ltd., Hamburgo, Germany). Ambas medidas se usaron para calcular el BMI (expresado en kg/m^2). También se midieron los perímetros de cintura y cadera con una cinta métrica inextensible, cuya precisión era de 1 mm, y se calculó el ratio cintura/cadera (cintura/cadera, expresado en cm) (González-Jiménez, Montero-Alonso y Schmidt-RioValle, 2013). Los participantes fueron categorizados en normopeso y sobrepeso (incluyendo obesidad), según los puntos de corte específicos para cada sexo y edad propuestos por Cole et al. (2007). El porcentaje de grasa corporal (BF%) fue calculado usando las ecuaciones de Weststrate y Deurenberg (1989), que tiene en cuenta el cambio de la densidad de la masa magra con la edad. La densidad corporal se calculó a partir de las medidas de los 4 pliegues cutáneos (bíceps, tríceps, subescapular y suprailiaco), mediante las fórmulas de Sarría et al. (1998).

2.6. Análisis estadístico

Los datos se presentan como media y DT o n (%). Las diferencias entre sexos fueron comparadas por ANOVA de un factor para las variables continuas y con el test χ^2 para variables nominales. Los análisis preliminares no mostraron interacción significativa entre sexo, edad, grasa corporal, población, nivel educativo de la madre, capacidad aeróbica y las asignaturas (todo $P > .18$); por tanto, decidimos realizar los análisis con el total de la muestra.

La asociación de la capacidad aeróbica, la fuerza muscular, y la habilidad motora (variables predictoras) con el RA (variables dependientes), fue analizada mediante regresión lineal usando modelos diferentes. El modelo 1 fue controlado por variables socioeconómicas (sexo, edad, población rural o urbana, y nivel educativo de la madre). Además, el modelo 1 se controló también por indicadores de fatness en tres modelos separados: modelo 1 + BMI, modelo 1 + Ratio cintura/cadera, y modelo 1 + BF%.

Los análisis se realizaron con el programa estadístico SPSS versión 22.0 para Windows (SPSS Inc., Chicago). El criterio para la significatividad estadística se fijó en $P < .05$.

3. RESULTADOS

La tabla 1 presenta las características descriptivas de la muestra de estudio. Un 20% de los adolescentes tenían madres con un nivel educativo universitario. El 28.4% de los adolescentes tenían sobrepeso u obesidad. Los niveles de capacidad aeróbica, fuerza en dinamometría manual y en salto horizontal, y de habilidad motora, fueron significativamente superiores en chicos que en chicas ($P < .001$). Los chicos tenían un peso, altura, ratio cintura/cadera y RA en EF superior a las chicas (all $P < .001$), mientras que las chicas tenían un BF%, RA en Matemáticas, Lengua y RA medio mayor que los chicos (all $P < .001$).

La tabla 2 muestra la asociación de la capacidad aeróbica, la fuerza mucular y la habilidad motora con el RA tras ajustar por sexo, edad, población rural o urbana y educación maternal. En este modelo, la capacidad aeróbica se asoció positivamente con todos los indicadores de RA (todos $p < .008$). Para la capacidad arόbica, los valores de la Beta estandarizada (β) fueron de .028 a .076. La habilidad motora mostró asociación con Matemáticas (β = -.135; p = .015) y EF (β = -.353; p < .001), además se asoció con la media de Matemáticas y Lengua (β = -.103; p = .033) y con la media incluyendo EF (β = -.186; p < .001). La puntuación z de la fuerza muscular, se asoció solo con el RA en EF, y con la media de Matemáticas, Lengua y EF (β = .474; p < .001, β = .143; p = .040, respectivamente).

La tabla 3 presenta las correlaciones parciales entre los distintos componentes de la condición física y fatness tras ajustar por sexo, edad, población y nivel educativo de la madre.

	Todos (n = 1164)		Chicos (n = 562)		Chicas (n = 602)		P
	Media	DT	Media	DT	Media	DT	
Edad (años)	14.49	1.6	14.54	1.61	14.46	1.6	.383
Peso (kg)	59.23	13.77	62.93	15.32	55.78	11.09	**<.001**
Estatura (m)	1.63	.08	1.67	.09	1.60	.06	**<.001**
IMC (kg/m^2)	22.01	4.14	22.28	4.39	21.76	3.87	**.032**
Ratio cintura/cadera	.79	.07	.83	.06	.76	.06	**<.001**
BF%	20.88	5.86	19.47	6.47	22.21	4.88	**<.001**
RA Matemáticas	6.34	2.05	6.07	2.17	6.59	1.97	**<.001**
RA Lengua	6.32	1.95	5.94	2.03	6.68	1.8	**<.001**
RA EF	7.53	1.41	7.68	1.42	7.39	1.39	**.001**
Media de las puntuaciones en Mat. y Lengua	6.33	1.81	6.01	1.87	6.63	1.71	**<.001**
Puntuación media de RA: (Mat+Lengua+EF)/3	6.73	1.45	6.56	1.37	6.89	1.41	**<.001**
Capacidad aeróbica, paliers	5.06	2.41	6.27	2.46	3.94	1.73	**<.001**
Capacidad aeróbica (VO_2 max, mL/kg/min)	41.54	6.73	44.78	6.67	38.51	5.21	**<.001**
Fuerza con dinamometría manual (puntuación media de mano izquierda y derecha), kg	24.65	7.41	28.56	8.06	21.02	4.27	**<.001**
Test de salto horizontal a dos piernas, cm	151.38	31.53	169.58	29.97	134.3	21.9	**<.001**
Fuerza muscular puntuación z*	-.06	.84	.46	.84	-.55	.46	**<.001**
Habilidad motora, s	12.33	1.3	11.63	1.1	12.97	1.12	**<.001**
Madres con nivel educativo universitario (%)	20		20.8		19.3		.599
Sobrepeso y obesidad (%)	28.4		29.2		27.7		.586
Población urbana (%)	55.9		59.1		52.6		**.001**

*Tabla 1. Características descriptivas de la muestra. Los valores estadísticamente significativos se identifican en negrita. IMC: Índice de Masa Corporal. BF% = Porcentaje de grasa corporal. RA = Rendimiento Académico (escala: 0 – 10 puntos). EF = Educación Física. VO_2 max = Consumo máximo de oxígeno. cm = centímetros. s = segundos. *puntuación z: se computó a través de la fuerza de dinamometría manual y la fuerza de salto horizontal a dos piernas.*

La capacidad aeróbica y la habilidad motora (considerando que a más segundos, el resultado es peor), se correlacionaron negativamente con las 3 variables de fatness (todas $p < .001$); sin embargo, la fuerza muscular no se asoció con el IMC y mostró una correlación negativa con el ratio cintura/cadera y con el BF% (ambos $p < .001$). Los 3 componentes de condición física mostraron una alta correlación entre sí (todos $p < .001$).

	Matemáticas		Lengua		EF		Media de Matemáticas y Lengua		Media de Matemáticas, Lengua y EF	
Modelo 1	β	P	β	P	β	P	β	P	β	P
Capacidad aeróbica (VO_2 max, mL/kg/min)	.028	**.007**	.031	**.002**	.076	**<.001**	.030	**.001**	.045	**<.001**
Puntuación z de fuerza muscular*	-.037	.711	-.007	.943	.474	**<.001**	-.022	.801	.143	**.040**
Habilidad motora, s	-.135	**.015**	-.071	.172	-.353	**<.001**	-.103	**.033**	-.186	**<.001**

*Tabla 2. Asociación de los componentes de la condición física con el rendimiento académico en adolescentes. β = valores de los coeficientes de regresión estandarizados. Análisis ajustados por sexo, edad (años), población rural o urbana y nivel educativo de la madre. Valores estadísticamente significativos aparecen en negrita. EF = Educación Física. VO_2 max = consumo máximo de oxígeno. s = segundos. *puntuación z, computada mediante la fuerza de prensión manual y el salto horizontal a dos piernas.*

	Capacidad aeróbica (VO_2 max, mL/kg/min)	Puntuación z de fuerza muscular*	Habilidad motora, s	IMC, (kg/m^2)	Ratio cintura/cadera	BF%
Capacidad aeróbica (VO_2 max, mL/kg/min)	1	.414**	-.451**	-.383**	-.142**	-.508**
Puntuación z de fuerza muscular*		1	.508**	.048	-.119**	-.240**
Habilidad motora, s			1	.243**	.167**	.359**
IMC, (kg/m2)				1	.262**	.778**
Ratio cintura/cadera					1	.297**
BF%						1

*Tabla 3. Correlaciones parciales entre componentes de condición física y de fatness en adolescentes. Análisis ajustados por sexo, edad (años), población, y nivel educativo de la madre. VO_2 max = consumo máximo de oxígeno. BF% = Porcentaje de grasa corporal. s = segundos. IMC: Índice de masa corporal. *puntuación z computada mediante la fuerza de prensión manual y el salto horizontal a dos piernas. **p < .001.*

	Matemáticas		Lengua		EF		Media de Matemáticas y Lengua		Media de Matemáticas, Lengua y EF	
	β	P	β	P	β	P	β	P	β	P
Modelo 1 + IMC										
Capacidad aeróbica (VO_2 max, mL/kg/min)	.031	**.007**	.034	**.001**	.076	**<.001**	.033	**.001**	.047	**<.001**
Puntuación z de fuerza muscular*	-.039	.693	-.009	.924	.463	**<.001**	-.024	.780	.138	**.048**
Habilidad motora, s	-.137	**.017**	-.070	.196	-.334	**<.001**	-.103	**.038**	-.180	**<.001**
Modelo 1 + Ratio cintura/cadera										
Capacidad aeróbica (VO_2 max, mL/kg/min)	.029	**.008**	.033	**.001**	.075	**<.001**	.031	**.001**	.045	**<.001**
Puntuación z de fuerza muscular*	-.054	.596	-.011	.911	.453	**<.001**	-.032	.715	.129	.067
Habilidad motora, s	-.132	**.021**	-.083	.119	-.347	**<.001**	-.108	**.030**	-.187	**<.001**
Modelo 1 + BF%										
Capacidad aeróbica (VO_2 max, mL/kg/min)	.042	**.001**	.042	**<.001**	.081	**<.001**	.042	**<.001**	.055	**<.001**
Puntuación z de fuerza muscular*	-.033	.746	-.009	.924	.419	**<.001**	-.021	.812	.125	.082
Habilidad motora, s	-.158	**.008**	-.078	.164	-.328	**<.001**	-.118	.023	-.188	**<.001**

*Tabla 4. Asociación de los componentes de la condición física con el rendimiento académico independientemente de los diferentes indicadores de fatness en adolescentes. Los valores estadísticamente significativos se resaltan en negrita. EF = Educación Física. IMC: Índice de masa corporal. VO_2 max = consumo máximo de oxígeno. s = segundos. BF% = Porcentaje de grasa corporal. *Puntuación z computada mediante fuerza de prensión manual y salto horizontal a dos piernas.*

La tabla 4 muestra la asociación de la capacidad aeróbica, la fuerza muscular y la habilidad motora con respect al RA tras ajustar por sexo, edad, población, y nivel educativo de la madre, y además, incluyendo distintos indicadores de fatness en modelos separados (IMC, ratio cintura/cadera y BF%). En el modelo 1 + IMC, la capacidad aeróbica se asoció positivamente con todas las variables de RA (rango de β desde .031 a .076, todas p < .008). La habilidad motora mostró asociación con todas las variables de RA, excepto con Lengua. Mostró asociación con Matemáticas (β = -.137; p = .017) y EF (β = -.334; p < .001), con la media de Matemáticas y Lengua (β = -.103; p = .038) y con la media incluyendo EF (β = -.180; p < .001). La puntuación z de fuerza muscular, fue asociada solo con EF y con la media entre Matemáticas, Lengua y EF (β = .463; p < .001, β = .138; p = .048, respectivamente). En el modelo 1 + Ratio cintura/cadera, la capacidad aeróbica se asoció positivamente con todas las variables de RA (rango de β desde .029 a .075, todos p < .009). La habilidad motora mostró asociación con todas las variables de RA, excepto con Lengua. Se asoció con Matemáticas (β = -.132; p = .021), EF (β = -.347; p < .001), con la media de Matemáticas y Lengua (β = -.108; p = .030), y con la media incluyendo EF (β = -.187; p < .001). La puntuación z de fuerza muscular se asoció solo con EF (β = .453; p < .001). Por último, en el modelo 1 + BF%, la capacidad aeróbica se asoció positivamente con todas las variables de RA (rango de β desde .042 a .081, todas p ≤ .001). La habilidad motora se asoció con todas las variables excepto con Lengua. Se asoció con Matemáticas (β = -.158; p = .008), EF (β = -.328; p < .001), con la media de Matemáticas y Lengua (β = -.118; p = .023), y con la media incluyendo EF (β = -.188; p < .001). La fuerza muscular solo se asoció con EF (β = .419; p < .001).

4. DISCUSIÓN

Los resultados del presente estudio sugieren que incrementar la capacidad aeróbica y la habilidad motora en adolescentes, podría tener un efecto positivo en el RA, teniendo en cuenta variables de confusión socioeducativas y de fatness. La habilidad motora no se asocia con el RA en Lengua, pero sí en Matemáticas, por lo que a continuación también se intenta discutir este efecto diferencial entre ambas asignaturas. Además, se ha comprobado que el indicador de grasa corporal que más influye en el RA es el BF%.

Los hallazgos de nuestro estudio están en consonancia a los de la mayoría de investigaciones previas que revelan una asociación positiva de la capacidad aeróbica con el rendimiento cognitivo (Chaddock et al., 2012; Aberg et al., 2009) y RA (Coe et al., 2013; Sardinha et al., 2014). Algunos estudios sugieren que una capacidad aeróbica elevada podría estar asociada con mejoras en el cálculo matemático y en la resolución de problemas de aritmética (Moore et al., 2014), así como con mayor riqueza de palabras y sus significados, lo que determina un mayor nivel y control del lenguaje (Scudder et al. 2014). Otros estudios transversales demostraron una asociación entre una mayor capacidad aeróbica y un mayor RA (Castelli et al., 2007). Además, en un estudio longitudinal en el que participaron más de un millón de adolescentes suecos, Aberg et al. (2009), demostraron que una mejora de la condición física aeróbica entre los 15 y los 18 años, predecía una mejor capacidad intelectual a los 18 años, medida con una serie de pruebas de lógica, verbales, visuoespaciales y de inteligencia técnica.

Existen varios mecanismos para explicar la asociación entre capacidad aeróbica y RA. En primer lugar, la mejora de la condición física aeróbica podría tener un efecto positivo sobre las funciones cognitivas del cerebro a nivel fisiológico y aumentar el nivel del factor neurotrófico derivado del cerebro (BDNF) (Pareja-Galeano et al., 2013). El ejercicio aeróbico estimula la expresión en el hipocampo del gen Fndc5 a través del complejo de transcripción PGC-1α /Errα. El aumento de este gen estimula a su vez al gen del BDNF, un regulador maestro de la supervivencia celular, diferenciación y plasticidad en el cerebro. Así se logra una mejora de la función cognitiva, del aprendizaje y de la memoria, actúa como un agente neuroprotector, incrementa la circulación sanguínea cerebral y mejora la funcionalidad neuroeléctrica (Pareja-Galeano et al., 2013). Además, la capacidad aeróbica aumenta la angiogénesis y está relacionada con un mayor potencial y menor latencia relacionada con eventos cerebrales P3, que se ve reflejado en una mayor habilidad para modular los índices neuroeléctricos del cerebro (Moore et al., 2014). Estos procesos están implicados en el control cognitivo, formando la base para un mejor RA (Chaddock et al., 2012).

En nuestros resultados, la habilidad motora también muestra asociación con todas las variables de RA, excepto en Lengua, antes y después de ajustar por indicadores de fatness. La habilidad motora está relacionada con mejor rendimiento en varias habilidades cognitivas, como el control inhibitorio, la memoria de trabajo y la atención, así como con mejor RA (Esteban-Cornejo et al., 2014). En este sentido, proponer programas de intervención que incluyan el entrenamiento motor, podrían mejorar la habilidad motora, y por consiguiente tener efectos positivos sobre el RA (Ericsson, 2008; Uhrich y Swalm, 2007). Diferentes neuromecanismos podrían explicar la asociación entre habilidad motora y RA. Una explicación podría ser que el procesamiento mental implicado en la habilidad motora puede afectar positivamente a las funciones cognitivas y mejorar el RA posterior (Esteban-Cornejo et al., 2014). En segundo lugar, los ejercicios de habilidad motora podrían incrementar el número de sinapsis neuronales. En tercer lugar, la médula espinal tiene un rol común muy relacionado con la cognición y con el comportamiento motor. Por lo que la mejora en este último, podría coactivar el neocerebelo y la corteza prefrontal dorsolateral, afectando notablemente al funcionamiento cognitivo (Diamond, 2000).

