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Cristina Comeras Chueca

Efecto de una intervención con videojuegos activos combinados con entrenamiento multicomponente en la condición física de niños y niñas con sobrepeso u obesidad: una propuesta disruptiva

Director/es
Casajús Mallén, José Antonio
González De Agüero Lafuente, Alejandro

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Autor

Cristina Comeras Chueca

Director/es

Casajús Mallén, José Antonio
González De Agüero Lafuente, Alejandro

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CRISTINA COMERAS CHUECA

Facultad de Ciencias de la Salud

Departamento de Fisiatría y Enfermería

Universidad de Zaragoza

Escuela de Doctorado - Programa de Doctorado en Ciencias de la Salud y del Deporte

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CRISTINA COMERAS CHUECA

A mis padres, Rosa y Arturo

por acompañarme, apoyarme y guiarme en este camino.

A mis directores, Alex y José Antonio,

a mis compañeros del grupo GENUD

y a mi familia y amigos.

Gracias por vuestra ayuda y por el apoyo incondicional.

No nos atrevemos a muchas cosas porque son difíciles, pero son difíciles porque no nos atrevemos a hacerlas.

Séneca

No siempre los más altos llegan más arriba, no siempre los más rápidos llegan antes, no siempre los más fuertes son los que ganan la batalla. Pero los que más entrenan, más se esfuerzan y más creen en el equipo son los que más veces conseguirán la victoria.

Pau Gasol

Efecto de una intervención con videojuegos activos combinados con entrenamiento multicomponente en la condición física de niños y niñas con sobrepeso u obesidad: una propuesta disruptiva

Effect of an active video game intervention combined with multicomponent training on the physical fitness of children with overweight or obesity: a disruptive approach

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1542

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Facultad de Medicina
Universidad de Zaragoza

JOSÉ ANTONIO CASAJÚS MALLÉN, CATEDRÁTICO DE LA UNIVERSIDAD DE ZARAGOZA, CERTIFICA:

Que la Tesis Doctoral titulada *"Efecto de una intervención con videojuegos activos combinados con entrenamiento multicomponente en la condición física de niños y niñas con sobrepeso u obesidad: una propuesta disruptiva"* que presenta Dña. **CRISTINA COMERAS CHUECA** al superior juicio del Tribunal que designe la Universidad de Zaragoza, ha sido realizada bajo mi dirección durante los años 2018-2023, siendo expresión de la capacidad técnica e interpretativa de su autor en condiciones tan aventajadas que le hacen merecedor del Título de Doctor, siempre y cuando así lo considere el citado Tribunal.

Fdo. José A. Casajús Mallén

Dr. **ALEJANDRO GONZALEZ DE AGÜERO LAFUENTE**

Profesor Titular de Universidad

Departamento de Fisiatría y Enfermería

Facultad de Ciencias de la Salud y del Deporte

Universidad de Zaragoza

ALEJANDRO GONZÁLEZ DE AGÜERO LAFUENTE, PROFESOR TITULAR DE LA UNIVERSIDAD DE ZARAGOZA, CERTIFICA:

Que la Tesis Doctoral titulada *"Efecto de una intervención con videojuegos activos combinados con entrenamiento multicomponente en la condición física de niños y niñas con sobrepeso u obesidad: una propuesta disruptiva"* que presenta Dña. **CRISTINA COMERAS CHUECA** al superior juicio del Tribunal que designe la Universidad de Zaragoza, ha sido realizada bajo mi dirección durante los años 2018-2023, siendo expresión de la capacidad técnica e interpretativa de su autor en condiciones tan aventajadas que le hacen merecedor del Título de Doctor, siempre y cuando así lo considere el citado Tribunal.

Fdo. Alejandro González de Agüero Lafuente

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Proyectos y contratos de investigación

La Tesis Doctoral que se presenta a continuación, así como varios de los artículos que la conforman, se enmarcan dentro del proyecto “Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva” (Proyecto VIDEOACTIVO), financiado por el Ministerio de Ciencia, Innovación y Universidades (DEP2017-85194) y por el Gobierno de Aragón a través de la Dirección General de Aragón (DGA IIU/2023/2017).

Contratos de investigación

Cristina Comeras Chueca fue contratada por la Universidad de Zaragoza gracias a las subvenciones destinadas a la contratación de personal investigador predoctoral en formación para el período 2017-2021 cofinanciadas con el Programa Operativo FSE Aragón 2014-2020.

Estancias de investigación

A lo largo del periodo de realización de la presente Tesis Doctoral la doctoranda Dña. Cristina Comeras Chueca, realizó dos estancias de investigación. Las características de las estancias de investigación se detallan a continuación:

I. Estancia de investigación internacional en la Universidad de Brighton, en el grupo de investigación "Sport and Exercise Science and Sports Medicine Research and Enterprise Group". Supervisor: Dr. Fergus Guppy. Duración: 3 meses y 6 días (02/10/2021 – 08/01/2022). Temática de la estancia: "Intervención para la mejora de la masa muscular (recuperación e incremento) y estrategias para la mejora de la condición física y composición corporal" enmarcado dentro de los siguientes proyectos: "El entrenamiento de restricción del flujo sanguíneo Kaatsu en los marcadores de inflamación y las percepciones del dolor y la fatiga inducidos por el ejercicio"; "Los efectos de la baja disponibilidad de energía y el síndrome de deficiencia energética relativa"; "Estudio observacional sobre los efectos de la terapia de afirmación de género en el rendimiento del ejercicio y la memoria muscular (The Tavistock Transgender Athelte Study [TTAS])"

II. Estancia de investigación internacional en la Universidad de Brighton, en el grupo de investigación "Sport and Exercise Science and Sports Medicine Research and Enterprise Group". Supervisor: Dr. Ifigeneia Giannopoulou. Duración: 1 meses y 21 días (14/06/2022 – 04/08/2021). Temática de la estancia: "Intervención para la mejora de la masa muscular (recuperación e incremento) y estrategias para la mejora de la condición física y composición corporal” enmarcado dentro de los siguientes proyectos: “El entrenamiento de restricción del flujo sanguíneo Kaatsu en los marcadores de inflamación y las percepciones del dolor y la fatiga inducidos por el ejercicio”; “Los efectos de la baja disponibilidad de energía y el síndrome de deficiencia energética relativa”; “Estudio observacional sobre los efectos de la terapia de afirmación de género en el rendimiento del ejercicio y la memoria muscular (The Tavistock Transgender Athelte Study [TTAS])”.

Listado de publicaciones

La presente Tesis Doctoral es un compendio de trabajos científicos previamente publicados. A continuación, se detallan las referencias de cada uno de los artículos que componen este documento:

I. **Comeras-Chueca C,** Marin-Puyalto J, Matute-Llorente A, Vicente-Rodriguez G, Casajus JA, Gonzalez-Aguero A. Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents With Overweight or Obesity: Systematic Review and Meta-Analysis. JMIR Serious Games. 2021 Oct 18;9(4):e29981. doi: 10.2196/29981. PMID: 34661549; PMCID: PMC8561411.

II. **Comeras-Chueca C,** Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, Matute-Llorente Á, Casajús JA, González-Agüero A. Assessment of Active Video Games' Energy Expenditure in Children with Overweight and Obesity and Differences by Gender. Int J Environ Res Public Health. 2020 Sep 15;17(18):6714. doi: 10.3390/ijerph17186714. PMID: 32942663; PMCID: PMC7560235.

III. **Comeras-Chueca C,** Marin-Puyalto J, Matute-Llorente A, Vicente-Rodriguez G, Casajus JA, Gonzalez-Aguero A. The Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents with Healthy Weight: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2021 Jun 29;18(13):6965. doi: 10.3390/ijerph18136965. PMID: 34209767; PMCID: PMC8296862.

IV. **Comeras-Chueca C,** Villalba-Heredia L, Perez-Lasierra JL, Marín-Puyalto J, Lozano-Berges G, Matute-Llorente Á, Vicente-Rodríguez G, Gonzalez-Aguero A, Casajús JA. Active Video Games Improve Muscular Fitness and Motor Skills in Children with Overweight or Obesity. Int J Environ Res Public Health. 2022 Feb 24;19(5):2642. doi: 10.3390/ijerph19052642. PMID: 35270330; PMCID: PMC8910272.

V. **<u>Comeras-Chueca C</u>**, Villalba-Heredia L, Perez-Lasierra JL, Lozano-Berges G, Matute-Llorente A, Vicente-Rodriguez G, Casajus JA, Gonzalez-Aguero A. Effect of an Active Video Game Intervention Combined with Multicomponent Exercise for Cardiorespiratory Fitness in Children with Overweight and Obesity: Randomized Controlled Trial. JMIR Serious Games. 2022 May 24;10(2):e33782. doi: 10.2196/33782. PMID: 35471240; PMCID: PMC9175106.

Listado de abreviaturas

AF	*Actividad física*
AFL	*Actividad física ligera*
AFM	*Actividad física moderada*
AFMV	*Actividad física moderada – vigorosa*
AFV	*Actividad física vigorosa*
ANOVA	*Análisis de varianza*
AVG	*Active Video Games*
CEICA	*Comité de ética de la investigación de la Comunidad Autónoma de Aragón*
CF	*Condición física*
DXA	*Densitometría dual de rayos X*
ECV	*Enfermedades cardiovasculares*
EF	*Educación física*
FC	*Frecuencia cardiaca*
HDL-c	*Colesterol de alta densidad*
IMC	*Índice de masa corporal*
LDL-c	*Colesterol de baja densidad*
MET	*Equivalente metabólico*
N	*Tamaño de la muestra*
OMS	*Organización Mundial de la Salud*
PRISMA	*Preferred reporting items for systematic reviews and meta-analyses*
SD	*Desviación estándar*
SE	*Error estándar*
SPSS	*Statistical Package for the Social Sciences*
VJA	*Videojuegos activos*
VO_2	*Consumo de oxígeno*
$VO_{2máx}$	*Consumo máximo de oxígeno*
VO_{2pico}	*Consumo pico de oxígeno*

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Resumen general

Introducción

La obesidad infantil es un grave problema de salud pública a nivel mundial debido a su alta prevalencia y al impacto negativo que tiene en la salud traducido en un mayor riesgo de desarrollar enfermedades respiratorias, cardiovasculares y cardiometabólicas, problemas psicosociales, peor rendimiento académico y el desarrollo de obesidad en la edad adulta. Se produce debido a un exceso de masa grasa consecuencia de un desequilibrio energético en el que la ingesta supera al gasto energético. Este desequilibrio está fomentado por la inactividad física y los comportamientos sedentarios característicos de la sociedad actual, por lo que el ejercicio físico será la mejor estrategia para prevenir y/o tratar la obesidad infantil, concretamente el entrenamiento concurrente combinando ejercicio aeróbico y ejercicio de fuerza. Sin embargo, la baja adherencia a los programas de ejercicio físico por parte de jóvenes con sobrepeso u obesidad limita su potencial o su efecto.