En relación al efecto diferencial de la habilidad motora en Matemáticas y Lengua, algunos estudios han revelado que un programa de ejercicio extraescolar, mejora la función ejecutiva, los logros matemáticos y activa el cerebro (Davis et al., 2011). Bassin y Breihan (1978) concluyeron que una intervención basada en la mejora de la habilidad motora, no afectaba al rendimiento en la lectura. Otro estudio, ha concluido que el incremento del número de sesiones de EF y de su intensidad, mejora el rendimiento cognitivo en Matemáticas, pero no el razonamiento verbal ni el RA en Lengua en adolescentes (Ardoy et al., 2014). Una explicación podría ser que niveles más altos de condición física repercuten positivamente sobre la memoria, la capacidad de cálculo y sobre la resolución de problemas de aritmética en Matemáticas. Además, según Moore et al. (2014), un aumento de la condición física, influye en la codificación simbólica, mejora los recursos atencionales y el procesamiento durante las tareas aritméticas. Sin embargo, los procesos del lenguaje siguen estando poco explorados (Scudder et al., 2014). En este sentido, propuestas combinadas desde las asignaturas de EF y Matemáticas, serían clave en aras de aumentar el RA en esta última materia.

Los resultados también muestran que cuando ajustamos el modelo por indicadores de fatness, la asociación entre la capacidad aeróbica y la habilidad motora con el RA se mantiene e incluso aumenta. Estos resultados y los de estudios anteriores, indican que el fatness puede ser también importante para el éxito académico, pero que el nivel de condición física es más determinante (Sardinha et al., 2014; Torrijos-Niño et al., 2014). Además, hemos comprobado que la variable más influyente y que mejor determina la masa grasa es la BF%, obtenida a través de los pliegues cutáneos (Sarría et al., 1998; Weststrate y Deurenberg, 1989). Sería recomendable ajustar los futuros modelos por el BF%, en vez de por el BMI, que era el estándar hasta hoy en día (Chen et al., 2013; Sardinha et al., 2014).

Por último, también resulta interesante mencionar que nuestros resultados muestran que la fuerza muscular no está relacionada con el RA, de forma similar a la conclusión de otros estudios (Chen et al., 2013; Esteban-Cornejo et al., 2014). Esto sugiere, que futuras intervenciones con el objetivo de mejorar el RA, tienen que ir dirigidas mayormente hacia la capacidad aeróbica y la habilidad motora, y no hacia la fuerza muscular.

Este estudio tiene algunas limitaciones, por ejemplo, incluye un diseño de carácter transversal, que no permite realizar relaciones de causalidad. Además, la muestra es de conveniencia, que limita la generalización de los resultados. Este estudio también tiene algunas fortalezas, por ejemplo que incluye una muestra amplia de adolescentes andaluces y una completa y estandarizada evaluación de la condición física y masa grasa a través de medidas objetivas y validadas. Así como el uso de calificaciones académicas reales y recientes de las asignaturas escolares más determinantes en el RA.

En conclusión, la capacidad aeróbica y la habilidad motora pueden tener una potencial influencia sobre el RA de los adolescentes, independientemente del nivel socioeducativo de las familias y del fatness de los jóvenes. Sugerimos a los profesores de EF que den más importancia al componente aeróbico y motor en sus clases, y animamos a promover acciones conjuntas de forma interdisciplinar entre la asignatura de EF y las asignaturas instrumentales estudiadas, así como a fomentar el aumento de la condición física aeróbica y motora durante la adolescencia, desde el ámbito educativo, político y familiar.

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VII

The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school

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The effect of cooperative high-intensity interval training on creativity and emotional intelligence in secondary school: A randomised controlled trial

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Abstract

Evidence suggests that moderate physical activity (PA) positively relates to creativity and emotional intelligence (EI) in adolescents. However, it is unknown whether cooperative PA (physical exercises in pairs or small groups to enhance motivation, self-efficacy, and pro-social behaviours), performed over less time but at higher intensity, could have similar effects within a school setting. The aim was to analyse the effect of cooperative high-intensity interval training (C-HIIT) on creativity and EI in adolescents aged 12–16 years, and whether improvement effects are different according to weekly PA level. A randomised controlled trial was conducted with a control group (CG, $n = 94$), which did static stretching, and an experimental group (EG, $n = 90$), which performed C-HIIT. Both groups performed the activity during 16 minutes at the beginning of physical education (PE) classes. Creativity was assessed with one factor, and EI through four factors (well-being, self-control, emotionality, and sociability). Age and body mass index (BMI) were used as confounders. Both were measured twice (baseline and after 12 weeks). The EG increased well-being and sociability factors after the C-HIIT programme (both $p < 0.001$). More specifically, inactive adolescents in the EG showed

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significant improvements in comparison to the CG in creativity, well-being, and sociability ($p = 0.028$, $p < 0.001$, and $p < 0.003$, respectively). However, we did not find changes among active adolescents. A programme of C-HIIT in PE is a novel strategy to improve creativity and EI, especially in physically inactive adolescents. Starting PE classes with 16 minutes of C-HIIT could be recommended, independently of other activities planned for the session.

Keywords
Cognitive performance, emotional intelligence, high-intensity interval training, physical activity, physical education, secondary education

Introduction

In the 21st century, creativity has become an element considered key to cognition because it contributes notably to the personal and work success of the individual (Heilman, 2016). Creativity has been defined as the capacity to invent an original and new product of value in the widest sense (Steinberg et al., 1997) and, according to Heilman, it can be distinguished by three stages: (1) preparation, in which the person acquires the knowledge and skills needed to discover, develop and produce a creative product; (2) innovation, in which a person's brain unconsciously searches for an answer, discovers it, and finds unity; and (3) verification, which yields final results. This last stage is of particular importance in the creative process, especially so because creativity is difficult to quantify.

Creativity is related to divergent thinking (Torrance, 1966), a style of thinking that allows many new ideas to be generated where more than one solution is correct as an answer to the same problem (Santos et al., 2016). 'Brainstorming', for instance, is a well-known and well-established version of divergent thinking (Colzato et al., 2013). It has been noted that a higher creativity level correlates with lower psychological distress and depression (Corbalán et al., 2010).

When cognitive aspects interact with emotional factors and behavioural responses, emotional intelligence (EI) is formed (Salovey and Mayer, 1990). EI is a construct composed of well-being, self-control, emotionality, and sociability (Petrides, 2009; Petrides et al., 2016). A good level of EI is associated with adaptive behaviours and social skills (Frederickson et al., 2012), leadership qualities, and fewer incidences of being disruptive, aggressive and dependent in the school context (Mavroveli et al., 2009). A study carried out among British adolescents showed that loneliness is one of the most linked variables with emotional skill deficits (Wols et al., 2015). Furthermore, EI can inhibit maladaptive actions such as bullying, victimisation and psychopathology in adolescence (Kokkinos and Kipritsi, 2012; Petrides et al., 2016; Salovey and Mayer, 1990). Finally, better levels of creativity and EI during adolescence are highly determinant with regard to achieving better academic performance at school and greater future job success (Frederickson et al., 2012; Mavroveli and Sanchez-Ruiz, 2011; Perera and DiGiacomo, 2013; Petrides et al., 2016).

Recent studies have associated physical activity (PA) with better creativity (Blanchette et al., 2005; Colzato et al., 2013; Santos et al., 2016) and better development of EI factors such as well-being (Ruiz-Ariza et al., 2015), self-control (Donnelly and Lambourne, 2011), emotionality (Azevedo et al., 2014) and sociability (Kato et al., 2016; Tateno et al., 2016). However, the level of sedentarism has increased in recent years (Cheung et al., 2017), and 62.6% of adolescents do not perform the minimum recommended one hour or more of moderate to vigorous PA (MVPA) five days per week (Mielgo-Ayuso et al., 2016).

Another study, by Calahorro-Cañada et al., (2016) showed that during Physical Education (PE) days Spanish young people practise significantly more PA than during days without PE. In spite of this, students only accrue between 5.7 and 8.7 minutes of MVPA during PE classes (Calahorro-Cañada et al., 2016). In addition, a study by Yli-Piipari et al. (2016) has shown that a higher amount of MVPA is achieved on school days with PE classes (nine more minutes in the United States and 16 more minutes in Finland) compared with school days without PE. Furthermore, PE has scarce curricular time in many countries – around two hours per week (Román-Viñas et al., 2016). Novel and effective methods are therefore required to enhance the effects of PA done in the shortest time possible.

High-intensity interval training (HIIT) is a method that allows maximising the scarce PA daily time, as high-intensity activities have shown a greater impact on health outcomes than longer and lower intensity activities in adolescents (Eddolls et al., 2017; Kerr et al., 2016; Logan et al., 2014). This method includes short intervals of high-intensity exercise (i.e. from $\leq$ 45 seconds to 2–4 minutes at >85% of heart rate maximum), and short break periods between intense exercises (Costigan et al., 2016). When PA is performed in a cooperative way — physical exercises in pairs or in small groups — effects on creativity and wellbeing could be enhanced (Santos et al., 2016). For some researchers, the social character of cooperative PA, playful entertainment, and group decision-making in cooperative exercises, are some determinant factors of this kind of PA (Davis et al., 2015; Marker et al., 2015; Santos et al., 2016). To the best of our knowledge, only two recent studies have highlighted the potential of incorporating high intensity PA within the secondary school day (Ardoy et al., 2014; Costigan et al., 2016). Ardoy et al. (2014) have demonstrated a positive chronic impact on cognitive and academic performance after four sessions per week of PE at high intensity, over four months. And Costigan et al. (2016) showed a positive effect on the physical self-concept (especially appearance) and well-being of adolescents after a programme of eight–10 minutes of HIIT, with a work-to-rest ratio of 30:30 seconds, three sessions per week, for eight weeks.

However, the effects on other important variables during adolescence, such as creativity or EI, are as yet unknown. Furthermore, no study has added a cooperative dynamic within an HIIT programme (Costigan et al., 2016; Logan et al., 2014). A cooperative dynamic has been previously found to increase motivation, promote continued play, and enhance self-efficacy and pro-social behaviours (Agbuga et al., 2012; Jaakkola et al., 2012; Marker et al., 2015; Theodoulides and Armour, 2001). In this sense, to use a new method such as cooperative HIIT (C-HIIT) – defined as physical exercises in pairs or small groups at high intensity – could be a novel educational strategy for enhancing the benefits of PA. However, the cognitive effects of PA at high intensity do not affect all students in the same way (Costigan et al., 2016; Ruiz-Ariza et al., 2016). Physically inactive students could have a higher margin of improvement due to the dose–response effect (Martínez-Gómez et al., 2011; Ruiz-Ariza et al., 2016). Thus, the aim of this study was to analyse the effect of 16 minutes of C-HIIT at the beginning of PE classes for 12 weeks on creativity and EI in adolescents between 12 and 16 years old. We also analysed whether the results were different according to participants' weekly PA level.

Methods

The study used a quantitative randomised controlled and blind trial with a control group (CG) (n = 94) that carried out static stretching, and an experimental group (EG) (n = 90) that performed 16 minutes of C-HIIT within PE classes (two days per week). This short C-HIIT programme at the beginning of the class would allow for verification of our hypothesis and checking to determine

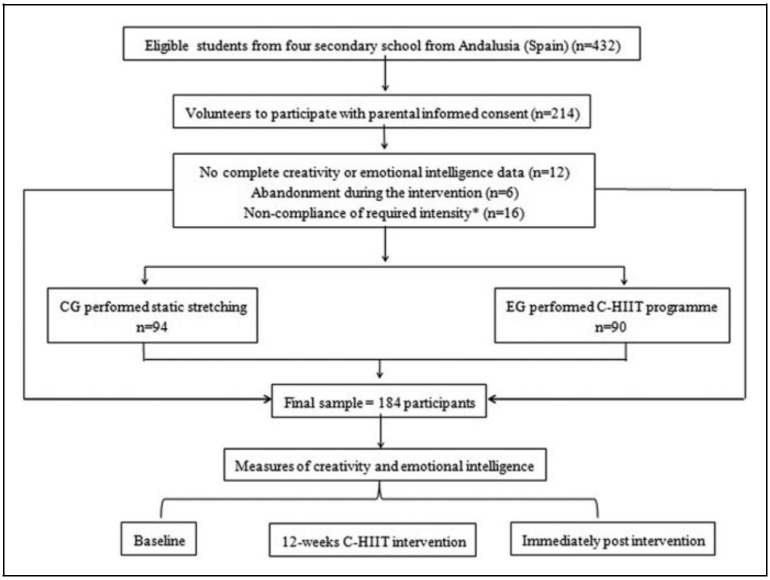

Figure 1. Study flow.
Note: CG = Control group, EG = Experimental group, C-HIIT = Cooperative high-intensity interval training. *Participants who did not maintain the required intensity (≈ 165–185 bpm) during at least 80% of the HIIT programme.

whether it was compatible with the development of daily instances of such a programme within each PE session.

Participants

A total sample of 184 adolescents from four secondary schools in the south of Spain participated in this study. Participants were 13.73 ± 1.34 years old with a Body Mass Index (BMI) of 21.34 ± 3.61 kg/m^2. Adolescents with some physical pathology or medical contraindication to perform PA were excluded from this study. Those diagnosed with learning disabilities (e.g. ADHD) were not included among the eligible students. Despite this exclusion, they performed the PA corresponding to their group, but these data were not included in the analysis. The final sample consisted of young people who completed the creativity or EI data and carried out the total intervention period correctly. Each participant had to maintain high intensity of over 85% of their heart rate maximum (range ≈ 165–185 beats per minute) during at least 80% of the 16 minutes of each session within the C-HIIT programme. Only 12 participants did not complete creativity or EI data and six left the study during the intervention. The structure used for group formation and intervention characteristics are shown in Figure 1.

Measures

Creativity. To assess this construct we used the CREA test (Corbalán et al., 2003), third edition (2015). The test uses the ability to elaborate questions as a measure of creativity. The task consists of briefly writing as many questions as possible about what an illustration represents for a period of four minutes. This divergent thinking test is designed to generate questions as indicators of creative talent, originality and effectiveness. Each question supports a new cognitive schema, which in turn relies on at least two others. A score was assigned to each question (possible scores: 1 = low, 2 = medium, 3 = high) according to their quality and complexity. Unlike previous tests such as the Alternative Uses Test (Guilford, 1967) and Torrance Tests of Creative Thinking (Torrance, 1974), the CREA test provides for better management of cognitive schemes because it does not contemplate the question as a final product; it puts divergent thinking into operation, promoting the process of thinking and not merely the final response. In addition, in this test the participants' disposition is not relaxed but concentrated and competitive (Corbalán et al., 2010).

Previous studies (Clapham and King, 2010; Corbalán et al., 2003; Corbalán-Berná and Limiñana-Gras, 2010), have shown a high predictive and concurrent validity of CREA compared with other creative batteries such as Guilford's Alternative Uses Test ($p < 0.05$). The CREA test also has good internal consistency (Spearman's rho > 0.650, $p < 0.001$), suggesting that CREA is a quick, easy and useful measure of divergent thinking (Clapham and King, 2010).

Emotional intelligence. To assess EI, this study used the Trait and Emotional Intelligence Questionnaire Short Form (TEIQue-SF) designed by Petrides (2009). This version has been used in the Spanish context with an internal consistency of alpha = 0.82 (Cejudo et al., 2016). TEIQue-SF is composed of 30 items with seven possible responses to each statement ranging from 'Completely disagree' = 1 to 'Completely agree' = 7. This test assesses four factors:

(1) Well-being: Items 5, 20, 9, 24, 12 and 27; for example, 'I generally don't find life enjoyable'.
(2) Self-control: Items 4, 19, 7, 22, 15 and 30; for example, 'I usually find it difficult to regulate my emotions'.
(3) Emotionality: Items 1, 16, 2, 17, 8, 23, 13 and 28; for example, 'Expressing my emotions with words is not a problem for me'.
(4) Sociability: Items 6, 21, 10, 25, 11 and 26; for example, 'I can deal effectively with people'.

Items 3, 18, 14 and 29 contribute only to the global average trait EI score (data not shown). The results obtained in this questionnaire rendered Cronbach's alpha coefficients of 0.91, 0.84, 0.81 and 0.79 respectively. The total alpha is 0.86. The reliability test–retest (48h, $n = 26$) in items showed high results (rho = 0.774 and rho = 0.912 for the lowest and highest respectively, all $p < 0.001$).

Cooperative high-intensity interval training (C-HIIT). A stratified random sampling procedure was conducted to ensure that equal numbers of boys and girls were allocated between the two groups. The CG performed static stretching, because some recent systematic reviews have concluded that this is the physical fitness component least associated with cognitive variables (Ruiz-Ariza et al., 2017; Santana et al., 2017); and the EG performed C-HIIT, whose sessions started with a short warm-up activity of four minutes including running, sideways movements and dynamic stretching at medium intensity. The programme consisted of sessions of 16 minutes of C-HIIT, two sessions per week, for 12 weeks. Previous studies had checked the cognitive effect of HIIT after different periods of daily practice in school; for example, four minutes (Ma et al., 2015), 8–10 minutes

(Costigan et al., 2016), or one complete PE session of 55 minutes (Ardoy et al., 2014). The present study considered that performing 16 minutes of C-HIIT at the beginning of each PE session would be sufficient to obtain significant effects. PE teachers could dedicate the rest of the time – approximately two-thirds of the PE session – to the normal activities of the programmed class.

Based on a study of HIIT by Costigan et al. (2016), each session had four series of each proposed exercise, with work-to-rest ratios varying from 20:40 seconds to 40:20 seconds in the last two weeks (weeks 1–2 = ratio 20:40 seconds; weeks 3–4 = ratio 25:35 seconds; weeks 5–8 = 30:30 seconds; weeks 9–10 = 35:25 seconds; weeks 11–12 = 40:20 seconds). The C-HIIT included a combination of cardiorespiratory, speed–agility and coordinative training exercises because they are the fitness components that mostly enhance cognitive capacity in adolescents (Ruiz-Ariza et al., 2017; Santana et al., 2016). In addition, all activities were carried out in pairs that rotated after each series to promote the cooperative context (Marker et al., 2015). To perform each activity correctly it was necessary to have collaboration between both participants. Members of each pair rotated every four minutes to ensure cooperation among all classmates. The C-HIIT sessions were taught by four PE teachers who were specialists in this method. Participants wore heart rate monitors (*Seego Realtracksystems*®, Spain) to encourage maintenance of the appropriate exercise intensity. Each participant from the EG had to be in an intensity $\geq$ 85% of heart rate maximum (Costigan et al., 2016). Figure 2 shows a graphical description of an example session of the C-HIIT programme.

Weekly practice of MVPA. A classification was obtained about the baseline level of PA based on Prochaska et al.'s (2001) MVPA questionnaire. The participants were asked whether they practised PA during the week. Thus, two questions were posed in relation to the number of days that participants did MVPA for at least 60 minutes. The questions concerned the level of PA performed during a typical week in addition to during the week just prior to when the measures were implemented. Using this approach, the average time of PA carried out per week was gauged as follows: 131 participants (71.7%) were classified as inactive (< five days/week at least one hour of MVPA) and 53 (28.3%) were classified as active ($\geq$ five days/week). Similar to previous studies (Martínez-López et al., 2015), internal consistency of PA items was high (Cronbach's alpha = 0.809).

Confounders. Age and BMI were controlled as confounders (Esteban-Cornejo et al., 2015; Ruiz-Ariza et al., 2017; Sardinha et al., 2014). BMI was calculated with weight and height [weight/height (m^2)]. A weighing machine *ASIMED*® B-type-class III (Spain) and a portable height metre *SECA* 214 (*SECA*® Ltd, Germany) were used, respectively. Both measurements were performed on barefoot individuals dressed in light clothes.

Procedure

Parents signed consent forms at the beginning of the data collection. The participants' creativity and EI were measured at two time points during the first school hour in the morning in both groups: at baseline and after 12 weeks. Pre- and post-tests were performed in a classroom with individual desks for the written tests, and a sociodemographic sheet was also completed during the pre-test. All tests were 'pen-and-paper' and group-administered.

During testing, one specialised researcher gave instructions and kept track of the time, while two research assistants observed any possible doubts and disturbances (e.g. noise outside the

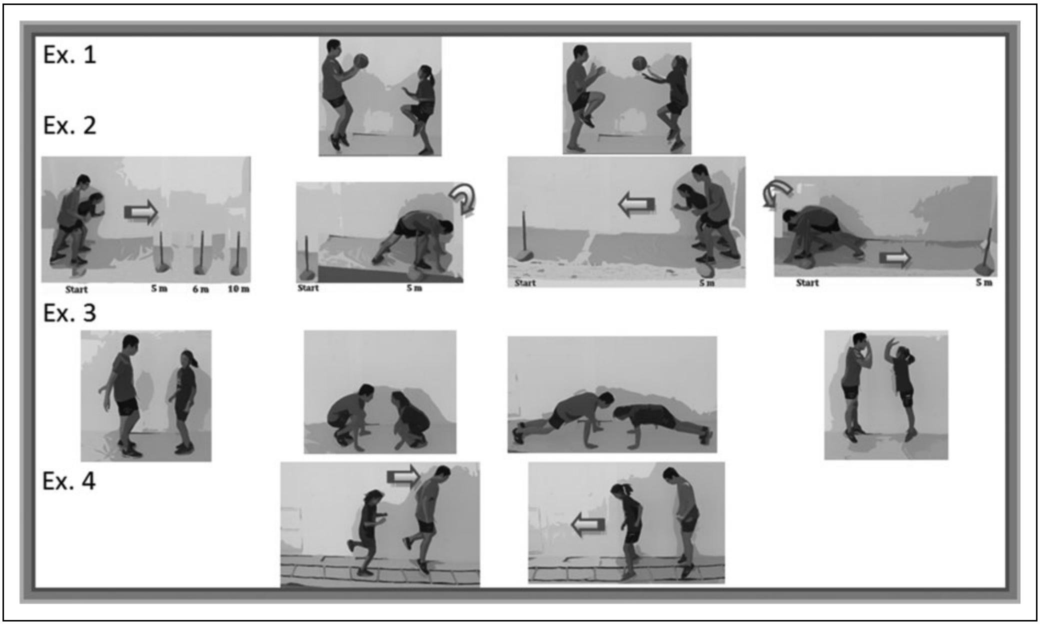

Figure 2. Graphical description of an example session of 12 weeks C-HIIT programme.
Note: **Ex. 1.** Skipping passing a ball in pairs at 2 metres of distance between them, as many times as possible during the work time.
Ex. 2. Running back and forth between lines at 5, 6, 10 metres. The two members must hold hands. When they cross the respective lines, must touch the ground, rotate, and change hands to return to the starting line, touch the ground again and repeat the hand change to start a new running until the following line (at 6 metres), and so on. The pair needs to sum the higher number of crossed lines during work time.
Ex. 3. Burpees in pairs clashing hands on the jump, repeated as many times as possible during the work time.
Ex. 4. Coordination ladder back and forth, imitating the partner during work time. When a one-way trip is completed, the roles are rotated.

classroom, confused students, mistakes on some sheet copies, or students having no ink in their pen). To perform C-HIIT in PE classes, each PE teacher was instructed about the 16 minutes C-HIIT programme of two times a week, for 12 weeks. For this objective, a one-day training programme in a real context was provided before the start of the intervention by the researchers who developed the programme. In addition, in the week before the start of the programme, the EG practised C-HIIT at an intensity near 85% of the heart rate maximum. This effort was always well tolerated by adolescents. Each family received an individualised report about their children with a full assessment about effort response.

To validate the performance of each student, each session was recorded with a heart rate monitoring system, the *Seego Realtracksystems*® (Spain). The programme was not interrupted for any vacation period. The C-HIIT design allowed all participants to reach the intensity range required without limitation resulting from their level of coordination. The CG performed static stretching exercises during the same time (Mayorga-Vega et al., 2015). None of the participants carried out extracurricular high-intensity PA during the 12 weeks of the study.

This study was approved by the Bioethics Committee of the University of Jaén. The design complies with the Spanish regulations for clinical research in humans (Law 14/2007, 3 July, Biomedical Research), with the regulations for private data protection (Organic Law 15/1999), and with the principles of the Declaration of Helsinki (2013 version, Brazil).

Data analysis

The comparison of the continuous and categorical variables according to participation in the study (CG vs. EG) was carried out using students'*t*-tests and χ^2, respectively. Tests of normal distribution and homogeneity (Kolmogorov–Smirnov and Levene's) were conducted before analysis. To study the relationship between variables, Spearman's correlation was used. The repeated measures analysis of covariance (ANCOVA) [two time (pre, post)] x [two group (CG, EG)] x [two PA level (inactive, active students)] was used to analyse the long-term effect of 16 minutes of C-HIIT. Creativity and EI factors were used as dependent variables, the group and MVPA were used as fixed factors, and age and BMI as confounders. Post-hoc analysis was adjusted by Bonferroni. The effect size was computed and reported as a partial η^2 value for the analysis of variance (ANOVA) evaluations. To quantify the magnitude of changes between and within groups in the dependent variables, we calculated the effect sizes Cohen's *d*. A Cohen's *d* value ≥ 0.8 indicates a large effect size, a Cohen's *d* value $\geq 0.5 < 0.8$ indicates a medium effect size, and a Cohen's *d* value $\geq 0.2 < 0.5$ indicates a small effect size (Cohen, 1998). Analyses were carried out separately for each dependent variable. For all the analyses, a 95% confidence level was used ($p < 0.05$). The analyses were completed using *SPSS* (v.22 for Windows).

Results

Descriptive analysis and correlations

Table 1 shows the anthropometric and sociodemographic characteristics of the participants. Participants had an average of 2.76 ± 1.59 computers at home, performed 2.80 ± 1.58 days/week of MVPA, studied 115.76 ± 47.39 minutes/day, and only 3.3% had no Internet access. Maternal educational level – an important factor of socio-educational family status (Ruiz-Ariza et al., 2015) –, showed that only 1.1% of mothers had no educational qualifications and 25% did not have a job. No initial differences between the CG and the EG were found in any of the variables analysed except for BMI ($p = 0.034$). A Spearman correlation showed that the well-being factor correlated significantly with self-control (rho = 0.341, $p<0.001$) and sociability (rho = 0.208, $p < 0.01$). Self-control correlated significantly with emotionality (rho = 0.354, $p<0.001$) and sociability (rho = 0.313, $p < 0.001$). Finally, sociability also correlated with emotionality (rho = 0.258, $p < 0.001$). No EI variable correlated significantly with creativity (all $p > 0.05$).

ANCOVA analysis of 12 weeks of C-HIIT on creativity and EI

ANCOVA [two time] x [two group] x [two PA level], on creativity (Figure 3), showed an [interaction effect group] x [PA level] $F(1,170) = 4{,}164$; $p = 0.043$; partial $\eta^2 = 0.024$; $1 - \beta = 0.528$. After 12 weeks, in inactive adolescents, the EG showed greater creativity than the CG (15.09 ± 4.22 vs. 12.59 ± 4.26, $p = 0.028$, Cohen's $d = 0.589$). No intragroup nor intergroup differences were found in physically active youth (all $p > 0.05$).

Table 1. Anthropometric and sociodemographic characteristics of participants. Values are presented as mean and standard deviation or percentage.

		All (n = 184)	CG (n = 94)	EG (n = 90)	p-value
Age (years)		13.73 ± 1.34	13.67 ± 1.29	13.79 ± 1.38	0.549
Sex (%)	Girl	86 (46.7)	42 (47.7)	44 (48.9)	0.567
	Boy	98 (53.3)	52 (53.3)	46 (51.1)	
Weight (kg)		56.87 ± 12.571	55.47 ± 10.13	58.27 ± 14.52	0.136
Height (m)		1.62 ± 0.093	1.63 ± 0.099	1.62 ± 0.086	0.530
BMI (kg/m^2)		21.34 ± 3.61	20.76 ± 2.97	21.92 ± 4.11	0.034
Computers at home (n)		2.76 ± 1.59	2.72 ± 1.63	2.81 ± 1.54	0.716
Daily time studying (minutes per day)		115.76 ± 47.39	120.72 ± 43.78	110.63 ± 50.60	0.160
MVPA (days/week)		2.80 ± 1.58	2.98 ± 1.58	2.62 ± 1.57	0.117
MVPA (%)	Inactive students	132 (71.7)	64 (68.1)	68 (75.6)	0.261
	Active students	52 (28.3)	30 (31.9)	22 (24.4)	
Internet access (%)	No	6 (3.3)	3 (3.2)	3 (3.3)	0.957
	Yes	178 (96.7)	91 (96.8)	87 (96.7)	
Mother's education level (%)	No educational qualifications	2 (1.1)	1 (1.1)	1 (1.1)	0.879
	Primary	21 (11.4)	9 (9.6)	12 (13.3)	
	Secondary	70 (38)	36 (38.3)	34 (37.8)	
	University	91 (49.5)	48 (51.1)	43 (47.8)	
Maternal work (%)	Not working	46 (25)	24 (25.5)	22 (24.4)	0.865
	Working	138 (75)	70 (74.5)	68 (75.6)	

Notes: CG = Control group; EG = Experimental group; BMI = Body mass index; MVPA = Moderate-to-vigorous physical activity.

The well-being analysis found a [time] x [group] interaction, $F(1,170) = 11.173$; $p = 0.001$; partial $\eta^2 = 0.062$; $1 - \beta = 0.914$: [time] x [group] x [PA level] $F(1,170) = 4122$; $p = 0.036$; partial $\eta^2 = 0.011$; $1 - \beta = 0.628$: [group] x [PA level] $F(1,170) = 9.440$; $p = 0.009$; partial $\eta^2 = 0.054$; $1 - \beta = 0.878$. The EG increased well-being after 12 weeks (post: 4.75 ± 0.71 vs. pre: 4.34 ± 0.77, $p < 0.001$, Cohen's $d = 0.553$). However, a more detailed analysis showed that only inactive students increased in well-being after the C-HIIT programme, in comparison to the initial measure (post: 4.83 ± 0.67 vs. pre: 4.32 ± 0.52, $p < 0.001$, Cohen's $d = 0.850$). In addition, in the inactive group, the EG also improved in the post measure compared to the CG (4.83 ± 0.67 vs. 4.41 ± 0.70, $p = 0.008$, Cohen's $d = 0.612$) (see Figure 4).

Regarding self-control (Figure 5), only the main group displayed a significant effect ($p = 0.085$). A more detailed analysis showed differences almost at the level of significance between groups in post measure (4.41 ± 0.75 vs. 4.17 ± 0.69, $p = 0.081$, Cohen's $d = 0.342$). For emotionality (Figure 6), no main effect or interaction effect was found in the participants (all $p > 0.05$).

The sociability analysis found a [time] x [group] interaction, $F(1,170) = 10.100$; $p = 0.022$; partial $\eta^2 = 0.050$; $1 - \beta = 0.811$: [time] x [group] x [PA level] $F(1,170) = 4{,}113$; $p = 0.042$; partial $\eta^2 = 0.024$; $1 - \beta = 0.523$: [group] x [PA level] $F(1,170) = 3.955$; $p = 0.041$; partial $\eta^2 =$

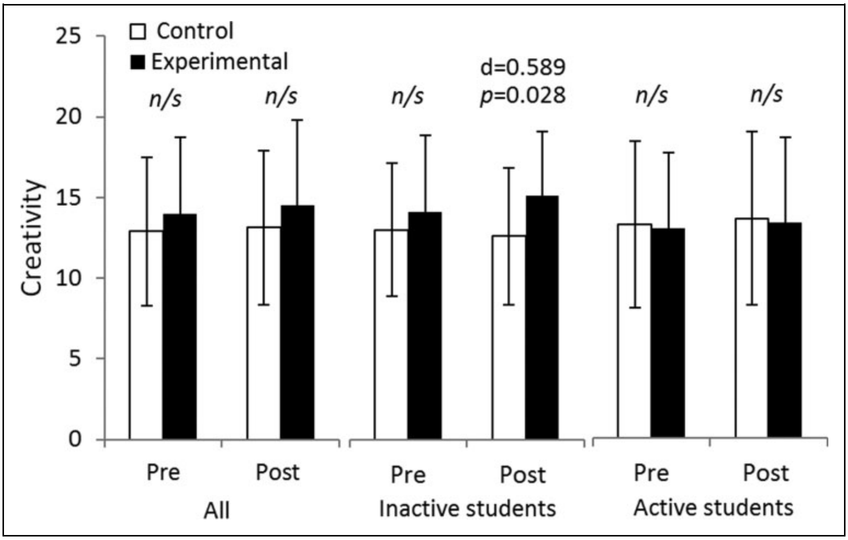

Figure 3. Results of creativity in adolescents after 12 weeks (16 minutes/2days/week) of high-intensity interval training.

Note: Inactive students < 5 days/week and active students $\geq$ 5 days/week at least one hour of MVPA. Data expressed in mean and SD. *n/s* denotes no significant differences between groups in the same measure.

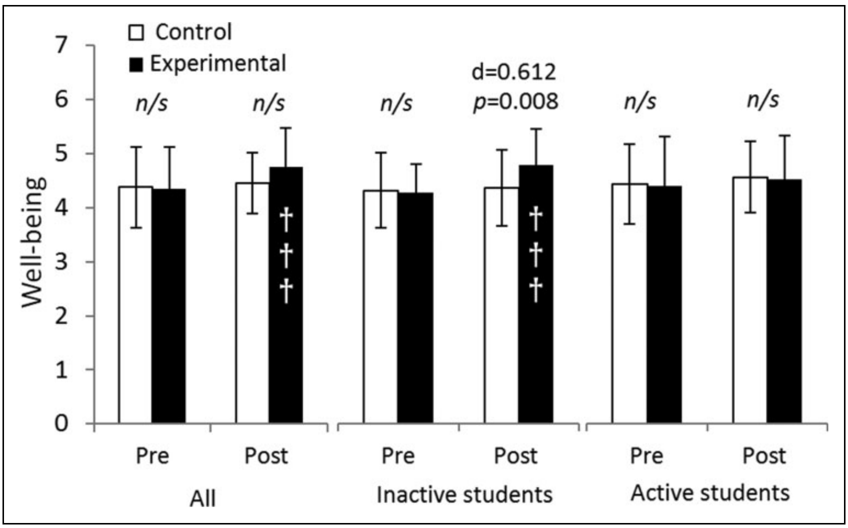

Figure 4. Results of well-being in adolescents after 12 weeks (16 minutes/2days/week) of high-intensity interval training.