Los videojuegos activos (VJA) requieren movimiento corporal y por consiguiente un gasto energético, por lo que pueden suponer una nueva y atractiva estrategia para promover la actividad física y por tanto la salud, aumentando el gasto energético, sustituyendo las conductas sedentarias y favoreciendo la mejora de la condición física.

Metodología

La presente Tesis Doctoral está compuesta por 5 artículos científicos, compuestos por dos revisiones sistemáticas elaboradas a partir de las indicaciones de la guía PRISMA, y por 3 estudios originales del proyecto "Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva". La muestra final fue de 66 niños/as con sobrepeso u obesidad, de los cuales 31 tienen mediciones pre-intervención y post-intervención. El estudio longitudinal incluyó a 21 niños/as en el grupo de intervención con VJA y a 8 niños/as en el grupo control. Se evaluó la antropometría y la composición corporal, la condición cardiorrespiratoria y muscular, el nivel de actividad física y el gasto energético durante las sesiones, la habilidad motriz (del grupo intervención con VJA), la madurez sexual, varios parámetros bioquímicos, la presión arterial y la dieta y hábitos nutricionales. El programa de intervención con VJA tuvo una duración de 5 meses, con una frecuencia de 3 sesiones por semana de 60 minutos cada una, y se controló la intensidad a través de la frecuencia cardíaca. El diseño del programa combinó VJA usando 5 dispositivos diferentes (Nintendo Wii®, Xbox Kinect®, esterillas de baile, BKOOL® ciclosimulador y Nintendo Ring Fit Adventures®) con ejercicio multicomponente. El objetivo fue evaluar la efectividad de una intervención de ejercicio físico con VJA combinados con ejercicio multicomponente para aumentar el gasto energético y mejorar la condición física y habilidad motriz en niños/as prepuberales con sobrepeso u obesidad.

Resultados

La evidencia científica resumida en las revisiones sistemáticas con meta-análisis realizadas muestra efectos positivos de intervenciones con VJA en el peso, el índice de masa corporal (IMC), Z-Score de IMC, el porcentaje de grasa corporal y la masa grasa de la población infantil, sobre todo aquellos con sobrepeso u obesidad. Los resultados son menos claros para la condición cardiorrespiratoria, con mejoras en niños/as con peso saludable, pero sin posibilidad de realizar análisis cuantitativo con la población infantil con sobrepeso u obesidad. La evidencia científica tampoco esclarece los efectos de los VJA en la fuerza muscular ni en la habilidad motriz, y aunque los VJA parecen tener el potencial para mejorar la fuerza y habilidad motriz, no se pudieron realizar análisis cuantitativos.

La intervención de ejercicio físico con VJA combinados con ejercicio multicomponente produjo un gasto calórico de entre 4.35 y 5.68 kcal/min y mejoró la composición corporal de los niños/as con una disminución del porcentaje de grasa corporal y del Z-Score del IMC. También mejoró la condición cardiorrespiratoria en intensidades submáximas, disminuyendo significativamente la frecuencia cardíaca y el consumo de oxígeno (VO_2) y los porcentajes de VO_2 durante las etapas submáximas del test máximo. Además, el grupo de intervención con VJA mostró una mejora significativa en los test de fuerza y en la habilidad motriz, con un aumento significativo de la altura de salto en CMJ y de los kilos de fuerza en la dinamometría manual.

Conclusión

Los VJA son efectivos para reducir o controlar el peso, el IMC y la grasa corporal, especialmente en niños/as con sobrepeso u obesidad, y parecen ser potencialmente efectivos para mejorar la condición física y la habilidad motriz. Una intervención de ejercicio físico con VJA combinados con ejercicio multicomponente es efectiva para aumentar el gasto energético y mejorar la condición física y habilidad motriz en niños/as prepuberales con sobrepeso u obesidad.

General abstract

Introduction

Childhood obesity is a major public health problem worldwide due to its high prevalence and the negative impact on health in terms of increased risk of developing respiratory, cardiovascular and cardiometabolic diseases, psychosocial problems, poorer academic performance and the development of obesity in adulthood. It is caused by excess fat mass resulting from an energy imbalance in which energy intake exceeds energy expenditure. This imbalance is fostered by physical inactivity and sedentary behaviours characteristic of today's society, so exercise is the best strategy to prevent and/or treat childhood obesity, specifically concurrent training combining aerobic and strength exercise. However, low adherence to exercise programs by overweight or obese youth limits their potential or effect.

Active video games (AVG) require body movement and therefore energy expenditure, so they could be a new and attractive strategy to promote physical activity and therefore health, increasing energy expenditure, replacing sedentary behaviours and favouring the improvement of physical fitness.

Methodology

This doctoral thesis is made up of 5 scientific articles, composed of two systematic reviews based on the PRISMA guidelines, and 3 original studies from the project "Active video games against obesity and sedentary lifestyles in children aged 9 to 11 years: a disruptive proposal". 66 overweight or obese children were included in the study, of which 31 have pre-intervention and post-intervention measurements. The longitudinal study included 21 children in the AVG intervention group and 8 children in the control group. Anthropometry and body composition, cardiorespiratory and muscular fitness, physical activity, energy expenditure during the sessions, motor skills (of the AVG intervention group), sexual maturation, biochemical parameters, blood pressure and diet and nutritional habits were assessed. The AVG intervention program lasted 5 months, with a frequency of 3 sessions of 60 minutes per week, and intensity was monitored recording heart rate. The program design combined AVG using 5 different devices (Nintendo Wii®, Xbox Kinect®, dance mats, BKOOL® cyclosimulator and Nintendo Ring Fit Adventures®) with multicomponent exercise. The main aim was to evaluate the effectiveness of an exercise intervention with AVG combined with multicomponent exercise to increase energy expenditure and improve physical fitness and motor skills in prepubertal children who are overweight or obese.

Results

The scientific evidence of the systematic reviews with meta-analyses showed positive effects of AVG interventions on weight, BMI, BMI Z-Score, body fat percentage and fat mass in children, especially those who are overweight or obese. The results are less clear for cardiorespiratory endurance, with improvements in children with a healthy weight, but with quantitative analysis not possible for overweight or obese children. The scientific evidence is also unclear on the effects of AVG on muscle strength and motor skills, and although AVG seem to potentially improve strength and motor skills, quantitative analyses could not be performed.

The exercise intervention with AVG combined with multicomponent exercise produced a caloric expenditure between 4.35 and 5.68 kcal/min and improved children's body composition with a decrease in body fat percentage and BMI Z-Score. It also improved cardiorespiratory fitness at submaximal intensities, with significant decreases in heart rate and oxygen consumption (VO_2) and VO_2 percentages during the submaximal stages of the maximal test. In addition, the AVG intervention group showed a significant improvement in strength testing and motor skills, with a significant increase in CMJ jump height and kilograms of force in manual dynamometry.

Conclusions

AVG are effective in reducing or managing weight, BMI and body fat, especially in children who are overweight or obese, and appear to be potentially effective in improving physical fitness and motor skills. An intervention with AVG combined with multicomponent exercise is effective in increasing energy expenditure and improving physical fitness and motor skills in prepubertal children who are overweight or obese.

1. Introducción

La presente Tesis Doctoral tiene como objetivo investigar la eficacia o el efecto de una intervención con videojuegos activos (VJA) combinados con transiciones activas de entrenamiento multicomponente en la condición física (CF) de niños y niñas con sobrepeso u obesidad. Por ello, la introducción se estructurará en los siguientes cuatro apartados: 1) la obesidad infantil y sus causas, consecuencias y propuestas de actuación; 2) los comportamientos sedentarios, tiempos de pantallas y ocio sedentario asociado; 3) el ejercicio como mejor estrategia para combatir la obesidad infantil, beneficios y la limitación de la baja adherencia al ejercicio y 4) la propuesta de los VJA como estrategia de alianza con las nuevas tecnologías para promover la actividad física (AF).

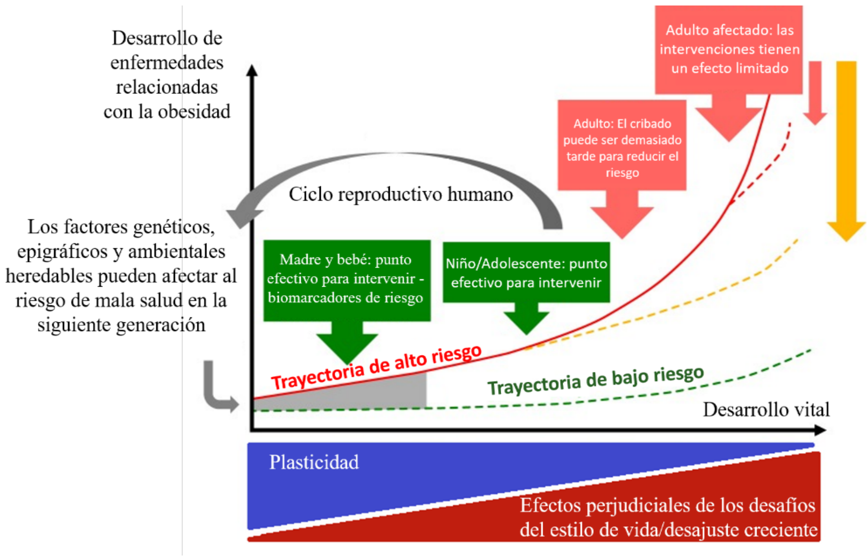
1.1 La obesidad infantil

La obesidad es una compleja enfermedad multifactorial, definida como una acumulación anormal o excesiva de grasa que supone un riesgo para la salud. Se ha identificado como un grave problema de salud pública a nivel mundial debido a su alta prevalencia y al importante factor de discapacidad y muerte asociado en la región europea de la Organización Mundial de la Salud (OMS) (1). La obesidad es uno de los factores de riesgo de enfermedades no transmisible particularmente preocupante y tiene la capacidad de disminuir la esperanza de vida (1).