Note: Inactive students < 5 days/week and active students $\geq$ 5 days/week at least one hour of MVPA. Data expressed in mean and SD. ††† denote $p < 0.001$ compared to pre-measure in the same group. *n/s* denotes no significant differences between groups in the same measure.

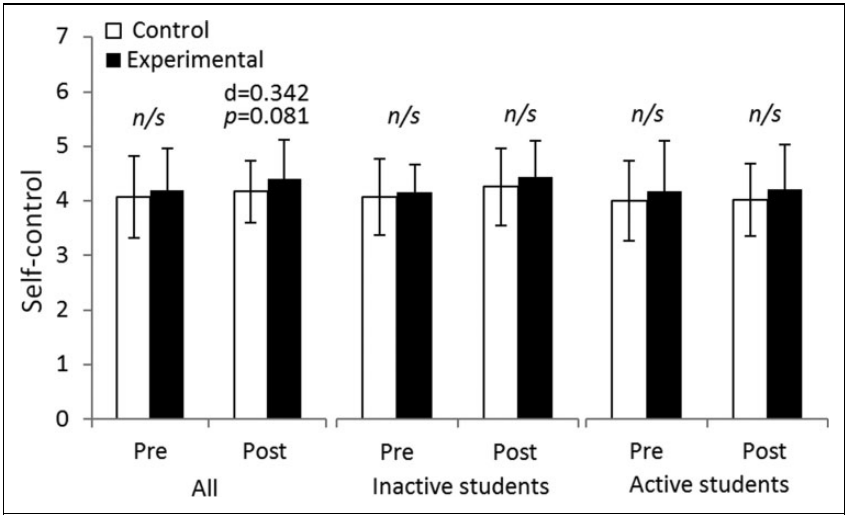

Figure 5. Self-control results after 12 weeks (16 minutes/2days/week) of high-intensity interval training in adolescents.
Note: Inactive students < 5 days/week and active students ≥5 days/week at least one hour of MVPA. Data expressed in mean and SD. *n/s* denotes no significant differences between groups in the same measure.

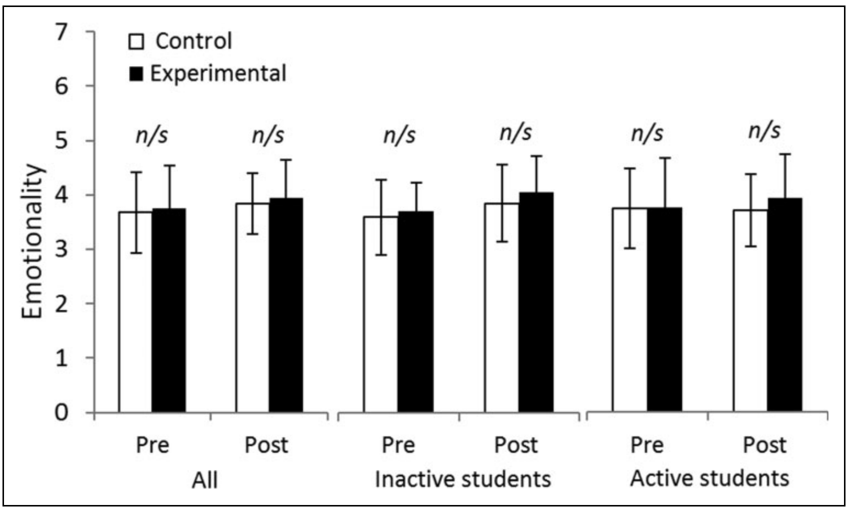

Figure 6. Results of emotionality after 12 weeks (16 minutes/2days/week) of high-intensity interval training in adolescents.
Note: Inactive students < 5 days/week and active students ≥ 5 days/week at least one hour of MVPA. Data expressed in mean and SD. *n/s* denotes no significant differences between groups in the same measure.

0.023; $1 - \beta = 0.507$. The EG showed increased sociability after 12 weeks (post: 4.57 ± 0.78 vs. pre: 4.04 ± 0.85, $p < 0.001$, Cohen's $d = 0.649$). However, a more detailed analysis showed this effect of the HIIT programme only for inactive students, compared to the initial measure

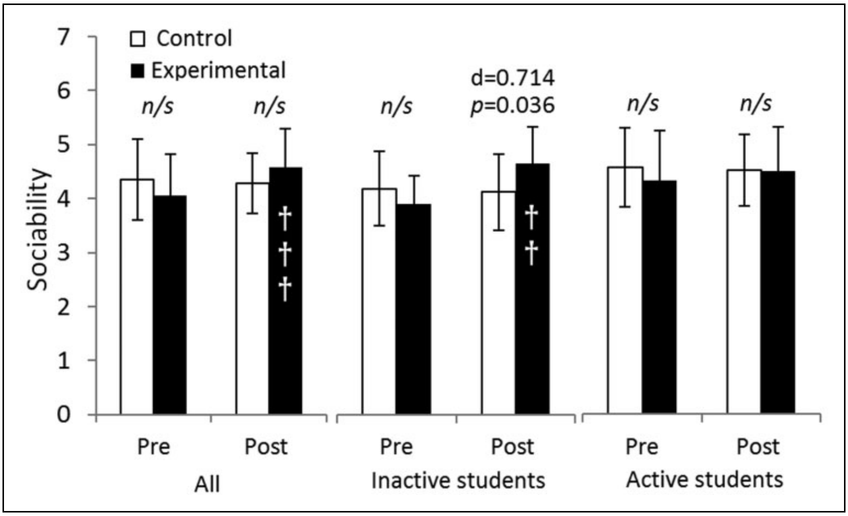

Figure 7. Results in sociability after 12 weeks (16 minutes/2days/week) of high-intensity interval training in adolescents.
Note: Inactive students < 5 days/week and active students ≥ 5 days/week at least one hour of MVPA. Data expressed in mean and SD. †† and ††† denote $p < 0.01$ and $p < 0.001$ compared to pre-measure in the same group, respectively. *n/s* denotes no significant differences between groups in the same measure.

(4.72 ± 0.75 vs. 3.95 ± 0.77, $p < 0.003$, Cohen's d =1.013). In addition, in the inactive group the EG also improved in the post measure with regard to the CG (4.72 ± 0.75 vs. 4.17 ± 0.79, $p = 0.036$, Cohen's $d = 0.714$) (see Figure 7). In active students, no main effect or interaction was found (all $p > 0.05$).

Additional analysis

An additional analysis showed that 86% of girls were inactive, more than the 58.8% of boys (χ^2 =16.682, $p < 0.001$). An ANCOVA [two group] x [two time], differentiated by gender (with age and BMI as covariables) showed a significant [group] x [time] interaction in well-being and sociability in girls: F(1,88) = 7.738; $p = 0.009$; partial $\eta^2 = 0.088$; $1 - \beta = 0.785$, and F(1,88) = 6,028; $p = 0.016$; partial $\eta^2 = 0.070$; $1 - \beta = 0.713$, respectively. In both cases there was a significant improvement in the EG in relation to the pre-measure for well-being ($p = 0.008$), and p < 0.012 for sociability (data not shown).

Discussion

The aim of this study was to analyse the effect of C-HIIT at the beginning of PE classes on creativity and EI in adolescents between 12 and 16 years of age, and C-HIIT's effect on results compared to the usual weekly PA level. Results have shown that two days of 16 minutes of PA at high intensity, performed in a cooperative and continuous way for 12 weeks, has an improvement effect on well-being and sociability in adolescents. In addition, improvements were especially significant in creativity, well-being and sociability among physically inactive students. No negative effects of C-HIIT were observed, and no injury occurred during the programme. These results suggest that promoting short programmes of collective activities at high intensity in young people can offer creative and emotional benefits, in addition to the traditional positive effects on health.

Our findings are similar to those obtained by Costigan et al. (2016), which showed a positive relationship between HIIT and well-being in adolescents after three sessions per week of 8–10 minutes, for eight weeks, with a work-to-rest ratio of 30:30 seconds at an intensity of $\geq$ 85% of heart rate maximum. A similar study conducted by Ardoy et al. (2014) examined the effect of a four-month training programme on cognitive performance in adolescents. Ardoy et al. used two experimental groups, the high frequency/normal-intensity group (four days/week; $HR_{mean} = 129$ bpm) and the high-frequency/high-intensity group (four days/week; $HR_{mean} = 147$ bpm). Overall cognitive variables were found to have improved significantly only for the high-frequency/high-intensity group. Furthermore, according to a recent systematic review by Li et al. (2017), the effect size was larger in the high-intensity group (4.87; $p < 0.001$). Contrary to the above-mentioned studies, Zervas et al. (1991) showed no effects on the *Cognitrone* test after three days/week for 25 weeks of individual chronic high-intensity training on a treadmill.

Other studies have found a specific association in young people between PA and creativity (Blanchette et al., 2005), well-being (Ruiz-Ariza et al., 2015), and sociability (Kato et al., 2016; Tateno et al., 2016), but at moderate intensity. For example, Azevedo et al. (2014) found a significant effect for a 12-month follow-up dance school intervention on psychological well-being that increased positive emotions, satisfaction with life, and the sense of socio-emotional balance. Based on the above, we consider that maintaining a C-HIIT programme during a period longer than 12 weeks could increase its effects and influence on other variables of psychological health.

In 2005, Blanchette et al. analysed the effect on creativity of three different extracurricular sessions with different periods of PA. Results showed positive effects only over a two-hour period. Unlike the Blanchette et al. study, our research showed improvements in a much shorter time for young inactive students, and the programme is applicable to the context of any PE class in secondary school.

Our long-term findings (12 weeks) do not allow knowing the acute effects immediately after C-HIIT. However, previous studies have concluded that PA could increase the short-term and long-term effects on creative thinking, but the effect size could vary (Blanchette et al., 2005; Gondola and Tuckman, 1985; Gondola, 1986, 1987; Ramocki, 2002; Steinberg et al., 1997). One of the pioneer studies along these lines showed positive effects of short-term and long-term PA in three creativity measures of spontaneous flexibility, originality, and different ideas (Gondola and Tuckman, 1985). The following year, Gondola (1986) used the same creativity tasks to compare the effect of long-term and short-term PA: he found improvements for both, for the three creativity variables. Other studies have researched short-term aerobic activity through a dance exercise (Gondola, 1987), an aerobic exercise programme, as compared to a traditional PE class (Herman-Tofler and Tuckman, 1998), or a team sport (Santos et al., 2016), and all reported enhanced effects in creativity. The main strength of the present study, therefore, is focused on its improvement effects in a short daily period of PA. To complete these findings, new research designs are necessary to analyse the short-term effect of C-HIIT on creativity and EI, immediately after 16 minutes of stimuli. Our results could help guide the recommended daily time for programme application both within school and during extracurricular activities.

An important finding of this study was the effect on creativity and EI when the sample was separated between inactive students (< five days/week for at least one hour of MVPA) and active students ($\geq$ five days/week). While inactive adolescents showed significant improvements in creativity, well-being and sociability after the C-HIIT programme, differences pre–post were not found in active adolescents. We have found previous studies that compare the results for creativity, but not for EI. Contrary to our data, some studies have shown gains in creativity among fit participants compared to those who were unfit. For example, Steinberg et al. (1997) found small improvements in the fit group, but only in one measure of the Torrance test of creative thinking. Ramocki (2002) extended these findings and used vigorous exercise for one hour to test the effects of various forms of aerobic PA for physically fit versus unfit groups on the Torrance test. The performance gains for the fit participants following exercise were generally larger than those for the unfit participants. These varied results could be due to the inherent features in each study sample; the characteristics of each creativity test (CREA vs. Torrance test), or to the type, duration and intensity of the stimuli.

The causes of the different effects on creativity, well-being and sociability in inactive and active young people cannot be explained from the results of this present study. However, it could be due to the dose–response effect; that is, the inactive group perceived a higher stimulus for PA practice than the active group and, thus, the benefits are greater (Martínez-Gómez et al., 2011; Ruiz-Ariza et al., 2016). Some of the effects of C-HIIT could be explained through these mechanisms. For instance, they may act as an arousal stimulus for the lower levels of inactivity, and may promote higher improvements in the microstructure of the white matter of the brain, improving neuronal efficiency and speed in decision-making (Chaddock-Heyman et al., 2014), and may increase angiogenesis, neurogenesis and synaptogenesis (Adkins et al., 2006).

Moreover, PA at high intensity could stimulate the accumulation of a ketone body (D-β-hydroxybutyrate) in the hippocampus, where it serves both as an energy source and an inhibitor of class I histone deacetylases to specifically induce the brain-derived neurotrophic factor (BDNF) (Sleiman et al., 2016). The BDNF is key in cell survival and brain plasticity (Piepmeier and Etnier, 2015). PA increases the level of brain neurotransmitters such as serotonin or norepinephrine (Lojovich, 2010). Along these same lines, Li et al. (2017) concluded that high-intensity PA could increase cerebral blood flow, catecholamines or BDNF simultaneously, inducing stimulation of the hippocampus and prefrontal cortex during this time. Additional explanations may be that the cooperative features of C-HIIT could reduce stress and anxiety, increase self-esteem and motivation, promote continued and playful entertainment, enhance self-efficacy and increase pro-social behaviours, through physical exercises in pairs or small groups that rotate after each series, facilitating group decision-making, personal contact and relationships between peers (Agbuga et al., 2012; Davis et al., 2015; Jaakkola et al., 2012; Marker et al., 2015; Santos et al., 2016; Theodoulides and Armour, 2001). All of these improvements could promote creativity, well-being and sociability, empowering the most inactive adolescents.

Finally, this research has focused on adolescence because it is a key stage to consolidating healthy lifestyles and increasing the PA level. In addition, during this period there is a high degree of plasticity in the brains of young people, which is decisive in enhancing creativity and EI, improving academic performance, securing appropriate behaviours and fostering future social success (Petrides et al., 2016; Ruiz-Ariza et al., 2017). In this sense, a recent study by Heilman (2016) indicated that physical stimulation during early ages enhances cognition and correct social behaviour, and can even alter the brain both anatomically and physiologically. It is necessary to deepen our understanding about what method could enhance young people's development of creativity and EI.

Strengths and limitations of the study

This study has some strengths, including the controlled experimental randomised design in the school setting, the large sample of adolescents, and the C-HIIT method to explore its effect on creativity and EI. C-HIIT is a novel and easy method to use in PE classes, with few materials and requiring only a few minutes of class time. However, this study also has some limitations. We carried out no long-term follow-up (i.e. 6 or 12 months). The lack of studies analysing the effect of HIIT on creativity and emotional variables in adolescents makes it difficult to compare our results. During C-HIIT, we noticed that it was difficult for some participants to be continuously active for 16 minutes at high-intensity. In some cases, the intensity of the PA may not have been at the targeted level during the entire time even though the heart rate monitors encouraged adolescents to maintain the correct intensity. We indicated that none of the participants carried out extracurricular high-intensity PA during the weeks of the study. However, it was measured with the MVPA questionnaire – a self-report measurement (Prochaska et al., 2001).

Conclusions and future research

It is concluded that performing 16 minutes of C-HIIT, at the beginning of PE classes, improves well-being and sociability in adolescents. Creativity, well-being and sociability increase in physically inactive youth in particular. It is suggested that PE classes should start with short-term programmes of collective activities at high intensity. Young people, especially those who are inactive, may benefit significantly at the creative and emotional levels, in addition to experiencing the traditional beneficial effects on health.

Future intervention studies are needed to discover whether the results of this research are generalisable to a broader target group and to determine innovative ways to maximise learning time and address multiple health and academic outcomes simultaneously during the school day. We also need to learn more about the effect of C-HIIT on other cognitive performance variables such as attention–concentration, memory, mathematical calculation and linguistic ability, as well as mediating factors in the psychosocial and academic performance of adolescents.

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Declaration of Conflicting Interests

The authors declare no potential conflicts of interest to exist with respect to the research, authorship, and/or publication of this article.

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VIII

24 sessions of monitored cooperative high-intensity interval training improves attention-concentration and mathematical calculation in secondary school

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24 sessions of Monitored Cooperative High-Intensity Interval Training Improves Attention-Concentration and Mathematical Calculation in Secondary School

Abstract

The aim was to analyse the effect of monitored cooperative high-intensity interval training (monitored C-HIIT) on memory, selective attention, concentration, mathematical calculation, and linguistic reasoning in adolescents. A randomized controlled trial was used with a control group (CG, n = 94), and an experimental group (EG, n = 90) that performed monitored C-HIIT at the beginning of physical education (PE) classes, during 12 weeks (24 sessions). The EG increased 14.2% in selective attention, 8.41% in concentration, and 15.5% in mathematical calculation relative to the CG after the monitored C-HIIT programme (all $p < 0.001$). These improvements are especially significant in inactive students (all $p < 0.001$), but there were no differences in memory or linguistic reasoning variables ($p > 0.05$). It is concluded that a 16-minute monitored C-HIIT programme applied at the beginning of PE classes improves some cognitive variables, especially in physically inactive adolescents.

Keywords: Cognitive performance, HIIT, physical activity, physical education, secondary education.

Introduction

Currently, physical fitness has been shown to have a potential improvement effect on cognitive capacities beyond the traditional physiological health effects (Etnier et al., 1997; Ruiz-Ariza, Grao-Cruces, Loureiro, & Martínez-López, 2017a; Schmidt, Jäger, Egger, Roebers, & Conzelmann, 2015). More concretely, fitness is related to better memory (Chaddock-Heyman et al., 2014; Sibley & Beilock, 2007), selective attention and concentration (Vanhelst et al., 2016), arithmetic skills (Moore, Drollette, Scudder, Bharij, & Hillman, 2014), and linguistic reasoning (Raine et al., 2017). The combined improvements in these cognitive variables could be fundamental in improving mental skills responsible for planning, task switching, problem solving, organization, strategy generation to achieve a particular objective, and behaviour control (Ruiz-Ariza et al., 2017a).

In spite of the above, four out of five adolescents do not reach the minimum daily amount of PA recommended by international institutions (Cheung, 2017). Thus, there is an imperative need to find new motivants and efficient methods targeted to enhance the effects of PA in the shortest time possible (Ruiz-Ariza, Suárez-Manzano, López-Serrano, & Martínez-López, 2017b). The majority of current studies about PA and CP are focused on moderate-intensity PA, as well as including acute interventions and a wide variety of different exercises and durations of the sessions, from 4 to 55 minutes (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Cooper, Bandelow, Nute, Morris, & Nevill, 2012). However, little evidence exists on the most favourable intensity, activity type, and long-term duration for improving CP (Ardoy et al., 2014; Costigan, Eather, Plotnikoff, Hillman, & Lubans, 2016; Ruiz-Ariza et al., 2017b; Zervas, Danis, & Klissouras, 1991).

In recent years, high-intensity interval training (HIIT) has appeared as a method that allows for maximizing the effects during a short time available for PA practice and increasing key fitness components for CP, such as cardiorespiratory fitness [CRF] (Batacan, Duncan, Dalbo, Tucker, & Fenning, 2017; Eddolls, McNarry, Stratton, Winn, & Mackintosh, 2017). This method includes short intervals of vigorous activity (from ≤ 45 seconds to 2–4 minutes at > 85% HRmax) and short break periods between them (Costigan et al., 2016). However, very few studies have highlighted the potential of incorporating high intensity within the secondary-school context. Ardoy et al. (2014), demonstrated a positive chronic effect on cognitive and academic performance after 4 sessions/week of PE at high intensity over 4 months. Another study showed a positive chronic impact effect on physical self-concept (especially appearance), executive functions, and psychological well-being among adolescents after a programme of 8–10 minutes of HIIT, with a work-to-rest ratio of 30:30 seconds, 3 sessions/week, during 2 months (Costigan et al., 2016).

Based on the above, recently a new didactic method has been proposed to enhance the emotional and creative potential of PE classes (Ruiz-Ariza et al., 2017b). This method adds individualized and centralized monitoring to control heart rate at high intensity, and a cooperative dynamic within the HIIT programme, termed monitored cooperative high-intensity interval training [monitored C-HIIT] (Ruiz-Ariza et al., 2017b). PA controlled and motivated with groupal heart rate monitoring, and performed in a cooperative way – physical exercises in pairs or in small groups – has been shown to provide increases in motivation, promotion of continued play and playful entertainment, group decision-making in cooperative exercises, and increases in self-efficacy and pro-social behaviors (Ruiz-Ariza et al., 2017b). In fact, according the the American College of Sports Medicine, HIIT, group training and wearable technology as pulsomtry, are forecast as the top 3 fitness trends for 2018 (Thompson, 2017). In the C-HIIT study by Ruiz-Ariza et al. (2017b), a monitored intervention during 12 weeks at the beginning of PE classes showed positive effects on creativity, well-being, and sociability, above all in inactive adolescents. Nevertheless, the evidence regarding whether monitored C-HIIT improves key CP variables for school performance is yet unknown. In this sense, monitored C-HIIT could be a novel educational strategy to enhance specific cognitive benefits of PA. In addition, there is evidence that these effects do not influence all students in the same way (Costigan et al., 2016; Ruiz-Ariza, De la Torre-Cruz, Latorre-Román, & Martínez-López, 2016). Physically inactive students could show different results because these individuals could have a higher margin of improvement due to the dose-response effect (Ruiz-Ariza et al., 2017b). Thus, the aim of this study was to analyse the effect of 16 minutes of monitored C-HIIT at the beginning of PE classes for 12 weeks on CP variables such as memory, selective attention and concentration, mathematical calculation, and linguistic reasoning in adolescents aged 12–16 years old. In addition, results were analysed to determine whether they differed according to the weekly PA level.

Materials and Methods

The study used a quantitative randomized controlled and blind trial with control group (CG; n = 94) that performed static stretching and an experimental group (EG; n = 90) that carried out 16 minutes of monitored C-HIIT within PE classes (2 days/week). This short C-HIIT time would make it possible to prove the hypothesis, confirming that its application is compatible with the development of the daily programmes provided for each PE teacher session.

Participants

A total sample of 184 adolescents from 4 secondary schools in the south of Spain participated in this study. Participants were 13.73 ± 1.34 years old, with a body mass index (BMI) of 21.34 ± 3.61 kg/m^2. Participants had an average of 2.76 ± 1.59 computers at home, performed 2.80 ± 1.58 days/week of MVPA, and studied 115.76 ± 47.39 minutes/day. Only 3.3% had no Internet access. With regard to maternal educational level, an important factor of socioeducational family status (Ruiz-Ariza, Casuso, Suarez-Manzano, and Martínez-López, 2018), only 1.1% of mothers did not have studies, and 25% did not have a job. No initial differences between the CG and the EG were found in any of the variables analysed except for BMI (p = .034) [see Table 1].

[Table 1]

Adolescents with some physical pathology or medical contraindication to perform PA were excluded from this study. Youth diagnosed with learning disabilities (e.g., ADHD) were not included among the eligible students. Despite this, they performed the activities corresponding to their groups; however, these data were not included in the analysis. The final sample was formed by youth who completed all CP data and carried out the total intervention period correctly. Each participant had to maintain high intensity of over 85% of their HRmax (range ≈ 165–185 beats per minute [bpm]) during at least 80% of the 16 minutes of each session within the monitored C-HIIT programme (Ruiz-Ariza et al., 2017b). From an initial sample of 214 volunteers with parental informed consent, finally took part in the study a final sample of 184 participants (12 did not complete CP data, 6 abandoned during the intervention and 16 did not compliance the required intensity).

Measures

Memory. To assess memory, an ad hoc test of 1 minute was used, from the memory test included in the Spanish adaptation of the RIAS test (Santamaría-Fernández & Fernández-Pinto, 2013). A poster of 15 Spanish playing cards, randomly selected, was projected for 20 seconds on a 3 x 2-metre screen. Immediately afterwards, the participants had 40 seconds to record on a standardized sheet all of the cards they could remember. This memory test has been previously used by Ruiz-Ariza et al. (2018). The reliability test–retest (48 hours, n = 24) was 0.921.

Selective attention and concentration. These variables were assessed under stress induced by a completion time by using Brickenkamp's d2 Test in the Spanish version (Seisdedos, 2012). Selective attention capacity was calculated by using the following formula: [number of processed elements –

(omissions + mistakes)]. In addition, concentration was calculated with the following formula: (number of hits – number of mistakes). The reliability test–retest (48 hours, n = 24) was 0.878.

Mathematical calculation. To analyse mathematical calculation, an ad hoc test was used (Ruiz-Ariza et al., 2018). This test included 2 groups of addition and subtraction with 6 digits (e.g., 8 – 6 + 5 + 8 – 6 = 9). Participants had 1 minute to perform as many operations as possible, and the total number of hits was counted. Test–retest reliability (48 hours, n = 24) was 0.887.

Linguistic reasoning. To evaluate the reading speed and semantic comprehension of participants (linguistic reasoning), an ad hoc test was developed (Ruiz-Ariza et al. (2018) The test showed 30 rows of 4 words each. In each row of words, 3 belonged to the same semantic field, while a fourth had no relation to the others (e.g., *car, dog, motorbike, lorry*). The order of these was randomly established. The reliability test–retest (48 hours, n = 23) was 0.811.

Monitored Cooperative high-intensity interval training (monitored C-HIIT). The sample was randomly selected to ensure the equality of sexes between the two groups. The CG carried out static stretching, because this is the fitness component least associated with cognitive variables (Ruiz-Ariza et al., 2017a). The EG performed monitored C-HIIT, whose sessions started with a short warm-up activity of 4 minutes including running and dynamic stretching at medium intensity. The programme was composed of sessions of 16 minutes of monitored C-HIIT, 2 sessions per week, for 12 weeks (24 sessions in total). Previous studies had checked the cognitive effect of HIIT after different periods of daily practice in school; for example, 4 minutes (Ma, Mare, & Gurd, 2015), 8–10 minutes (Costigan et al., 2016), or one complete PE session (Ardoy et al., 2014). The present study considered that 16 minutes/day – approximately one-third of a PE session – could be enough to obtain significant physical and cognitive effects, allowing the teacher to dedicate the rest of the time to the usual development of the programmed PE class – two-thirds of the PE session.

Following the base of previous studies with HIIT (Costigan et al., 2016), each session had 4 series of each proposed exercise, with a work-to-rest ratio varying from 20:40 seconds to 40:20 seconds in the last 2 weeks (weeks 1 and 2 = ratio 20:40 seconds; weeks 3 and 4 = ratio 25:35 seconds; weeks 5 through 8 = 30:30 seconds; weeks 9 and 10 = 35:25 seconds; weeks 11 and 12 = 40:20 seconds). The monitored C-HIIT included a combination of cardiorespiratory, speed/agility (S/A), and coordinative training exercises because these are the fitness components that mostly enhance cognitive capacity in adolescents (Ruiz-Ariza et al., 2017a). In addition, all activities were carried out in pairs that rotated after each series to promote the cooperative context. Participants wore heart rate monitors (Seego Realtracksystems, Spain, http://seego.realtracksystems.com/) to encourage maintenance of the appropriate exercise intensity and to motivate the individual effort (Figure 1b). They could see their hear rate percentages projected with a slide projector on a 6 x 3-metre screen. Each participant from the EG had to be in an intensity ≥ 85% of HRmax (Costigan et al., 2016). Figure 1 shows a graphical example of a session of the monitored C-HIIT programme (figure 1a), an example of Seego screen (figure 1b), and the intensity of effort (figure 1c).

[Figure 1]

Weekly practice of MVPA. The participants were classified based on the baseline level of PA according to Prochaska, Sallis, and Long's (2001) MVPA questionnaire. Of the students, 131 (71.7%) were included as inactive (< 5 days/week of at least 1 hour of MVPA), and 53 (28.3%) were classified as active (≥ 5 days/week). Similar to other studies (Ruiz-Ariza et al., 2018), internal consistency of PA items was high (Cronbach's alpha = 0.809).

Confounders. Age and BMI [weight/height (m^2)] were used as confounders (Ruiz-Ariza et al., 2016, 2017a). An ASIMED B-type-class III (Spain) and a portable height meter, the SECA 214 (SECA Ltd., Germany), were used to measure weight and height. Both measurements were carried out on barefoot participants dressed in light clothes.

Other measurements (physical fitness assessment). Fitness was measured with the ALPHA-Fitness battery. The reliability of these tests for young people has been previously published (Ruiz et al., 2011). CRF was measured with the 20-metre shuttle run test. S/A was measured with the 4 x 10-metre shuttle run test of speed, agility, and coordination. Muscular strength (MS) was measured with the standing long jump test. The S/A and MS tests were performed twice in each measure (pre and post), and the better record was registered. They showed an excellent intraclass correlation (ICC = .921, 95% CI = .874–9.520, and ICC = .911, 95% CI = .872–.935, respectively).

Procedure

Parents signed a written consent before the study commenced. The participants' fitness level and CP were measured at 2 time points during the first school hours in the morning in both groups: at baseline and after 12 weeks. The students underwent a full assessment of their responses to the effort, and each family received an individual report. The monitored C-HIIT design allowed all participants to reach the intensity range required without limitation resulting from their level of ability or coordination. The CG performed static stretching exercises during the same time (Mayorga-Vega, Merino-Marban, Real, & Viciana, 2015). None of the participants carried out extracurricular high-intensity PA during the 12 weeks of the study. This study was approved by the Bioethics Committee of the University of XXXXXXX [hidden for anonymity]. The design complies with the Spanish regulations for clinical research in humans (Law 14/2007, July 3rd, Biomedical Research), and with the principles of the Declaration of Helsinki (2013 version, Brazil).

Data analysis

The comparison of the continuous and categorical variables according to participation in the study (CG vs. EG) was carried out through student's t-tests and χ^2, respectively. Tests of normal distribution and homogeneity (Kolmogorov-Smirnov and Levene's) were conducted before analysis. The repeated measures analysis of covariance (ANCOVA), 2 times (pre, post) x 2 groups (CG, EG) x 2 PA levels (inactive, active students), was used to analyse the chronic effect of 16 minutes of monitored C-HIIT. Memory, attention, concentration, mathematical calculation, and linguistic reasoning tests were used as dependent variables; the group and MVPA were used as fixed factors; and age, BMI, and baseline values of the dependent variables were studied as covariates. Post-hoc analysis was adjusted by Bonferroni. The effect size was computed and reported as a partial η^2 value for the analysis of variance (ANOVA) evaluations. To quantify the magnitude of changes between and within groups in the dependent variables, the effect sizes were calculated by Cohen's *d*. A Cohen's *d* value $\geq .8$ indicates a large effect size, a Cohen's *d* value $\geq .5$ and $< .8$ indicates a medium effect size, and a Cohen's *d* value $\geq .2$ and $< .5$ indicates a small effect size (Cohen, 1998). These analyses were carried out separately for each dependent variable. Partial correlations between changes in fitness and changes in study outcomes were performed for all the participants together, after adjusting for age, BMI, and baseline values of the outcomes studied (these variables were included in the partial correlation models as covariates). The percentage of change between groups after the monitored C-HIIT programme was calculated as follows: [(GE post-measurement – GC post-measurement) / GC post-measurement] x 100. For all the analyses, a 95% confidence level was used ($p < .05$). The analyses were completed by using SPSS (v.22 for Windows).

Results

Analysis of intensity of monitored C-HIIT

Values of heart rate were similar between the two study groups at the beginning of the study (CG = 81.68 ± 19.9 vs. EG = 81.12 ± 23.2 bpm, $p > .05$). However, during the monitored C-HIIT programme, the mean of heart rate in CG (X = 102.3 ± 14.6 bpm) was lower than in the monitored C-HIIT group (X = 148.7 ± 16.2 bpm, range: X_{max} = 176.11 ± 16.7 and X_{min} = 81.12 ± 23.2 bpm, all $p < .001$) [Figure 1c].

ANCOVA analysis of 12 weeks of monitored C-HIIT on CP

ANCOVA 2 times x 2 groups x 2 PA levels carried out on memory showed neither main nor interaction effects (all $p > .05$). Group x PA level was the interaction effect closer to significance ($p = .322$). See Figure 2.

[Figure 2]

Data regarding selective attention showed a main group effect F(1,170) = 15.017, $p < .001$, partial η^2 = .081, 1 – β = .971; a group x PA level interaction on the verge of significance F(1,170) = 3.149, $p = .078$, partial η^2 = .018, 1 – β = .423; and a time x group x PA level interaction F(1,70) = 4.015, $p = .047$, partial, η^2 = .023, 1 – β = .513. After 12 weeks, selective attention in the EG increased relative to the pre measure within the same group (165.07 ± 45.68 vs. 147.443690 ± 40.49, $p = 0.018$, Cohen's d = 0.404). However, a more detailed analysis showed that only inactive students increased in selective attention after the monitored C-HIIT programme, in comparison to the initial measure (170.62 ± 40.68 vs. 144.31 ± 35.55, $p < .001$, Cohen's d = .779). Analysis between groups revealed that in post measure, selective attention in the EG increased 14.20% relative to the CG (165.07 ± 45.68 vs. 144.48 ± 39.16, respectively, $p < .001$, Cohen's d = .498). In the inactive group, the EG also improved 18.05% relative to the CG in the post measure (170.62 ± 40.68 vs. 144.90 ± 42.777, $p < .001$, Cohen's d = .621). See Figure 3a.