La lucha contra la obesidad es un objetivo tan prioritario en la sociedad actual que se tiene muy presente en el programa europeo de trabajo planificado por la OMS (2). Se han propuesto y establecido varios marcos políticos y planes de acción para frenar el aumento de la obesidad infantil, como la Conferencia Ministerial Europea contra la obesidad de 2006 (3), el Informe de la Comisión para acabar con la obesidad infantil de 2016 (4), y los Objetivos Mundiales de Nutrición 2025: Informe de política sobre el sobrepeso infantil (5).

La prevención y el tratamiento de la obesidad adquiere incluso mayor importancia durante la infancia y adolescencia, ya que los efectos positivos de las intervenciones en las primeras etapas vitales, cuando la biología es más "plástica" o más reactiva, pueden ser mayores y sobre todo más perdurables, principalmente porque los hábitos y estilo de vida adquiridos durante la niñez y adolescencia tienden a mantenerse en las etapas vitales posteriores, como se muestra en la Figura 1.

Figura 1. Continuidad de hábitos y estilos de vida adquiridos.



Fuente: La figura pertenece al informe de «WHO Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity Report of the Ad hoc Working Group on Science and Evidence for Ending Childhood Obesity». (4) Licencia: Creative Commons (CC BY 3.0 IGO).

Bien es cierto que los factores de riesgo relacionados con las enfermedades no transmisibles, como la hipertensión arterial, el colesterol y la hiperglucemia, el consumo de tabaco, la inactividad física y por supuesto el sobrepeso y la obesidad, no contribuyen de forma significativa en los años de vida ajustados por discapacidad (una medida de carga de la enfermedad global expresada como el número de años perdidos debidos a enfermedad, discapacidad o muerte prematura); sin embargo, se convierten en importantes amenazas para la salud pública en etapas posteriores de la vida (6). Además, la forma de distribución de la grasa en el cuerpo determina las consecuencias negativas del exceso de grasa para la salud, siendo la obesidad abdominal la peor para la salud, medida a través de la circunferencia de cintura o el ratio cintura-altura, ya que está estrechamente relacionada con el riesgo cardiovascular (7). Un niño/a se clasifica como con obesidad abdominal si el ratio cintura-altura supera 0,5, con una circunferencia de cintura por encima del percentil 90 y con una grasa en el tronco elevada obtenida con una densitometría, en función de los valores para una edad y sexo específicos (8). En definitiva, abordar la obesidad es clave para promover la salud pública en España como en el resto del mundo.

1.1.1 Prevalencia y evolución

El sobrepeso y la obesidad son un grave problema común en la Región Europea de la OMS, ya que, en 2020, afectaba a 4,4 millones de niños menores de 5 años, lo que se traduce en una prevalencia del 7,9% de los niños de este grupo de edad (1). En la Figura 2 se puede ver que, en el grupo de edad de 5 a 9 años, la prevalencia del sobrepeso y la obesidad aumenta, con uno de cada ocho niños, es decir el 11,6% de los niños/as con obesidad y casi uno de cada tres niños/as con sobrepeso u obesidad, afectando al 29,5%. La prevalencia disminuye ligeramente en el grupo de edad de 10 a 19 años, con una prevalencia de obesidad del 7,1% y el 24,9% con sobrepeso u obesidad, como se indica en la Figura 3.

Figura 2. Prevalencia de sobrepeso y obesidad entre los niños de 5 a 9 años en la Europa de la OMS .

[a] UE13: países que pasaron a formar parte de la UE después de 2004 - Bulgaria, Croacia, Chipre, Chequia, Estonia, Hungría, Letonia, Lituania, Malta, Polonia, Rumanía, Eslovaquia y Eslovenia.

[b] UE14: países que formaban parte de la UE antes de 2004 - Alemania, Austria, Bélgica, Dinamarca, España, Finlandia, Francia, Grecia, Italia, Irlanda, Luxemburgo, Países Bajos, Portugal y Suecia.

[c] Dimensión Norte: UE, Federación Rusa, Noruega, Islandia.

[d] CEI: miembros y miembros asociados de la Comunidad de Estados Independientes: Armenia, Azerbaiyán, Bielorrusia, Kazajistán, Kirguistán, República de Moldavia, Federación Rusa, Tayikistán, Turkmenistán y Uzbekistán.

Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

Figura 3. Prevalencia de sobrepeso y obesidad entre los niños de 10 a 19 años en la Europa de la OMS.

[a] UE13: países que pasaron a formar parte de la UE después de 2004 - Bulgaria, Croacia, Chipre, Chequia, Estonia, Hungría, Letonia, Lituania, Malta, Polonia, Rumanía, Eslovaquia y Eslovenia.

[b] UE14: países que formaban parte de la UE antes de 2004 - Alemania, Austria, Bélgica, Dinamarca, España, Finlandia, Francia, Grecia, Italia, Irlanda, Luxemburgo, Países Bajos, Portugal y Suecia.

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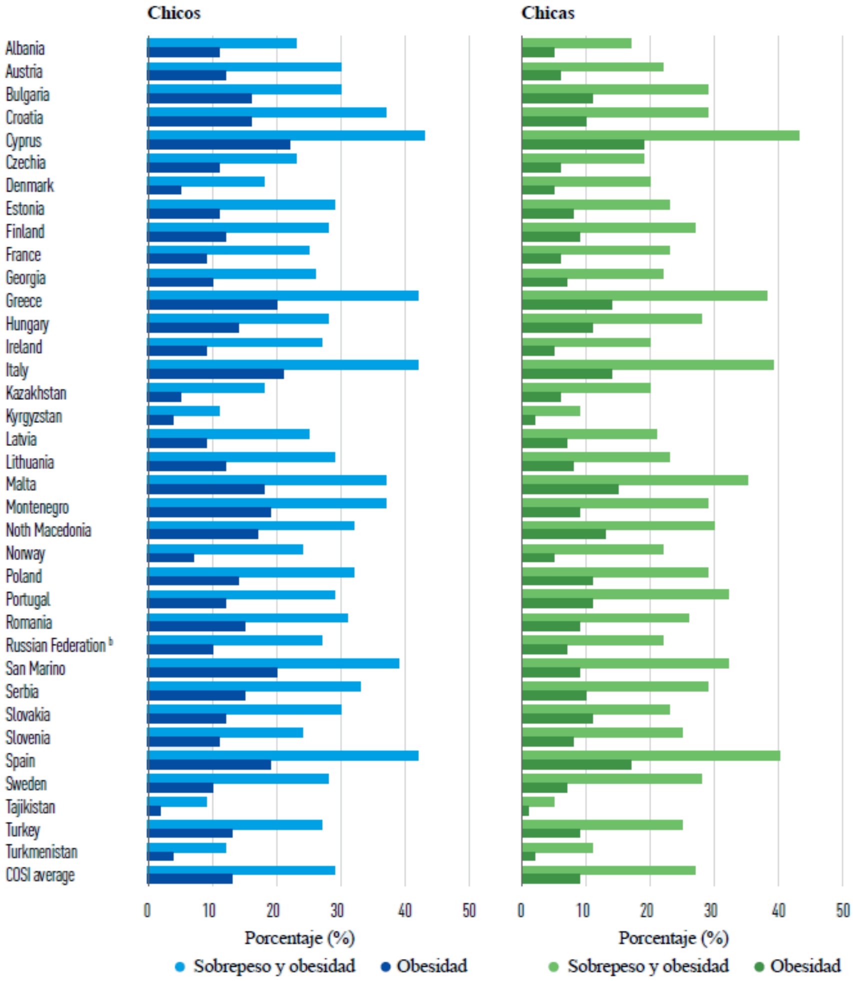
Tayikistán, Turkmenistán y Uzbekistán.

Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

Cabe destacar que el sobrepeso y la obesidad son más prevalentes en los varones y en los países de la cuenca mediterránea. Entre los años 2015 y 2017 se reportaron casi uno de cada tres niños de 7 a 11 años, concretamente el 29% de los niños y el 27% de las niñas con sobrepeso u obesidad, y aproximadamente uno de cada 10 con obesidad, con un 13% de los niños y un 9% de las niñas, como se muestra en la Figura 4. Datos de 2017-2018 revelan que la prevalencia de sobrepeso y obesidad era mayor entre los chicos en los grupos de edad de 11, 13 y 15 años, y disminuía con la edad en ambos sexos, como se puede observar en la Figura 5.

Figura 4. Prevalencia de sobrepeso y obesidad en niños de 7 a 9 años de 36 países de la Región Europea de la OMS por sexo.



[a] Los datos se refieren a la recogida de datos de la cuarta ronda: (i) niños de 7 años de Bulgaria, Chequia, Dinamarca, Estonia, Finlandia, Georgia, Grecia, Hungría, Irlanda, Kirguistán, Letonia, Lituania, Malta, Montenegro, Portugal, Macedonia del Norte, Federación Rusa (sólo en Moscú), Serbia, Eslovaquia, Eslovenia, España, Tayikistán, Turkmenistán y Turquía; (ii) niños de 8 años de Albania, Austria, Croacia, Francia, Italia, Noruega, Polonia, Rumanía, San Marino y Suecia; y (iii) niños de 9 años de Chipre y Kazajistán.
[b] Sólo en Moscú

Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

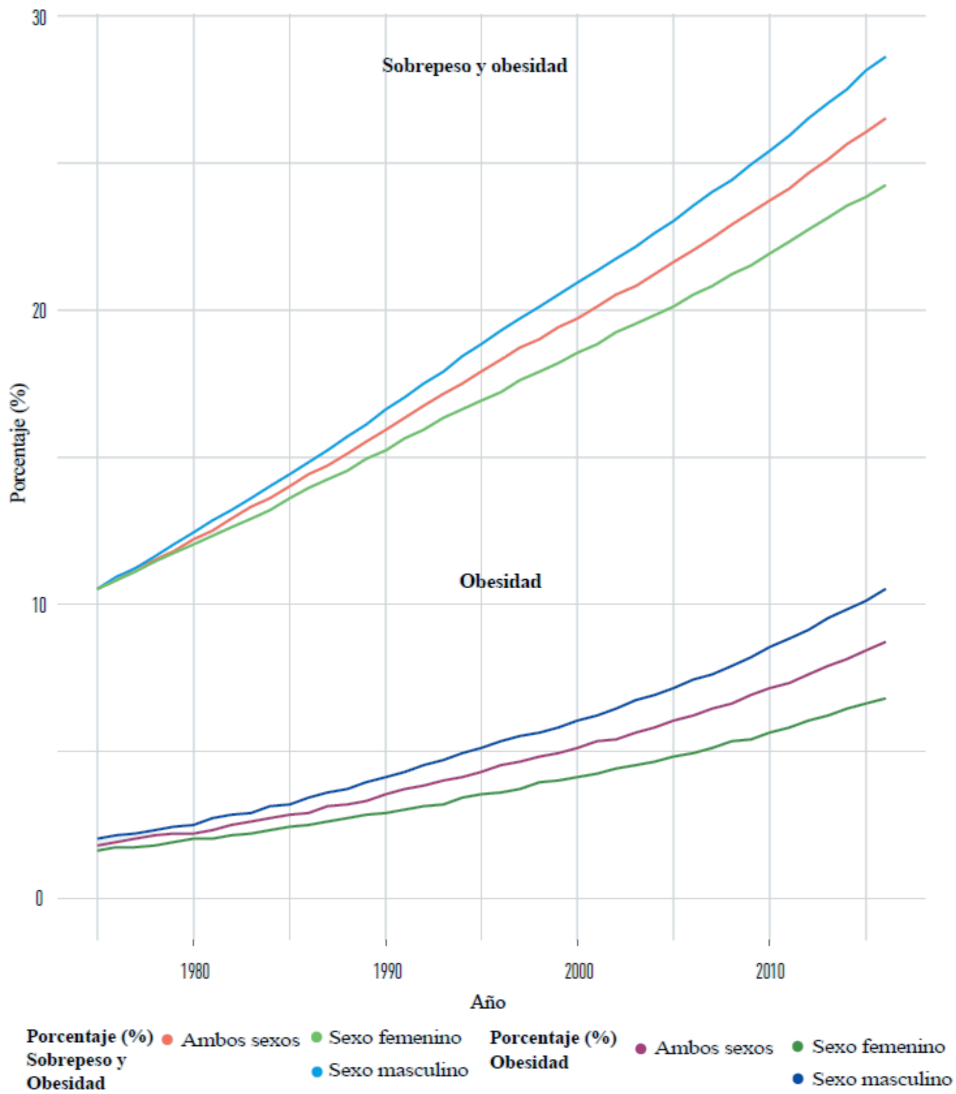
Figura 5. Prevalencia de sobrepeso y obesidad en adolescentes de 11, 13 y 15 años en países europeos seleccionados por sexo.

[a] Datos de la encuesta HBSC 2017/2018 en Europa y Canadá.
[b] Los valores de HBSC representan la media de los países que han proporcionado información relevante; esto incluye todos los países enumerados en la tabla más Canadá y Groenlandia.

Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

Atendiendo a la tendencia de la prevalencia de sobrepeso u obesidad en comparación con las cifras de hace 40 años, se puede observar que la prevalencia del sobrepeso y la obesidad en niños/as y adolescentes de entre 5 y 19 años casi se ha triplicado en varones y se ha duplicado con creces en las mujeres entre los años 1975 y 2016. Esta tendencia aparece representada en la Figura 6.

Figura 6. Prevalencia de sobrepeso y obesidad en niños y adolescentes de 5 a 19 años en la Región Europea de la OMS por sexo entre los años 1975 y 2016.

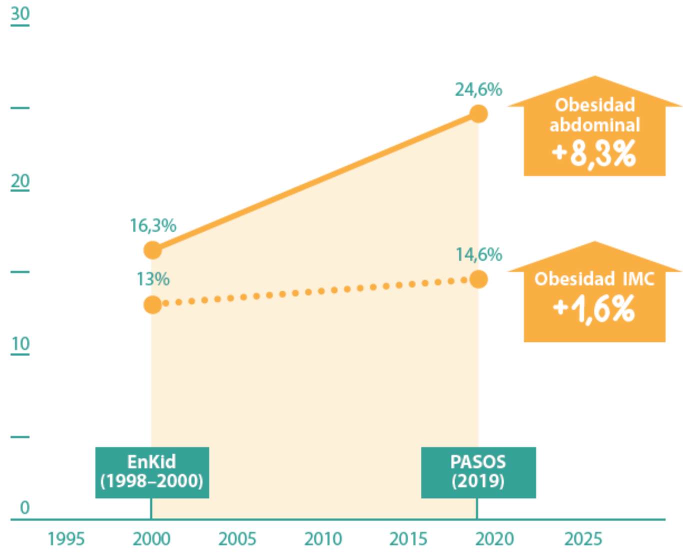


Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

Hay dos aspectos que afectan al riesgo de desarrollar sobrepeso u obesidad por parte de los niños: el nivel educativo de los padres y los ingresos de la familia. Los niños de familias con un nivel educativo alto de los padres mostraban una mayor prevalencia de sobrepeso y obesidad que los niños de familias con un nivel educativo de los padres más bajo. En cuanto a la economía familiar, en la mayoría de los países europeos, se observó una mayor prevalencia en los individuos de familias con menores ingresos, una tendencia que fue más aparente en los países de ingresos altos.

En España, un 14,2% de la población infanto-juvenil padece obesidad y un 20,7% padece sobrepeso, haciendo un total de 34,9% de niños/as y adolescentes con sobrepeso u obesidad, además de que un 24,5% presenta obesidad abdominal (9). España ocupa el cuarto puesto en cifras de sobrepeso y obesidad en infantes de entre 5 y 10 años a nivel europeo y el segundo lugar en niñas de esa edad (9). La evolución de la epidemia de exceso de peso en España no está siendo prometedora, como se puede ver en la Figura 7, mostrando un incremento del 2% en sobrepeso u obesidad, desglosado en un aumento del 0,4% en sobrepeso y de 1,6% en obesidad, además de un aumento preocupante de la obesidad abdominal del 8,3% (9). Incluso en áreas de mayor pobreza relativa las cifras de exceso de peso pueden alcanzar hasta un porcentaje de entre 30 y 40% (9). Más concretamente en la región de Aragón en el año 2007, la prevalencia de sobrepeso fue de un 30% de los niños y un 33% de las niñas con sobrepeso, mientras que la prevalencia de obesidad fue de un 5% en niños y un 8% en niñas (10).

Figura 7. Evolución de la prevalencia de obesidad infantil y obesidad abdominal en las dos últimas décadas en España - según IMC y CC/talla.

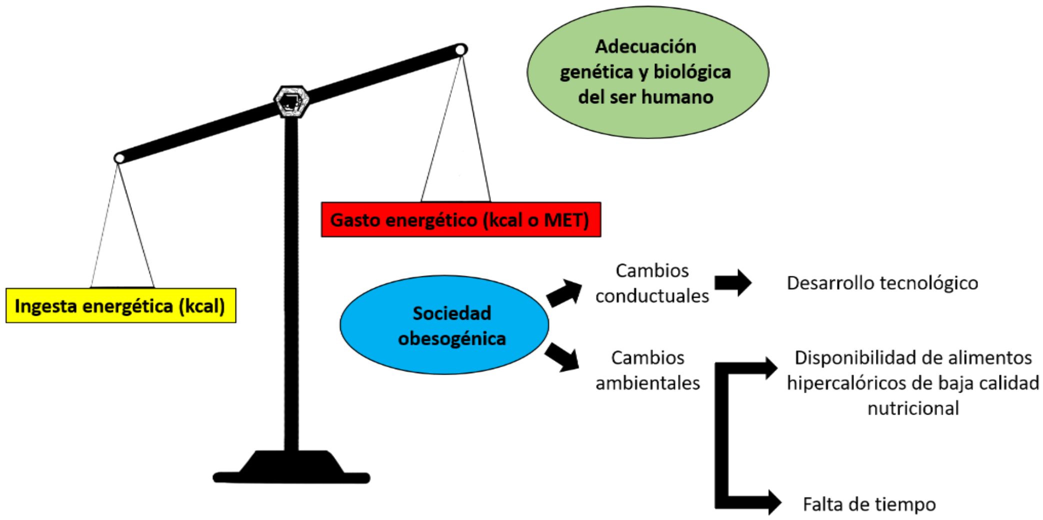


Fuente: La figura pertenece al «Estudio PASOS (Physical Activity, Sedentarism and Obesity of Spanish youth) - Resultados principales del estudio PASOS 2019 sobre la actividad física, los estilos de vida y la obesidad de la población española de 8 a 16 años». (9)

1.1.2 Causas fisiológicas y sociales

La acumulación excesiva de grasa que da lugar al sobrepeso y obesidad se produce como consecuencia de un desequilibrio energético en el que la cantidad de energía ingerida es mayor que el gasto energético. Este concepto de equilibrio energético puede parecer simple, pero entraña una gran complejidad en la manera que se puede manifestar la ingesta y/o el gasto energético, además de las interacciones e influencias que pueden ocurrir sobre esa ingesta y ese gasto energético (1), como se ve en la Figura 8.

Figura 8. Causas de la obesidad: desequilibrio energético.



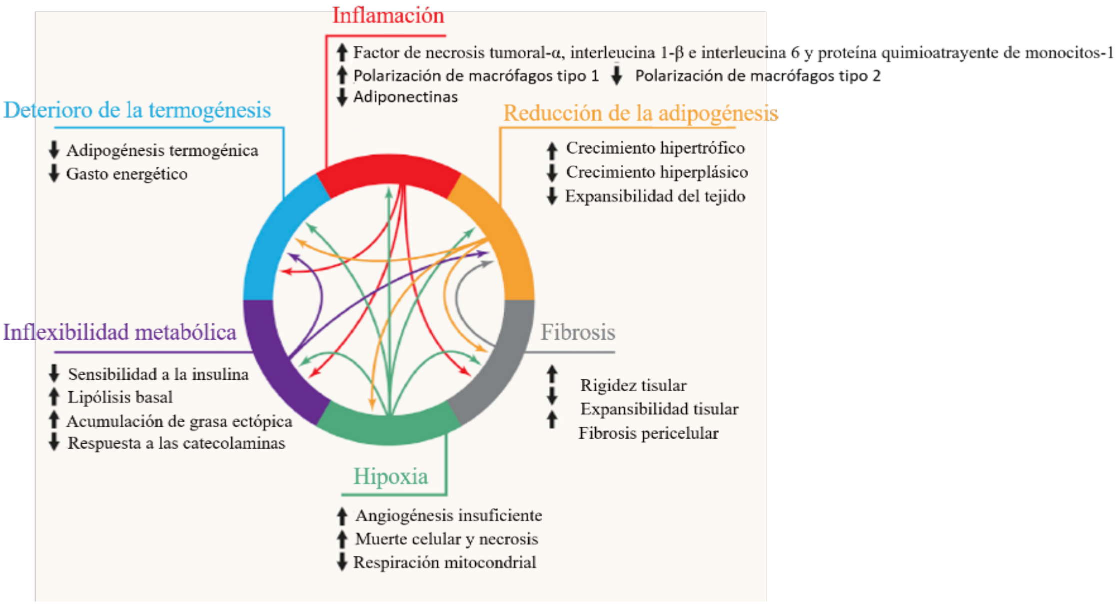
Fuente: Elaboración propia.