Concentration analysis found a group main effect F(1,170) = 4.398, $p < .037$, partial η^2 = .025, 1 – β = .550; an interaction group x PA level F(1,170) = 5.628, $p = .019$, partial η^2 = .032, 1 – β = .655; and an interaction time x group x PA level near to significance F(1,70) = 2.868, $p = .067$, partial η^2 = .017, 1 – β = .391. After 12 weeks of monitored C-HIIT, concentration increased in EG relative to pre measure within the same group (150.33 ± 31.03 vs. 138.3 ± 30.42, $p = .041$, Cohen's d = .404). Similar results were observed in inactive students (158.53 ± 36.40 vs. 137.68 ± 38.93, $p = .009$, Cohen's d = .551). Analysis between groups showed that concentration increased 8.41% in EG relative to CG after 12 weeks of monitored C-HIIT (150.33 ± 31.03 vs. 138.36 ± 37.70, respectively, $p = .033$, Cohen's d = .315). In the inactive group, the EG also improved 17% relative to the CG in the post measure (158.53 ± 36.40 vs. 134.17 ± 42.89, respectively, $p = .002$, Cohen's d = .626). See Figure 3b.

[Figure 3]

Mathematical calculation analysis found a group main effect F(1,170) = 3.776, *p* = .054, partial η^2 = .022, 1 – β = .489; a group x PA level interaction F(1,170) = 9.799, *p* = .002, partial η^2 = .055, 1 – β = .875; and a time x group x PA level interaction F(1,170) = 25.166, *p* = .012, partial η^2 = .037, 1 – β = .715. The post analysis of interest showed that the EG increased mathematical calculation 15.5% relative to CG (6.70 ± 2.10 vs. 5.83 ± 2.42 exercises correctly solved, *p* = .012, Cohen's *d* = 0.383). More specifically, inactive students improved relative to the pre measure (7.06 ± 2.32 vs. 5.93 ± 2.36, *p* < .001, Cohen's *d* = 0.487) and increased 16.6% relative to CG (7.06 ± 2.32 vs. 6.01 ± 2.12 exercises correctly solved, *p* = .002, Cohen's *d* = .472). Active students also increased their mathematical calculation relative to CG, but the differences were not significant (*p* = .274). See Figure 4a.

[Figure 4]

Results in linguistic reasoning showed a time x group interaction near significance F(1,170) = 3.706, *p* = .056, partial η^2 = .021, 1 – β = .482. The EG increased linguistic reasoning scores relative to the pre measure after 12 weeks of monitored C-HIIT (23.64 ± 4.79 vs. 21.83 ± 5.28 linguistic test score, *p* = .009, Cohen's *d* = .359). See Figure 4b. Differences were not found between groups (all together) nor within the inactive and active student groups (all *p* > .05).

Additional analyses

Additional analyses consisted of partial correlation analysis in the full sample (data not shown), adjusted for age, BMI, and baseline values of the study outcomes. These showed that higher values of improvements in CRF were positively correlated with selective attention, concentration, and mathematical calculation (*r* = .262, *p* = .021; *r* = .202, *p* = .042; and *r* = .311, *p* = .002, respectively). Higher values of improvements in S/A were correlated with higher mathematical calculation (*r* = –.203, *p* = .023; lower values in the S/A test mean higher performance). No associations were observed between fitness and other cognitive variables. Overall, the results did not differ when sex was used in the models instead of age and BMI.

Discussion

The aim was to analyse the effects of monitored C-HIIT at the beginning of PE classes on cognitive variables in adolescents between 12 and 16 years, as well as monitored C-HIIT's effects according to the usual weekly PA level. Results showed that 2 days of 16 minutes of PA at high intensity, performed in a cooperative and continuous way for 12 weeks, improves selective attention, concentration, and mathematical calculation levels in adolescents. In addition, improvements are especially significant among physically inactive students. Positive modifications in memory and linguistic reasoning have not been sufficiently proved. No negative effects of monitored C-HIIT were observed, and no injury occurred during the programme.

Some of the main cognitive results of this study show that a monitored C-HIIT programme improves selective attention and concentration levels relative to CG by 14.2% and 8.4%, respectively. These findings confirm, in part, the authors' previous hypothesis and are similar to those obtained by Costigan et al. (2016), who showed a positive effect of 8 weeks of HIIT on executive functions and psychological well-being in adolescents. A recent study showed improvements in overall cognitive variables after an intervention of 4 months, with 4 PE classes/week of 55 minutes, at a mean intensity of 147 bpm (Ardoy et al., 2014). Vanhelst et al. (2016) concluded that it would be necessary to reach a threshold of > 12 minutes/day of high-intensity exercise to improve attentional capacity in adolescents 12–17 years old. This study showed that 2 weekly stimuli of 16 minutes of C-HIIT at the beginning of PE classes is sufficient. However, contrary to the above-mentioned, Zervas et al. (1991) demonstrated no significant cognitive effects after individual running training at high intensity on a treadmill for 3 days/week for 25 weeks in PE classes (warm-up: 15 minutes, intervention: 60 ± 15 minutes).

With regard to mathematical calculation, EG increased 15.5% relative to CG after 12 weeks of C-HIIT. Several studies have showed that a higher CRF level, S/A, coordination, motor skill, organized leisure-time sport participation and bicycling, and active commuting to school are related with better success in maths (Castelli, Hillman, Buck, & Erwin, 2007; Correa-Burrows, Burrows, Orellana, & Ivanovic, 2014; Raine et al., 2017; Sævarsson et al., 2017). Another recent study of association conducted by Ruiz-Ariza et al. (2016) showed that enjoyment of vigorous PA is related to higher grades in maths among adolescent girls. More specifically, Moore et al. (2014) suggest that higher CRF is associated with better mathematical calculation skills and resolution of arithmetic problems. Nevertheless, the results from the current study and the above differ from pioneer cross-sectional studies performed by McNaughten and Gabbard (1993) and Daley and Ryan (2000), who did not find an association of PA with a timed test of mathematical calculation, nor of time of daily moderate PA with performance in maths, respectively.

Because data regarding chronic effects is scarce, this study also reviewed evidence from acute studies to search for possible explanations of effects of monitored C-HIIT in attention-concentration and mathematical calculation in young people. Two educational interventions found significant acute improvements in attention-concentration (Budde et al., 2008; Zervas et al., 1991). In addition, Travlos (2010), in a study with adolescents, found that maths ability was enhanced after a high-intensity (> 85% HRmax) running exercise, but only when it was performed early in the school day. Similarly, a single vigorous bout of PA in PE at 70–85% HRmax improved the results of a standardized maths test at 30 minutes post intervention by 11–22% (Phillips, Hannon, & Castelli, 2015). All of these studies agree that low-to-moderate-intensity activity does not show effects on selective attention and mathematical calculation. However, the studies using a higher PA intensity have shown more satisfying results.

Although the results of the present study did not find an effect of monitored C-HIIT on memory or linguistic reasoning, the majority of studies show that memory increases after short-term exercise (Budde et al., 2008; Cooper et al., 2012; Samuel et al., 2017), and a current chronic study shows that 6 weeks of a high-intensity training regimen resulted in improvements in working memory (Moreau, Kirk, & Waldie, 2017). Sjöwallm, Hertz, and Klingberg (2017) found in a 2-year school-based intervention in preadolescent children (ages 6–13) that the increase of weekly PE classes (aimed at increasing CRF) from 2 to 5 days a week did not affect working memory. Therefore, the above disagreement shows the need to continue studying acute and chronic effects of monitored C-HIIT in memory factors, as well as the chronic physio-psychological mechanisms that could act in this relationship and the intensity, duration, and kind of exercise that is more adequate to affect memory. With regard to linguistic reasoning, in agreement with the present study's data, Ardoy et al. (2014) and Samuel et al. (2017) did not find an effect on the verbal reasoning factor. However, a current systematic review representing 414 participants from 5 different countries shows that 60% of studies found beneficial effects on the language domain (Carson et al., 2016). In this line, Raine et al. (2017) concluded that changes in aerobic fitness were positively related to changes in reading between sixth and eighth grade. Physical activity even enhances the learning of a second non-maternal language (Liu et al., 2017). This disagreement among research could be caused by the specific neuromechanisms for these cognitive functions, the variability of linguistic tests, or the inherent characteristics of each study sample. It is necessary to continue studying to determine what could be the best physical and mental stimuli to achieve significant effects on important academic variables such as memory and linguistic reasoning.

On the other hand, one of the most important results of this study is the effect on CP when the sample was separated into inactive and active students. The data showed that higher values of change in CRF were positively correlated with selective attention, concentration, and mathematical calculation, and higher values of change in S/A were correlated with higher mathematical calculation scores. While in the inactive group the EG improved selective attention, concentration, and mathematical calculation by 18.05%, 17%, and 16.6%, respectively, relative to the CG after the monitored C-HIIT programme, differences were not found in active adolescents. A recent pioneer study concluded that performing 16 minutes of monitored C-HIIT at the beginning of PE classes improves creativity, well-being, and sociability in physically inactive youth, and it did not find effects in active students (Ruiz-Ariza et al., 2017b). Contrary to these findings, some studies have showed that adolescents aged 15 years with the highest allocation of time to regular PA performed better in maths than inactive students (Correa-Burrows et al., 2014). Sævarsson et al. (2017), in a further analysis, showed that a less active group (≤ MVPA once a week) had significantly lower improvements in maths compared to the most active group (≥ MVPA 4 times/week or more 2-3 times/week). These varied results could be due to the characteristics of each CP test or to the type and duration of activity; however, the greatest evidence indicates that the most important variable is the intensity of the programme. The causes of the different effects on CP in inactive and active young people cannot be explained from the present study. However, the differences could be mainly due to the dose-response effect. In this later case, the inactive group perceived a higher stimulus for PA practice than the active group, and the margin for improvement is greater (Ruiz-Ariza et al., 2017b). Monitored C-HIIT may act as an arousal stimulus for lower levels of inactivity, and it may promote greater improvements in the microstructure of the white matter of the brain, improving neuronal efficiency, decision speed, and information-processing capacity (Chaddock-Heyman et al., 2014).

Despite all of the above, the results shown here must be taken with caution, because this study has some limitations. During monitored C-HIIT, it was noticed that it was rather difficult for some participants to be continuously active for 16 minutes at high intensity. In some cases, the intensity of the PA bouts may not have been at the targeted level during the full 20 minutes, although the heart rate monitors encouraged the adolescents to maintain the correct intensity. Also, although it was indicated that none of the participants carried out extracurricular high-intensity PA during the weeks of the study, this was measured with the MVPA questionnaire, a self-report measurement (Prochaska, Sallis, & Long, 2001).

It is concluded that a programme of 12 weeks of 16 minutes of monitored C-HIIT, twice a week at the beginning of PE classes (24 sessions in total), improves attention, concentration level, and mathematical calculation skill in adolescents, but it does not produce differences in memory or linguistic reasoning variables. In addition, improvements are especially significant among physically inactive students. It is suggested that PE classes involve cooperative high-intensity interval exercises to promote physical, cognitive, and academic success, and that educative institutions promote the inclusion of daily monitored C-HIIT during secondary school. Further intervention studies are required to learn more details of the acute effects of monitored C-HIIT, including its influence on other important academic performance variables, such as behaviour for learning, technological stress, and teamwork skills.

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Figure captions

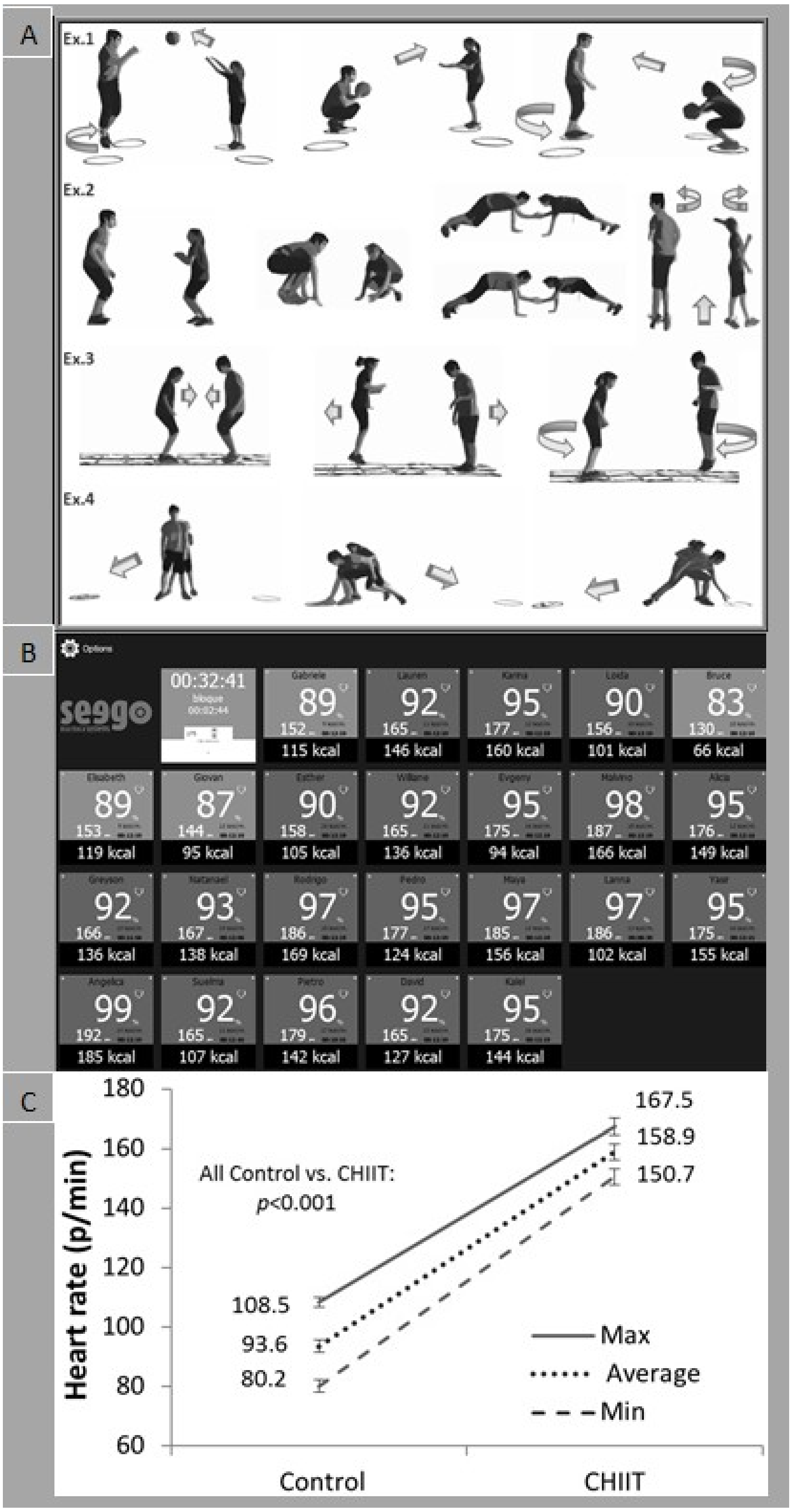

Figure 1: Graphical description of an example session of the 12-week monitored C-HIIT programme. Figure 1a: C-HIIT activities: **Ex. 1.** At 4 metres of distance between participants, lateral jump in hoops with legs together, passing a ball in pairs in each jump, crouching when receiving the ball, as many times

as possible during the work time. **Ex. 2.** Burpees in pairs, clasping hands in the push-up position and turning during the jump, repeated as many times as possible during the work time. **Ex. 3.** Coordination ladder, one in front of the other, imitating the partner during the work time. When one series is completed, the roles are rotated. **Ex. 4.** Lateral running back and forth between hoops at 5 metres. The two members must be one behind the other, holding by the waist. They must pick up a sponge on the ground and change it to the other hoop. The pair must add up the number of sponges changed from one hoop to the other. Figure 1b: Example of visual control of the heart rate. Figure 1c: Minimum, maximum and average intensity values in the class group.

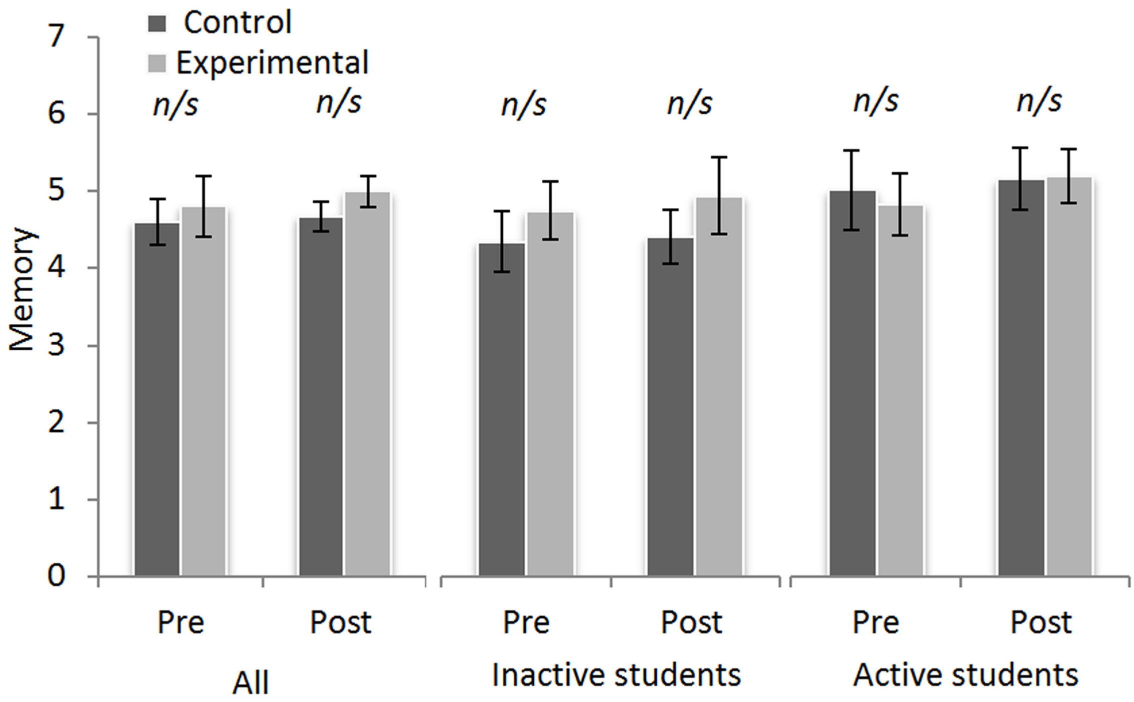

Figure 2: Results of memory in adolescents after 12 weeks (16 minutes for 2 days/week) of monitored C-HIIT. Inactive students exercised < 5 days/week, and active students exercised ≥ 5 days/week with at least 1 hour of MVPA. Data expressed in mean and SD. n/s denotes no significant differences between groups in the same measure.

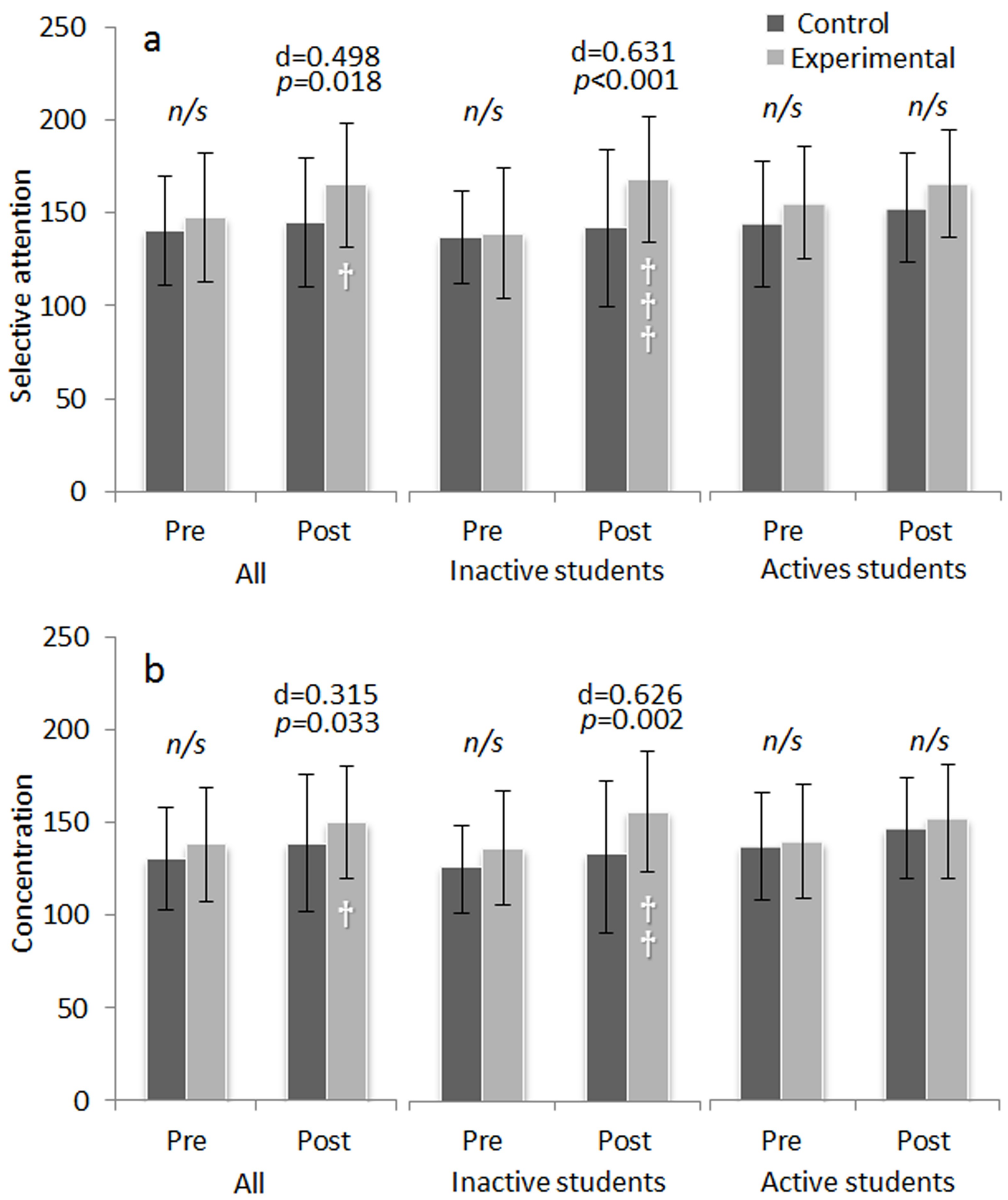

Figure 3: Results for attention and concentration in adolescents after 12 weeks (16 minutes, 2 days/week) of monitored C-HIIT. Inactive students exercised < 5 days/week, and active students exercised ≥ 5 days/week for at least 1 hour of MVPA. Data expressed in mean and SD. ††† denotes $p < .001$ relative to pre measure in the same group. n/s denotes no significant differences between groups in the same measure.

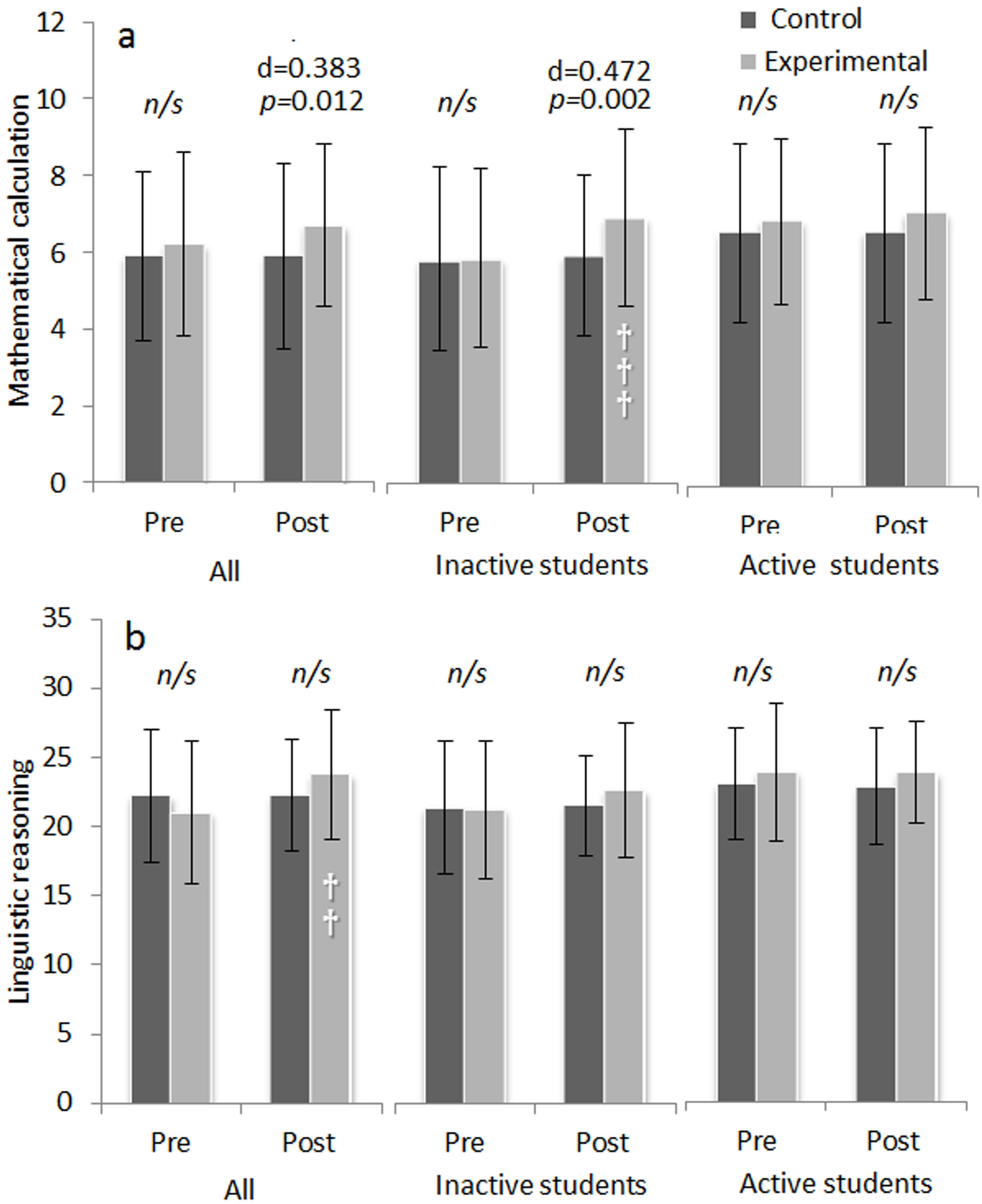

Figure 4: Results for mathematical calculation and linguistic reasoning in adolescents after 12 weeks (16 minutes, 2 days/week) of monitored C-HIIT. Inactive students exercised < 5 days/week, and active students exercised ≥ 5 days/week for at least 1 hour of MVPA. Data expressed in mean and SD. †† denotes $p < .01$, and ††† denotes $p < .001$ relative to pre measure in the same group. n/s denotes no significant differences between groups in the same measure.

Table 1 Anthropometric and sociodemographic characteristics of participants. Values are presented as mean and standard deviation or percentage.

		All (n=184)	CG (n =94)	EG (n =90)	P-value
Age (years)		13.73±1.34	13.67±1.29	13.79±1.38	.549
Sex (%)	Girl	86 (46.7)	42 (47.7)	44 (48.9)	.567
	Boy	98 (53.3)	52 (53.3)	46 (51.1)	
Weight (Kg)		56.87±12.571	55.47±10.13	58.27±14.52	.136
Hight (m)		1.62±.093	1.63±.099	1.62±.086	.530
BMI (Kg/m^2)		21.34±3.61	20.76±2.97	21.92±4.11	.034
Computers at home (n)		2.76±1.59	2.72±1.63	2.81±1.54	.716
Daily time studying (min/day)		115.76±47.39	120.72±43.78	110.63±50.60	.160
MVPA (days/week)		2.80±1.58	2.98±1.58	2.62±1.57	.117
MVPA	Inactive students	132 (71.7)	64 (68.1)	68 (75.6)	.261
	Active students	52 (28.3)	30 (31.9)	22 (24.4)	
Internet access (%)	No	6 (3.3)	3 (3.2)	3 (3.3)	.957
	Yes	178 (96.7)	91 (96.8)	87 (96.7)	
Maternal studies	No studies	2 (1.1)	1 (1.1)	1 (1.1)	.879
	Primary	21 (11.4)	9 (9.6)	12 (13.3)	
	Secondary	70 (38)	36 (38.3)	34 (37.8)	
	University	91 (49.5)	48 (51.1)	43 (47.8)	
Maternal work	No work	46 (25)	24 (25.5)	22 (24.4)	.865
	Work	138 (75)	70 (74.5)	68 (75.6)	

Note. CG = Control group; EG = Experimental group; BMI = Body mass index; MVPA = Moderate-to-vigorous physical activity.

LIMITACIONES Y FORTALEZAS

Limitaciones

- Los diseños transversales no permite establecer relaciones de causalidad, y las muestras por conveniencia limitan la generalización de los resultados.
- Cabe la posibilidad de que los encuestados respondan de un modo que preserve la imagen más positiva de sí mismos. También que en algunos casos los adolescentes podrían haber contestado a los test y cuestionarios erróneamente de forma deliberada o sin mala intención. Es importante tener presente que las respuestas fidelignas de quienes se prestaron a colaborar, pueden no reflejar o ser totalmente representativas de aquellos otros que no lo hicieron. Por ello, se ha de ser cauto a la hora de generalizar los resultados obtenidos.
- La evaluación de la práctica de AF por cuestionario autoinformado, podría no representar al 100% la práctica diaria de AF de los jóvenes. En alguno de los estudios aquí presentados el uso de métodos más objetivos como acelerómetros hubiesen ofrecido más información sobre esta variable.
- Con respescto a la revisión sistemática, un análisis más exhaustivo a través de metanaálisis, podría haber cuantificado de una forma exacta nuestros hallazgos.
- En dicha revisión, le hemos dado igual importancia a los estudios con muestras pequeñas y con muestras amplias. Otras importantes bases de datos, como EMBASE, no fueron incluídas en la revisión sistemática. Otras limitaciones podrían ser el sesgo por idioma de búsqueda (solo inglés) o por incluir solo estudios ya publicados. Además, la revisión no incluye estudios centrados en enfermedades metabólicas (por ejemplo: sobrepeso-obesidad) u otros tipos de enfermedades (por ejemplo: mentales, alergias, o trastornos del desarrollo). Además, algunos efectos de la asociación pueden ser inconsistentes debido a la influencia de inter-componentes dentro de la misma muestra. Por ejemplo, en estudios donde hay solo una media global de condición física sin separar por componentes, podría haber un efecto colateral de alguno de ellos (Por ejemplo: la capacidad cardiorrespiratria, velocidad-agilidad o la coordinación motora), sobre componentes menos relacionados con el RC y RA (por ejemplo: la flexibilidad), diluyendo por tanto el impacto real de cada componente. No obstante, la mayoría

de los estudios de la revisión, separan por componentes. Finalmente, otra posible limitación podría ser que la herramienta usada para analizar la calidad de los estudios no está validada, aunque ha sido basada en la usada por otros estudios previos.

- Durante el programa de C-HIIT monitorizado, apreciamos que algunos participantes tuvieron dificultades para mantener los 16 minutos a la intensidad requerida. En algunos casos, la intensidad de los estímulos de AF podría no haber sido la totalmente correcta durante toda la sesión, aunque el empleo de la pulsometría proyectada para que pudieran ver y controlar su propia frecuencia cardiaca, animó y motivó a los participantes a mantenerse próximos a la intensidad correcta. También, aunque se indica que ninguno de los participantes llevó a cabo AF extracurricular a alta intensidad durante las semanas del estudio, esto fue medido mediante cuestionario autoinformado (Prochaska, Sallis, & Long, 2001), y en alguno de los casos las respuestas pueden no haber sido del todo fidelignas, pudiendo contaminar los efectos del programa empleado.
- No llevamos a cabo un estudio de seguimiento a largo plazo "*long-term follow-up*" (por ejemplo de 6 ó 12 meses). La escasez de estudios que analizan el efecto del HIIT sobre la creatividad, IE o variables de RC en adolescentes dificulta la discusión y comparación de nuestros hallazgos con otros estudios similares.

Fortalezas

- Se han usado muestras amplias de adolescentes en los diferentes estudios transverales y de intervención.
- Para evaluar la condición física, se han empleado medidas objetivas y validades, mediante una batería completa y estandarizada como la ALPHA-fitness.
- La inclusion de covariables en los analálisis de los diferentes estudios llevados a cabo, también es un punto a favor de la actual tesis, ya ofrece resulados más fiables debido a que elimina posibles influencias que podrían confundir los resultados y su interpretación.
- Para el RA se han tenido en cuenta las calificaciones académicas reales y recientes de las asignaturas escolares más determinantes, así como variables fiables para el rendimiento cognitivo.
- Consideramos que los posibles errores en las respuestas a los cuestionarios han sido reducidos notablemente por el hecho de que se ha utilizado la codificación

para asegurar el anonimato y confidencialidad de los participantes.