La elevada prevalencia de sobrepeso y obesidad surge como consecuencia de una adaptación y adecuación tanto genética como biológica del ser humano con el objetivo básico de supervivencia, adecuado desarrollo y adaptación al medio, que ha hecho que el cuerpo humano busque almacenar energía como estrategia de protección. Sin embargo, esta estrategia de almacenaje de energía no solo no es necesaria, sino que es perjudicial en la sociedad obesogénica actual, que ha surgido como consecuencia de cambios conductuales y ambientales que afectan al equilibrio energético (1). El cambio ambiental se ha caracterizado por una mayor disponibilidad y a un mejor precio de alimentos hipercalóricos, pero menos beneficiosos desde el punto de vista nutricional. A este exceso energético en la ingesta se le añade el cambio conductual del ser humano hacia un menor gasto de energía principalmente debido al desarrollo tecnológico que ha favorecido la inactividad física y los comportamientos sedentarios tanto en las actividades de la vida diaria como por ejemplo los desplazamientos como en el ocio. En niños/as es determinante el estilo de vida y los hábitos parentales, ya que son los que eligen los alimentos consumidos por la familia y determinan las actividades desarrolladas durante el tiempo de ocio. Otro determinante importante en relación a la participación deportiva de los niños/as es la disponibilidad de tiempo. Todos estos factores van a afectar a la facilidad o no de desarrollar sobrepeso u obesidad en los infantes.

1.1.3 Consecuencias

El tejido adiposo, además de su función de almacenamiento de energía en forma de lípidos, es un órgano endocrino metabólicamente activo, con células grasas (adipocitos) que liberan y reciben hormonas. Esto puede provocar cambios en los patrones hormonales, especialmente entre las personas con grasa abdominal. Los adipocitos liberan unas sustancias denominadas adipocitoquinas, que se asocian a una serie de acciones sistémicas o locales, como el metabolismo de la glucosa y los lípidos, el desarrollo celular, la inflamación y el estrés oxidativo, que pueden provocar una serie de problemas de salud (11). Como se puede ver en la Figura 9, la obesidad a menudo conduce a una disminución de la plasticidad del tejido adiposo que, entre otras cosas, empeora la termogénesis que produce una disminución del gasto energético y promueve la inflamación, y en última instancia, estos cambios patológicos que empeoran la función del tejido adiposo conducen a la resistencia a la insulina y a la enfermedad metabólica (12).

Figura 9. Características del tejido adiposo disfuncional.



Fuente: La figura pertenece al artículo «Adipose-tissue plasticity in health and disease». (12) Licencia: by Elsevier and Copyright Clearance Center (License Number: 5457550726564).

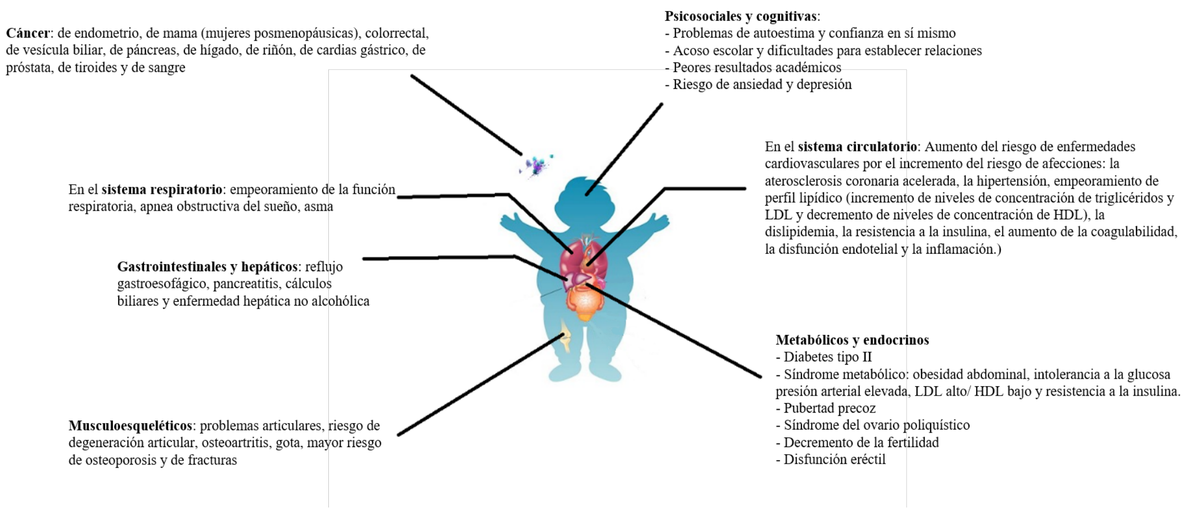
La grasa visceral, que rodea los órganos dentro de la cavidad abdominal, tiene un mayor impacto en la salud que la grasa subcutánea, ya que es más activa biológicamente, tiene una mayor densidad de células, transporta más flujo sanguíneo y está situada cerca de la vena porta, lo que provoca una mayor concentración de ácidos grasos que llegan al hígado. El resultado es un aumento de las cantidades de ácidos grasos que llegan al hígado y que afectan a la producción de lípidos en la sangre. Se ha encontrado una asociación entre la grasa visceral y niveles más altos de colesterol total, en particular de colesterol de baja densidad (LDL), lo que también conduce a concentraciones más bajas de colesterol de alta densidad (HDL).

Según datos recientes de 2022, los efectos negativos de la obesidad sobre la salud no se derivan simplemente de un exceso de grasa, sino de la disminución de su capacidad para responder a los cambios o, en otras palabras, de su plasticidad (63). La composición y el funcionamiento de este tejido cambian en respuesta a las fluctuaciones de peso y al envejecimiento. A medida que la grasa disminuye su plasticidad debido al envejecimiento y la obesidad, pierde su capacidad de responder a las señales corporales. En el modelo actual de este fenómeno, el rápido crecimiento del tejido adiposo supera su suministro de sangre, privando a las células grasas de oxígeno y provocando la acumulación de células que ya no se dividen. Esto conduce a los problemas metabólicos ya mencionados anteriormente, como la resistencia a la insulina, la inflamación y la muerte celular.

La masa y la actividad metabólica del tejido adiposo hacen que afecte a casi todos los sistemas corporales, y el exceso de adiposidad tiene implicaciones para la salud a lo largo de toda la vida, incluso en el periodo prenatal (13).

Como se puede observar en la Figura 10, el sobrepeso y la obesidad conllevan unas consecuencias negativas para la salud. La principal consecuencia o perjuicio de la obesidad, incluso en la niñez, ocurre en el sistema circulatorio. El exceso de tejido adiposo está estrechamente relacionado con afecciones que conllevan un incremento del riesgo de enfermedades cardiovasculares (ECV), que es la causa más común de muerte en Europa (14). Entre estas afecciones se incluye el empeoramiento del perfil lipídico, dislipidemia, aterosclerosis coronaria acelerada, hipertensión, resistencia a la insulina y desarrollo de diabetes tipo II, aumento de la coagulabilidad, disfunción endotelial y la inflamación (14,15).

Figura 10. Consecuencias de la obesidad.



Fuente: Elaboración propia.

Otro sistema cuya función puede verse afectada como consecuencia del sobrepeso u obesidad es el respiratorio, produciéndose un empeoramiento de la función respiratoria y con mayor riesgo de apnea obstructiva del sueño y de desarrollar asma. Las funciones metabólicas y endocrinas también se ven empeoradas, incrementándose el riesgo de desarrollar patologías como diabetes tipo II, pubertad precoz y síndrome metabólico. Para determinar que los pacientes padecen síndrome metabólico deben tener un Índice de Masa Corporal (IMC) ≥ 30 o una obesidad central específica de la etnia definida por el perímetro de la cintura, además de dos de las siguientes condiciones: Triglicéridos elevados (>150 mg/dL o 1,7 mmol/L), colesterol HDL reducido (< 40 mg/dL o 1,03 mmol/L en hombres y < 50 mg/dL o1. 29 mmol/L en mujeres), presión arterial elevada (sistólica ≥130 mmHg; diastólica ≥85 mmHg) y glucosa plasmática en ayunas elevada (≥100 mg/dL o 5,6 mmol/L) o tratamiento específico para esta anomalía lipídica o diabetes de tipo 2 o hipertensión previamente diagnosticada.

La función gastrointestinal y hepática también se verá comprometida, con un mayor riesgo de desarrollar patologías como reflujo gastroesofágico, pancreatitis, cálculos biliares y enfermedad hepática no alcohólica.

Del mismo modo, los individuos que viven con sobrepeso u obesidad tienen un mayor riesgo de desarrollar varios tipos de cáncer, siendo el riesgo de cánceres dependientes de hormonas (endocrinos) mayor para aquellos con obesidad abdominal. Los tipos de cáncer más relacionados con el exceso de tejido adiposo son el cáncer de endometrio, de mama (mujeres posmenopáusicas), de colon, de vesícula biliar, de páncreas, de hígado, de riñón, de cardias gástrico, de próstata, de tiroides y de sangre. Este riesgo incrementado de cáncer en personas con sobrepeso u obesidad ocurre principalmente en adultos, aunque se debe tener en cuenta ya también en niños debido a la tendencia de los niños/as y adolescentes a continuar con el exceso de masa grasa en la etapa adulta (16). De hecho, entre un 42% y un 63% de los niños/as con obesidad presentarán obesidad en la edad adulta (9). Ante la probabilidad de que esta obesidad infantil perdure hasta la etapa adulta, se debe tener presente que las consecuencias de este exceso de tejido adiposo pueden ser incluso más graves para la salud tanto a nivel individual como poblacional ya que una población de individuos con sobrepeso u obesidad habrá estado expuesta al impacto del exceso de adiposidad durante un largo periodo de tiempo.