- En referencia a la revisión sistemática, se ha examinado la asociación individual y combinada para RC y RA con respecto a los diferentes componentes de condición física. La revisión cubre un perido de 10 años e incluye investigaciones con revisión por pares abarcando 10 países países. Una lista estandarizada de evaluación de la calidad de los estudios también fue usada. La revisión incluyó estudios transversales, longitudinales y de intervención, y tuvo en cuenta potenciales covarialbes influyentes en la relación condición física-cognición.
- El diseño experimental aleatorizado en el contexto escolar, y la amplia muestra experimental y de control, pueden ser también fortalezas a destacar.
- La novedosa creación del método C-HIIT para las clases de EF, durante solo los primeros minutos de las mismas, y la exploración de sus efectos en creatividad, IE y RC, consideramos que es un gran punto a favor del presente proyecto, que podría potenciar además el rendimiento en el resto de asignaturas escolares.

LIMITATIONS AND STRENGTHS

Limitations

- The cross-sectional designs do not allow to establish relations of causality, and the samples for convenience limit the generalization of the results.
- It is possible that the participants answer of a way that preserves an image more positive of yes same. Also, in some cases, the adolescents might have answered to the test and questionnaires erroneously of deliberate form or without bad intention. It is important to have present that the answers reliable of whom they offered to collaborate, cannot reflect or be totally representative of those others that did not do it. For it, we should be careful at the moment of generalizing the obtained results.
- The assessment of PA practice by self-reported questionnaire might not represent at 100% the PA daily practice of adolescents. The use of most objective methods like accelerometers, could have offered more information about this variable.
- With regard to the systematic review, a most exhaustive analysis across meta-analysis might have quantified our findings in an exact way.
- In the above mentioned review, we have given the same importance to the studies with small samples and with wide samples. Other important databases, as EMBASE were not included in the systematic review. Other limitations might be the bias for language of search (just English) or for including only already published studies. In addition, the review does not include studies focused on metabolic diseases (i.e., overweight-obesity) or other types of diseases (i.e., mental, allergies, or development disorders). In addition, some effects of the association can be weak due to the influence of inter-components inside the same sample. For example, in studies where there is only a global average of physical fitness without separating for components, there might be a collateral effect of someone of them (i.e., the capacity cardiorespiratory, speed-agility or coordination), on components less related to the CP and AP (i.e., the flexibility), diluting the true impact of each component. Nevertheless, the majority of the studies of the review separate for components. Finally, another possible limitation might be that the tool used to analyse the quality of the studies is not validated, though it has been based in tools used by other previous studies.

- During the program of monitored C-HIIT, we estimate that some participants had difficulties to maintain 16 minutes at right intensity. In some cases, the intensity of PA stimuli might not have been totally correct during all the session, though the employment of pulsometry projected on the wall. In this way, they could see and control their own heart rate, encouraged and motivated the participants to keep the adequate intensity. Also, though it is indicated that none of the participants carried out extracurricular PA to high intensity during the weeks of the study, this was just measured by means of self-reported questionnaire (Prochaska, Sallis & Long, 2001). For this reason, the answers cannot have been completely obtained in a reliable way in some cases.
- We do not carry out a long-term follow-up study (i.e., of 6 or 12 months). The scarce studies that analyse the HIIT effects on the creativity, EI or CP variables in adolescents make difficult the discussion and comparison of our findings with other similar studies.

Strengths

- Wide samples of adolescents have been used in the different cross-sectional and interventional studies.
- To assess the physical fitness, objective and validated measures have used through the ALPHA-fitness battery.
- The incorporation of confounders in the analysis of the different studies, is also a favourable point of the current thesis, it eliminates possible influences that might confuse the results and his interpretation.
- For AP, academic marks in the most determinant subjects have been taken into account. As well as reliable variables for CP.
- We consider that possible mistakes in the answer in questionnaires have been reduced because we have used codification to ensure the anonymity and confidentiality of the participants.
- Regarding to systematic review, independent and combined association of CP and AP have beeen examined with regard the different physical fitness components. The review encompasses a 10 years period and includes researchers with peer-review assessment, including samples from 10 different countries. A standardised quiality list was also used. The review included cross-sectional, longitudinal and interventional studies, and took into account potential

confounders for the relationship between physical fitness and cognition.

- The experimental randomised design in school context, and the wide sample with control and experimental groups, can be also outstanding strengths.
- We consider that the novelty creation of C-HIIT method for PE classes, just during the first minutes of them, and the exploration of their effects on creativity, EI and CP, are important favourable points in this project. Besides, this could potentiate the performance in other subjects.

CONCLUSIONES

- El grado de atracción hacia la AF influye en el RA de los adolescentes y distingue diferencias importantes en función del sexo. Aunque los chicos tienen una mayor atracción general hacia la AF que las chicas, en ambos sexos todos los factores de atracción hacia la AF están asociados positivamente con mejores calificaciones en la asignatura de EF. El disfrute con la AF vigorosa es el principal factor de atracción que se relaciona, en chicas, con mejores calificaciones en Matemáticas y Lengua. Se evidencia, por tanto, que además de la ya conocida relación entre AF y RA es necesario tener en cuenta los factores de la atracción hacia la AF, ya que en buena medida pueden predecir diferentes resultados de RA en función del sexo.
- Emplear un tiempo superior a 15 minutos al día en desplazarse activamente al instituto se asocia con mayores niveles de felicidad y bienestar, y menor angustia psicológica en adolescentes. El desplazamiento al instituto andando, al menos cinco trayectos semanales de más de 15 minutos, se relaciona con mayores calificaciones en Matemáticas en las chicas adolescentes.
- Nuestra revisión sistemática concluye una asociación positiva de la condición física con RC y RA. La capacidad cardiorrespiratoria, velocidad-agilidad, coordinación motora, y habilidad perceptivo-motora son los componentes mayormente asociados con la cognición en adolescentes, mientras que la relación respecto a la fuerza y flexibilidad no está clara. Finalmente, se destaca que las covariables juegan un papel fundamental en esta relación.
- Nuestros estudios transversales muestran relación entre la capacidad aeróbica, la habilidad motora y la fuerza muscular (aunque en menor medida), con el RA de los adolescentes en importantes materias como Matemáticas o Lengua, independientemente de la edad, nivel socioeducativo de las familias y del fatness (IMC).
- Un programa de 12 semanas de C-HIIT monitorizado, durante los primeros 16 minutos de las clases de EF, mejora el bienestar, sociabilidad, atención, concentración y cálculo matemático en adolescentes. Las anteriores variables, así como la creatividad, mejoran particularmente en los jóvenes físicamente inactivos.

Conclusión general:

Se concluye que la atracción por la práctica de AF, sobre todo vigorosa y en chicas, el empleo de desplazamiento activo en chicas, y el nivel de condición física están positivamente relacionados con la cognición durante la adolescencia. El desplazamiento activo también se asocia a mejores niveles de felicidad y bienestar psicológico. La capacidad cardiorrespiratria, velocidad-agilidad, coordinación motora o la habilidad perceptivo motora, son los componentes de la condición física mayormente relacionados con la cognición. Sin embargo, la relación con respecto a la fuerza muscular o la flexibilidad, aún no está clara, obteniendo significativi solo en uno de nuestros estudios de asociación, en la variable fuerza, y solo en chicas. La presente tesis también concluye que para cualquier estudio entre estas variables, es determinate controlar los análisis en función de importantes coavariables, como la edad, el IMC o el nivel socioeducativo de las familias, por ejemplo a través de los estudios de la madre. Finalmente, 12 semanas de un programa monitorizado de C-HIIT, de 16 minutos de duración al comienzo de las clases de EF basado en retos por parejas o pequeños grupos a alta intensidad, mejora el bienestar psicológico, la sociabilidad, la creatividad, la atención, la concentración y el cálculo matemático, especialmente en los jóvenes físicamente inactivos.

CONCLUSIONS

- The degree of attraction to PA influences on AP in adolescents, and distinguishes important differences according to sex. Although boys have a greater general attraction to PA than girls, all the factors of attraction to PA are positively associated with better grades in PE in both sexes. Enjoyment with vigorous PA is the main factor of attraction that is related, in girls, with better grades in Math and Language. It is evident, therefore, that in addition to the already known relationship between PA and AP, it is necessary to take into account the factors of the attraction to PA, since to a large extent they can predict different AP results depending on the sex.
- Using more than 15 minutes per day of active commuting to Secondary school, is associated with higher levels of happiness and well-being, and less psychological distress in adolescents. The commuting walking, at least five weekly travles of more than 15 minutes, is related to higher scores in Math in adolescent girls.
- Our systematic review concludes a positive association of physical fitness with CP and AP. Cardiorespiratory fitness, speed-agility, motor coordination, and perceptual-motor skills are the components most associated with cognition in adolescents, while the relationship regarding strength and flexibility is not clear. Finally, it is emphasized that confounders play a fundamental role in this relationship.
- Our cross-sectional studies show a relationship between cardiorespiratory capacity, motor ability and muscular strength (although to a lesser extent), with the AP of adolescents in important subjects such as Math or Language, regardless of age, socio-educational level of families and fatness (BMI).
- A 12-week program of monitored C-HIIT, during the first 16 minutes of PE classes, improves well-being, sociability, attention, concentration and mathematical calculation in adolescents. The above variables, as well as creativity, improve particularly in physically inactive young people.

General conclusion:

It is concluded that the attraction to PA practice, especially to vigorous PA and in girls, the use of active commuting, in girls, and the level of physical fitness, are positively related with cognition during adolescence. Active commuting is also associated with better levels of happiness and psychological well-being. The cardiorespiratory capacity, speed-agility, motor coordination or motor perceptual ability are the components of physical fitness mostly related to cognition. However, the relationship regarding to muscular strength or flexibility is not yet clear, obtaining significance only in one of our association studies, in muscular strenght variable, and just in girls. This thesis also concludes that for any study, it is important to control the analyses according confounders, such as age, BMI or the socio-educational level of the families, for example through the maternal education level. Finally, 12 weeks of a monitored C-HIIT program, of 16 minutes at the beginning of PE classes based on challenges by pairs or small groups at high intensity, improves psychological well-being, sociability, creativity, attention, concentration and mathematical calculation, especially in physically inactive young people.

APLICACIONES PRÁCTICAS Y PROSPECTIVAS FUTURAS DE ESTUDIO

Aplicaciones prácticas

- Fomentar por parte de las familias y Centros educativos, el gusto por la práctica de AF vigorosa, sobre todo en chicas, para influir positivamente sobre la cognición durante la adolescencia.
- Las instituciones educativas, deberían proponer programas integrales para el aumento de la cantidad de AF diaria, donde por ejemplo, el desplazamiento activo fuese promocionado en adolescentes. Además, se sugiere crear de forma conjunta, por parte de los estamentos públicos y educativos, rutas seguras, y carriles especializados para caminar o para ir en bicicleta. Esto podría llevar a un aumento de la práctica, y por consiguiente a una mejora del bienestar mental y RA de los jóvenes.
- Conocer por parte de los padres y familias, los anteriores efectos del desplazamiento activo, podría hacer que se promocionara desde el contexto familiar el ir y volver caminando al Centro educativo, ya no solo para el fomento de hábitos saludables fisiológicos, si no también psicológicos y académicos.
- Conocer cuales son los componentes de la condición física mayormente relacionados con la cognición (capacidad cardiorrespiratoria, velocidad-agilidad, coordinación motora, y habilidad perceptivo-motora), puede facilitar el trabajo de los profesores de EF y entrenadores en horario extraescolar, para proponer programas acordes a este objetivo.
- Los puntos de corte mostrados con respecto a los niveles de condición física más adecuados para fomentar el RA, pueden ser clave también para orientar los programas y UDs de los profesores de EF.
- Los profesores de EF deberían aumentar el empleo de actividades con alto componente aeróbico o motor. De forma especial, se deberían favorecer programas de ejercicio físico de alta intensidad llevados a cabo de forma cooperativa (C-HIIT). Estos programas son de fácil aplicación y ocupan poco tiempo diario perimitiendo el trascurso normalizado de las UDs.
- Llevar a cabo estas intervenciones, especialmente en los jóvenes adolescentes físicamente inactivos, podría potenciar sus efectos a nivel cognitivo y emocional.

Prospectivas futuras

- Creación de programas de intervención fomentando la atracción hacia la AF vigorosa, y el aumento de la AF diaria por ejemplo a través del desplazamiento activo), especialmente en chicas.
- Llevar a cabo más investigaciones para explicar los efectos diferenciales de los diferentes componentes de la condición física en la cognición, para clarificar el rol de las covariables, el por qué de las diferencias entre sexos, y analizar si nuestros hallazgos son generalizables a un grupo más amplio de participantes.
- Determinar los puntos de corte en la práctica diaria objetiva de AF necesaria, y niveles de condición física adecuados para predecir un mejor rendimiento en otras variables de bienestar psicológico, IE o RC.
- Profundizar en los efectos a corto plazo del C-HIIT. Por ejemplo realizando programas donde se comience la jornada escolar con C-HIIT para anlizar sus efectos durante el día y la semana escolar.
- Aumentar el número de días de C-HIIT, y comprobar sus posibles efectos en una mayor cantidad de variables, desde un punto de vista integral (físicas, psicológicas y sociales).
- Comprobar los efectos del programa C-HIIT en poblaciones especiales (por ejemplo: Trastorno por Déficit de Atención e Hiperatividad, o Trastorno del Espectro Autista).

PRACTICAL APPLICATIONS AND PROSPECTS FOR FUTURE RESEARCH

Practical applications

- Families and educational centers should encourage the attraction to vigorous PA, above all in girls, to positively influence on cognition during the adolescence.
- Educational institutions should propose integral programs to the increase the amount of daily PA, where for instance, active commuting to School is promoted in adolescents. In addition, it is suggested to create jointly safe routes and especialised paths to walk or cycle. This could lead to an increase in PA practice, and therefore in better psychological well-being and AP in young people.
- Parents and families should know the active commuting effects, to promote this trend from family context. Not only to promote physical healthy habits, unless also to psychological and academic benefits.
- To know the components of physical fitness mostly associated with cognition (cardiorrespiratory capacity, speed-agility, motor coordination, and perceptive-motor skill), could facilitate the work of PE teachers and coaches after school hours, to propose programs according to this objective. The most adequate cutt-off points showed regarding to physical fitness levels to increase AP, could be key to target programs and didactical units of PE teachers.
- PE teacher should enhance the use of activities with a high aerobic or motor component. Especially C-HIIT programs. These programs are easy to apply and take up little time per day for the normalised course of the didactical units.
- Carrying out these interventions, especially in physically inactive adolescents, could potentiate their effects at a cognitive and emotional level.

Prospects for future research

- To create interventional programes to promote the attraction to vigorous PA, and the daily active commuting, especcially in girls.
- To carry out more researches to explain the differential effects of th different components of physical fitness on cognition, to clarify the rol of confounders, the differences between sexes, and to analyse if our findings are generalizable to a wider group of participants.
- To determine the adequate cutt-off points for the objective daily PA practice and physical fitness levels to predict better performance in other variables of psychological well-being, EI or CP.
- To depth in short-term effects of C-HIIT. For example, performing programes to begin the school day with C-HIIT, and to analyse its effects during the schoolar day and week.
- To increase the number of days of C-HIIT, and to test the possible effects on more variables, from an integral point of view (physical, psychological and social).
- To prove the effects of C-HIIT in special population (i.e., Attention Deficit and Hyperactivity Disorder, or Autistic Spectrum Disorder).

CURRICULUM VITAE RESUMIDO [SHORT CV]

Datos personales

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Actividad académica

- Diplomado en Magisterio de Educación Física (2007-2010). Universidad de Granada (Granada, España).
- Licenciado en Ciencias de la Actividad Física y el Deporte (2010-2012). Universidad de Granada (Granada, España).
- Máster Universitario en Investigación y Docencia en Ciencias de la Actividad Física y Salud (2012-2013). Universidad de Jaén (Jaén, España).
- Máster Universitario en Profesorado de Educación Secundaria Obligatoria y Bachillerato, Formación Profesional y Enseñanza de Idiomas (2013-2014). Universidad de Jaén (Jaén, España).

Participación en proyectos de investigación

- Influencia de la Actividad Física en las Actitudes y Cognición de Escolares con Trastorno de Déficit de Atención e Hiperactividad. Diputación Provincial de Jaén. Instituto de Estudios Giennenses. Anual (2017-2018).
- Actividad física en adolescentes y contexto familiar. Estudio transversal y programa de intervención en padres e hijos de dos años de duración (UJA2016/08/05). Plan de Apoyo a la Investigación, Desarrollo Tecnológico e Innovación de a Universidad de Jaén (anual 2016-2017).
- Influencia de las relaciones parentales sobre la actividad física, obesidad juvenil, calidad de vida y rendimiento académico en adolescentes andaluces (R5/8/2013). Plan de Desarrollo Tecnológico e Innovación de la Universidad de Jaén (bianual 2014-2016).

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(Únicamente se citan algunos ejemplos relacionados con la presente tesis)

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“Sólo aquellos que se arriesgan a ir
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T. S. Eliot