Finalmente, los niños/as y adolescentes con sobrepeso u obesidad se verán especialmente afectados por problemas musculoesqueléticos debido al estrés y la carga extra que sufren sus articulaciones, por lo que son más propensos a sufrir problemas articulares, riesgo de degeneración articular, osteoartritis y mayor riesgo de osteoporosis y de fracturas. Además, debido a la naturaleza de la etapa vital de la niñez y adolescencia, los niños/as y adolescentes con sobrepeso u obesidad son especialmente vulnerables a los efectos psicosociales y cognitivos negativos que tiene el exceso de tejido adiposo, pudiendo desarrollarse problemas de autoestima y autoconfianza, aislamiento social, dificultades para las relaciones sociales, situaciones de acoso escolar, dificultades para establecer relaciones, disminución en el rendimiento académico y riesgo de ansiedad y depresión.

Cabe destacar que las ECV y otras consecuencias negativas de la obesidad infantil pueden suponer un problema serio de salud en etapas vitales posteriores, aunque esta relación es moderada, por lo que las acciones de prevención de la obesidad no solo deben centrarse en niños/as y adolescentes con sobrepeso u obesidad (17).

1.1.4 COVID-19

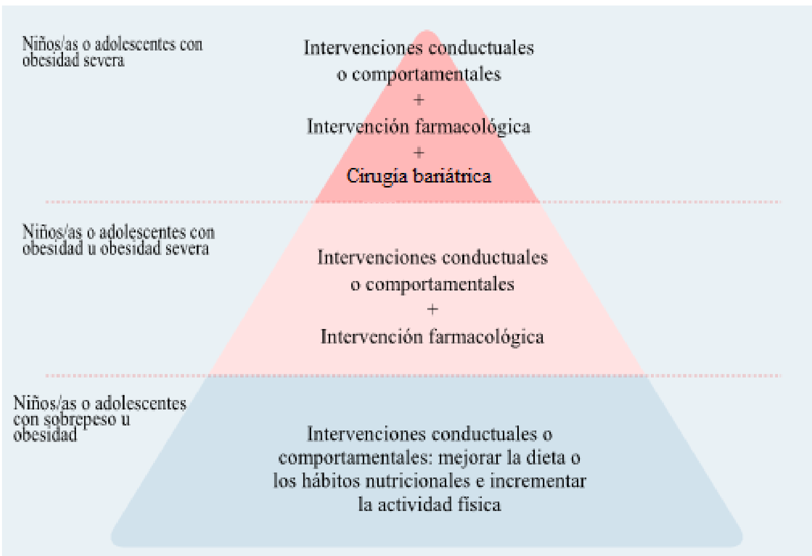
Los primeros estudios realizados en varios países europeos han indicado un aumento de la prevalencia del sobrepeso y la obesidad, o del IMC medio, en niños y adolescentes durante la pandemia de COVID-19 (18,19). Además, durante la pandemia se ha observado una disminución de la AF y un aumento del consumo de alimentos con alto contenido en grasa, azúcar y sal (18). Esto demuestra la importancia de medidas preventivas y de tratamiento del sobrepeso y obesidad después de COVID-19 para evitar un empeoramiento que podría ser catastrófico de la salud y el bienestar. Además, se teme que muchas de las medidas que perduran tras el periodo de pandemia, tales como restricciones de actividades deportivas o limitaciones comerciales continúen afectando negativamente a la dieta y los niveles de AF de la población, promoviendo un estilo de vida más sedentario y menos saludable (20).

1.1.5 Soluciones y propuestas

La primera solución o estrategia propuesta con el objetivo de luchar contra la obesidad infantil deberían ser las estrategias preventivas. Estas estrategias preventivas deben incluir a toda la familia y comenzar, idealmente, antes de la concepción. Es probable que las familias con miembros obesos compartan no sólo los riesgos genéticos, sino también las exposiciones ambientales y relacionadas con el estilo de vida. El mayor riesgo de obesidad comienza ya antes y durante el embarazo (1). Los resultados de numerosos ensayos clínicos indican la influencia de la salud de los padres en el desarrollo del feto y el riesgo de obesidad en la infancia y la adolescencia (21).

Los tratamientos de la obesidad en niños/as y adolescentes varían en función del grado de sobrepeso u obesidad que tengan. En niños/as y adolescentes con sobrepeso u obesidad se realizarán intervenciones conductuales o comportamentales con el objetivo de modificar y mejorar la dieta o los hábitos nutricionales e incrementar la AF junto con la promoción del ejercicio físico y la participación deportiva. Este tipo de intervenciones se llevarán a cabo desde los centros de atención primaria o escuelas trabajando junto a la familia. En un segundo nivel con niños/as o adolescentes con obesidad severa se contemplará el tratamiento farmacológico en colaboración con el tratamiento conductual/comportamental. En un nivel extremo de obesidad severa, se valorará el tratamiento de cirugía bariátrica en combinación con los dos tratamientos anteriormente explicados. En la Figura 11 se muestran los tres tratamientos de acuerdo al nivel de sobrepeso u obesidad del niño/a o adolescente.

Figura 11. Tratamientos para la obesidad infantil.



Fuente: La figura pertenece al informe de «WHO European Regional Obesity Report 2022». (1) Licencia: Creative Commons (CC BY-NC-SA 3.0 IGO).

La obesidad infantil se asocia a un riesgo moderadamente mayor de morbilidad relacionada con la obesidad en la edad adulta, pero el aumento del riesgo no es lo suficientemente grande como para que el IMC en la infancia sea un buen predictor de la incidencia de morbilidades en la edad adulta. Esto se debe a que la mayor parte de la morbilidad relacionada con la obesidad en la edad adulta se produce en adultos que tenían un peso saludable en la infancia. Por lo tanto, dirigir las estrategias de prevención de obesidad únicamente a los niños obesos o con sobrepeso puede no reducir sustancialmente la carga global de enfermedades relacionadas con la obesidad en la edad adulta (17). Se deben aplicar las estrategias de prevención de la obesidad a través de la promoción de hábitos nutricionales saludables y de promoción de la AF y el ejercicio físico a todo el grupo poblacional perteneciente a la infancia y adolescencia.

1.2 Comportamientos sedentarios e inactividad física en la sociedad de hoy en día

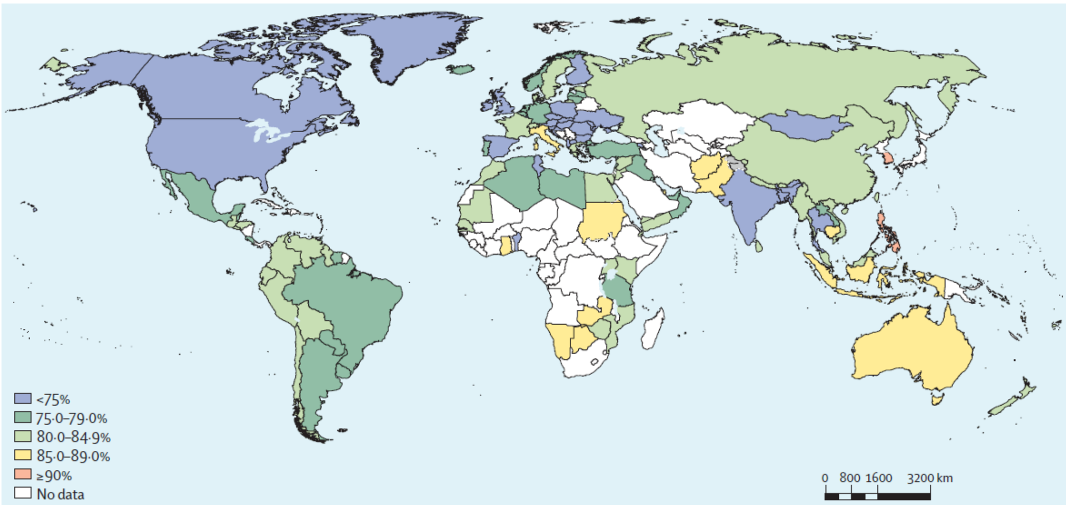
La mayoría de los adolescentes no cumplen las directrices actuales de AF, y esta alta prevalencia de inactividad física entre los jóvenes es un problema creciente por lo que es necesario ampliar urgentemente las estrategias de acción promotoras de AF (22). A esta inactividad física se le añaden numerosos comportamientos sedentarios promovidos por la sociedad de hoy en día. El sedentarismo aumenta la morbilidad y todas las causas de mortalidad (23), lo que lo convierte en otro problema de salud pública grave e insuficientemente abordado.

1.2.1 Inactividad física

La inactividad física es un problema creciente entre los niños/as y adolescentes de la sociedad actual. Según los datos de la OMS, 3 de cada 4 adolescentes (81%) de entre 11 y 17 años no cumplen actualmente las recomendaciones globales de AF establecidas por la

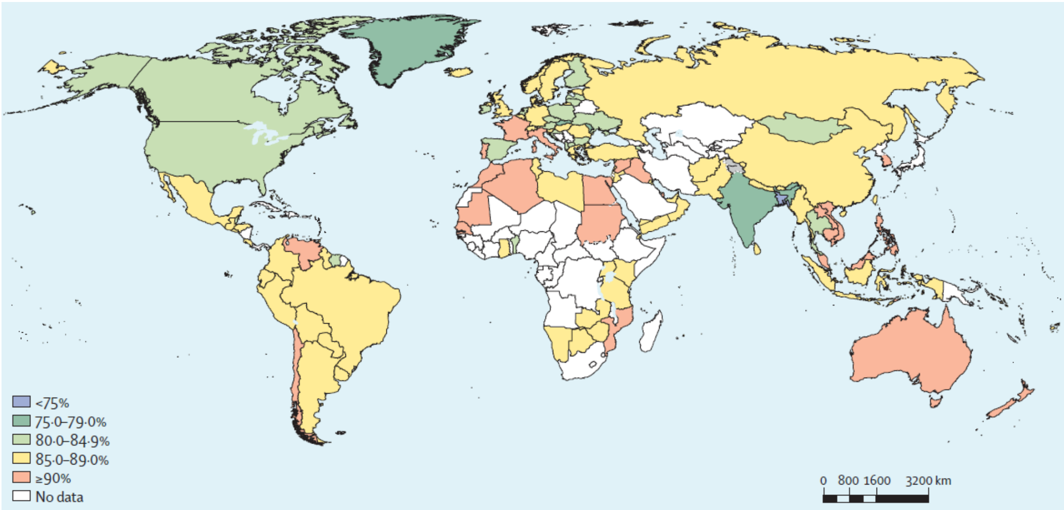
OMS (22). En 2016, los datos de escolares de entre 11 y 17 años mostraron que el 81 % (IC 95%, 77,8-87,7%) fueron insuficientemente activos con un mayor porcentaje de chicas inactivas con un 84,7% (83,0-88,2%) que de chicos inactivos, con un 77,6% (76,1–80,4%) (24), como se observa en las Figuras 12 y 13. El objetivo es una reducción relativa del 15% en la prevalencia mundial de la inactividad física en los adolescentes para el año 2030 (22).

Figura 12. Prevalencia de actividad física insuficiente entre los chicos escolarizados de 11 a 17 años.



Fuente: La figura pertenece al artículo «Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants». (24) Licencia: Creative Commons (CC BY 3.0 IGO).

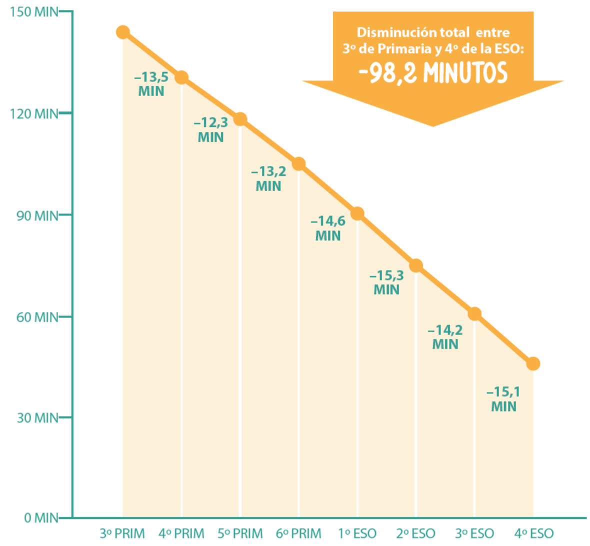
Figura 13. Prevalencia de actividad física insuficiente entre las chicas escolarizados de 11 a 17 años.



Fuente: La figura pertenece al artículo «Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants». (24) Licencia: Creative Commons (CC BY 3.0 IGO).

En España, el 63,3% de la población juvenil de entre 8 y 16 años no cumple con las recomendaciones de AF diarias (9). El incumplimiento de las recomendaciones de AF es mayor en la adolescencia con un 69,9% que en la infancia con un 55,5% y es mayor en la población femenina con un 70,1% que en la masculina con un 56,1%, por lo que habrá que extremar las precauciones con la población adolescente femenina (9). En cuanto a las diferencias según la edad, como se puede observar en la figura 14, entre los 8 y los 16 años (de 3º de primaria a 4º de la ESO) se muestra una disminución del tiempo dedicado a la actividad física moderada-vigorosa (AFMV) de más de hora y media, en concreto de 98,2 minutos.

Figura 14. Promedio de minutos diarios dedicados a la práctica de actividad física - según curso académico.



Fuente: La figura pertenece al «Estudio PASOS (Physical Activity, Sedentarism and Obesity of Spanish youth) - Resultados principales del estudio PASOS 2019 sobre la actividad física, los estilos de vida y la obesidad de la población española de 8 a 16 años». (9)

La inactividad física es una pandemia mundial que genera no sólo morbilidad y mortalidad, sino también una importante carga económica en todo el mundo. Esta carga económica se distribuye de forma desigual entre las regiones, y de forma desproporcionada en relación con la carga de la enfermedad. Es probable que esto se deba a los niveles diferenciales de desarrollo económico y, en consecuencia, al gasto sanitario. Además, si se tiene en cuenta el análisis sobre quién asume los gastos, las regiones más empobrecidas podrían resultar aún más afectadas desde el punto de vista tanto económico como sanitario, ya que, por lo general, cuanto más pobre es el país, mayores son las necesidades sanitarias insatisfechas, por lo que son las personas y los hogares quienes acaban pagando en forma de morbilidad y mortalidad prematuras (25).

Más de 5,3 millones de muertes al año se atribuyen a la inactividad física (26), lo que ha llevado a la OMS a advertir que el sedentarismo y la inactividad física podrían estar entre las 10 principales causas de muerte y discapacidad en el mundo (23).

La inactividad física, junto con el aumento del consumo de tabaco y la mala alimentación y nutrición, forman parte cada vez más del estilo de vida actual, lo que provoca el rápido aumento de enfermedades como las ECV, la diabetes o la obesidad. Las enfermedades crónicas causadas por estos factores de riesgo son ahora las principales causas de muerte en todas las partes del mundo, excepto en el África subsahariana, donde las enfermedades infecciosas como el SIDA siguen siendo el principal problema. Estas enfermedades crónicas son, en su mayoría, totalmente prevenibles.

El persistente fracaso en la promoción de la AF en todo el mundo sugiere que las campañas públicas y el reconocimiento social de los beneficios para la salud de un estilo de vida físicamente activo no son suficientes para cambiar el comportamiento de las personas. Sin embargo, las campañas de salud pública para mejorar la AF se han centrado casi exclusivamente en el mensaje de que la inactividad física y el sedentarismo son perjudiciales para la salud y que, por el contrario, el cumplimiento de los niveles recomendados de AF aporta múltiples beneficios para la salud. Sin embargo, la mejora o mantenimiento de la salud es sólo uno de los muchos factores que pueden fomentar la AF, y puede no ser considerado el más importante para las personas (27). Así mismo, esa mejora de la salud puede no ser lo suficientemente valorada como para invertir tiempo en realizar AF, ya que, según el Eurobarómetro de 2020, lo que más motiva la realización de AF es la mejora de la salud, pero el principal motivo de no realizarla es la falta de tiempo (28).

Un enfoque diferente podría ser el bienestar psicológico experimentado durante y después del ejercicio, además de enfocar las estrategias de promoción no solo a cumplir con las recomendaciones, con el trasfondo de obligación que parece tener, sino en el bienestar durante y después de la práctica.

No ayuda el escaso número de horas que se le otorga a la Educación Física (EF) en el currículo nacional español, con un total de 100 horas por ciclo (50 horas por curso escolar), siendo la tercera asignatura con menos horas, tras religión y tras educación en valores cívicos y éticos (29). Esto quiere decir que el Estado sigue considerando menos de hora y media semanal como el mínimo de tiempo efectivo de la materia de EF. Pero el escaso número de horas de EF es tan solo una pequeña contribución a los preocupantes datos de inactividad física reportados por grandes proyectos llevados a cabo en España como el estudio IDEFICS (30), el proyecto ALADINO (31), el estudio ANIBES (32), el estudio HBSC (33) o el estudio HELENA (34) entre otros. El primer informe español sobre niños/as activos y saludables (35) realizado en 2016 reportó, tras analizar los datos de los estudios anteriormente nombrados, que sólo el 30% de los niños y el 12% de las niñas de 2 a 10 años cumplían las recomendaciones de AF (35). En el caso de los niños y niñas de 9 años fue de 60% y 34,1% para niños y niñas respectivamente, y en el caso de los adolescentes de 15 años, el cumplimiento fue del 58% para los chicos y 24% para las chicas (35). Según los datos autodeclarados obtenidos de una amplia muestra de participantes españoles del HBSC para 2010, el 32% de los niños de 11 a 12 años y el 15% de los adolescentes mayores de 17 -18 años eran adecuadamente activos (35). Los datos del estudio ANIBES recogidos en 2013 también mostraron grandes diferencias entre las edades y los géneros, y las directrices fueron cumplidas por el 52% de los adolescentes de 9 a 12 años y por el 37% de los adolescentes de 13 a 17 años (35). En cuanto a las diferencias de género, el 56% de los varones y el 27% de las mujeres eran suficientemente activos (35). En definitiva, la población más vulnerable es la de las adolescentes mayores. Esta inactividad física es promovida por la baja adherencia al transporte activo, que incluso va incrementando con la edad (35).

La inactividad física está relacionada con la tríada de la inactividad pediátrica, que se muestra en la Figura 15, una condición observada por Faigenbaum y col. (36) que incluye el trastorno por déficit de ejercicio, dinapenia pediátrica e incompetencia motriz. El término "trastorno por déficit de ejercicio" se utiliza para resaltar la gravedad de esta condición clínica con el objetivo de concienciar sobre la importancia de cumplir las recomendaciones de AF. Los niños con dinapenia pediátrica muestran bajos niveles de fuerza y potencia muscular y, en consecuencia, limitaciones funcionales que no están causadas por enfermedades neurológicas o musculares (36). El concepto de "incompetencia motriz" describe la falta de competencia, confianza y motivación para moverse con destreza (36).

Figura 15. La triada de la inactividad pediátrica.

Fuente: La figura adaptada del artículo «Pediatric Inactivity Triad: A Risky PIT». (36) Licencia: Creative Commons (License Number: 5422740651186)

El déficit de AF está estrechamente relacionado con otros componentes, ya que los niños y adolescentes que muestran una falta de aptitud muscular y un nivel disminuido de habilidades motrices son menos propensos a participar en actividades deportivas o simplemente en realizar AF, lo que imposibilita la mejora de la aptitud muscular o de las habilidades motrices (36).

1.2.2 Sedentarismo, tiempo de ocio y tiempo de pantalla

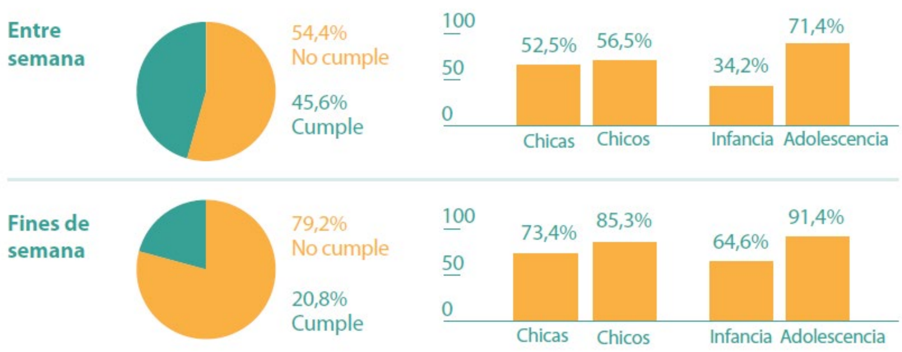
El sedentarismo está adquiriendo un papel protagonista entre los problemas de la salud pública debido a sus consecuencias para la salud, ya que aumenta todas las causas de mortalidad, duplica el riesgo de ECV, diabetes y obesidad, y aumenta los riesgos de cáncer de colon, hipertensión arterial, osteoporosis, trastornos lipídicos, depresión y ansiedad (23). Según la OMS, entre el 60% y el 85% de los habitantes del mundo, tanto de los países desarrollados como de los que están en vías de desarrollo, llevan un estilo de vida sedentario, lo que lo convierte en uno de los problemas de salud pública más graves, aunque insuficientemente abordados, de nuestro tiempo (23).

Los niños y adolescentes deben limitar los comportamientos sedentarios, en particular la cantidad de tiempo de pantalla considerado tiempo de ocio (37). En los niños y adolescentes, el comportamiento sedentario se asocia con un empeoramiento de la salud debido a un aumento de la adiposidad (38), peor salud cardiometabólica, peor estado físico, menores habilidades sociales y menor duración del sueño. Por lo tanto, los niños y los adolescentes deberían limitar el tiempo de sedentarismo, especialmente el tiempo de pantalla recreativa (37). Sin embargo, ciertos tipos de comportamiento sedentario, como leer y hacer los deberes fuera de la escuela, se asocian con un mayor rendimiento académico, lo que indica que hay diferencias según el tipo de actividad (37). Uno de los comportamientos sedentarios más perjudiciales y a la vez más recurrentes es el tiempo frente a una pantalla, que se correlacionó con inversamente con la CF y la salud psicológica (39). Además, este tiempo de pantalla ha ido cambiando de una preferencia por la televisión a una mayor tendencia a tiempo sedentario con ordenadores y videojuegos (40).

En España, los datos del estudio ANIBES (41) muestran que el 48,4% del total de los niños/as y adolescentes pasa más de 2 horas al día frente a la pantalla todos los días de la semana, y concretamente el 49,3% excede las dos horas durante la semana mientras que el 84,0% lo hace durante los fines de semana. Los adolescentes pasan más tiempo viendo la televisión, jugando con el ordenador y navegando por Internet que los niños. Casi el 38,5% de los niños y el 60,2% de los adolescentes pasan más de 2 horas al día frente a una pantalla entre semana, y el 82,2% y el 85,8%, respectivamente, durante los fines de semana. Incluso el 16,9% de los niños y el 25,1% de los adolescentes superan las 2 horas al día sólo en lo que respecta a la televisión entre semana, mientras que este porcentaje aumenta los fines de semana con un 57,7% de los niños y 59,8% de los adolescentes. Destaca también la disponibilidad de pantallas en el hogar ya que más del 30% tenía un televisor, un ordenador y/o una consola en sus dormitorios, y un 44% de los varones declaró tener tres o más televisores en casa (41).

En cuanto a los datos obtenidos del estudio PASOS (9), el tiempo medio de pantalla de los niños/as y adolescentes fue de casi tres horas al día (178,7 min al día) entre semana, superando las recomendaciones en casi una hora y de más de 4 horas y media al día (282,3 minutos al día) los fines de semana, superando las recomendaciones en dos horas y cuarenta y dos minutos por día. Como se observa en la Figura 16, el 54,4% de la población infanto-juvenil supera las dos horas diarias entre semana, cifra que asciende a 79,2% durante el fin de semana.

Figura 16. Prevalencia de incumplimiento/cumplimiento de la recomendación de la OMS en cuanto al uso diario de pantallas entre semana y el fin de semana - global y según género y curso académico en España.



Fuente: La figura pertenece al «Estudio PASOS (Physical Activity, Sedentarism and Obesity of Spanish youth) - Resultados principales del estudio PASOS 2019 sobre la actividad física, los estilos de vida y la obesidad de la población española de 8 a 16 años». (9)

Las intervenciones dirigidas a reducir los comportamientos sedentarios en los jóvenes tienen éxito con un efecto pequeño pero significativo y robusto dada la amplia muestra (42). De este modo, aunque sea un efecto pequeño, si afecta a una gran parte de la población, al igual que lo hace el tiempo de pantalla, puede tener un alto impacto a nivel de salud de la población. El efecto pequeño puede deberse a la dificultad para cambiar comportamientos o conductas sedentarias muy establecidas en la cotidianeidad, por ejemplo, la televisión, que es el comportamiento de tiempo libre más frecuente, con estimaciones medias de alrededor de 2 a 3 horas al día, y aproximadamente el 25% de las niñas y el 30% de los niños ven más de 4 horas al día (42). Además, las intervenciones pueden estar enfocadas a convertir algunos comportamientos sedentarios en AF, pero no se pueden abarcar todas las conductas sedentarias debido a la gran variedad de comportamientos sedentarios que existen con los prolongados tiempos de pantalla, el transporte motorizado y diversas actividades educativas/culturales como el tiempo de estudio y el tiempo lectivo. La investigación muestra que las intervenciones en entornos comunitarios tuvieron un mayor tamaño del efecto y el reclutamiento de los niños a través de las familias y la participación de los padres pueden ser más importantes que el entorno (42).

La evidencia científica muestra una disminución significativa del tejido adiposo al sustituir periodos sedentarios por AFMV o incluso simplemente acortando esos periodos sedentarios prolongados haciendo pausas activas con mayor frecuencia, lo que nos da una pista a la hora de diseñar intervenciones más eficaces para prevenir y controlar la obesidad infantil (43). Los resultados también muestran que el aumento de tiempo sedentario se relacionaba con una menor calidad de vida en niños y adolescentes (44).

La reciente pandemia de la COVID-19 ha favorecido e incrementado los comportamientos sedentarios y la inactividad física ante la imposibilidad incluso de salir de casa durante la etapa del confinamiento, ante la limitación de las actividades deportivas ofertadas y ante la tendencia de continuar con menores desplazamientos y actividades (45). Tras esta pandemia es especialmente importante fomentar la AF y el ejercicio físico, especialmente en la etapa de la niñez y adolescencia, favoreciendo la participación deportiva y el transporte activo.

1.3 Efecto del ejercicio para prevenir y tratar la obesidad

La AFMV se asocia con una menor adiposidad independientemente de la edad, el sexo, el estado de madurez, los niveles de referencia y el tiempo de sedentarismo. Los resultados sugieren que la promoción de la AFMV es importante para prevenir el aumento de la adiposidad en niños sanos (46). También se ha visto una fuerte asociación de la AFMV y la CF, independientemente del comportamiento sedentario (47,48), mostrando que las interrupciones de comportamientos sedentarios o bloques de tiempo sedentario de menos duración producen beneficios en la CF (47)

Es bien sabido que el ejercicio físico es una de las herramientas más útiles para prevenir la obesidad infantil y para tratarla con el objetivo de mejorar la composición corporal (49). De hecho, el incremento de AFV parece ser más apropiada que las intervenciones nutricionales para luchar contra la obesidad infantil (50). Un análisis de subgrupos reveló que, mientras que la intervención de ejercicio condujo a una mejora pequeña-moderada del IMC, la intervención de ejercicio combnada con una intervención nutricional dio lugar a mejoras moderadas del IMC y la grasa corporal, y a una mejora de la masa de tejido magro, y una intervención únicamente de nutrición no mostró efectos concluyentes (49). Los resultados del meta-análisis muestran una disminución media de 3,7 kg en el peso corporal, un aumento medio de la masa magra de 1,6 kg y una disminución media de la grasa corporal del 3,1 % (49).

Por otro lado, el ejercicio físico es una de las mejores armas en la lucha contra la obesidad infantil. Los términos de AF y de ejercicio físico se utilizan a menudo indistintamente, pero estos términos no son sinónimos. La AF se define como cualquier movimiento corporal producido por la contracción de los músculos esqueléticos que da lugar a un aumento sustancial de las necesidades calóricas sobre el gasto energético en reposo (51). El ejercicio es un tipo de AF que consiste en un movimiento corporal planificado, estructurado y repetitivo realizado para mejorar y/o mantener uno o más componentes de la aptitud física (52). Para tratar la obesidad infantil, se han visto efectivos tanto el entrenamiento continuo de intensidad moderada como el entrenamiento interválico de alta intensidad (53), con incluso mejores resultados en cuanto a la mejora de la CF por parte del entrenamiento interválico de alta intensidad (54). Así mismo, la aptitud física o CF es la capacidad de llevar a cabo las tareas diarias con vigor y diligencia, sin fatiga excesiva, y con energía suficiente para disfrutar de las actividades de ocio y hacer frente a las situaciones del entorno de forma exitosa (52). La aptitud física se compone de varios elementos que generalmente se verán empeorados en niños/as y adolescentes con sobrepeso u obesidad y que mejorarán con la aplicación de una intervención con ejercicio físico (55–57). Estos componentes pueden agruparse a su vez en componentes relacionados con la salud y componentes relacionados con el rendimiento (52), como se puede ver en la Figura 17 . Los niños/as y adolescentes con sobrepeso u obesidad tienden a tener peor rendimiento en las pruebas de valoración de la CF, tanto en condición cardiorrespiratoria como en fuerza y resistencia muscular (55,58), mostrándose una asociación inversa entre la aptitud física y el porcentaje de grasa corporal (59). Por otro lado, una mejor CF se asoció con ser más físicamente activo durante las clases de Educación Física, el recreo y las actividades deportivas extraescolares, pero interesantemente no durante la AF no organizada como el juego libre (60), lo que demuestra la importancia de la participación organizada.

Figura 17. Los componentes de la condición física.

Fuente: Elaboración propia

El ejercicio físico es la mejor estrategia para combatir la obesidad infantil y mejorar la salud de los niños/as que padecen esta enfermedad (61). La evidencia científica actual muestra que el ejercicio más beneficioso para los niños/as y adolescentes con sobrepeso u obesidad es el entrenamiento concurrente con una combinación de ejercicio aeróbico y entrenamiento de fuerza (62), el cual mejora la composición corporal, los perfiles metabólicos, el estado inflamatorio en la población pediátrica obesa (63), la CF (64) y disminuye los factores de riesgo cardiometabólicos y cardiovasculares (49,65).

Sin embargo, parece claro que la lucha contra la obesidad, incluida la obesidad infantil, no consiste en la realización de una intervención con ejercicio físico únicamente, sino que es necesario un enfoque sistémico complejo considerando las interacciones de los diferentes ámbitos de una persona para conformar su estado de salud, incluyendo los ámbitos laboral, social y familiar. De esta manera, en cuanto a las políticas de salud pública, la obesidad no debe abordarse de forma aislada, sino que, para lograr un cambio sostenible a largo plazo, hay que tener en cuenta los determinantes ambientales, sociales y económicos de las poblaciones afectadas.

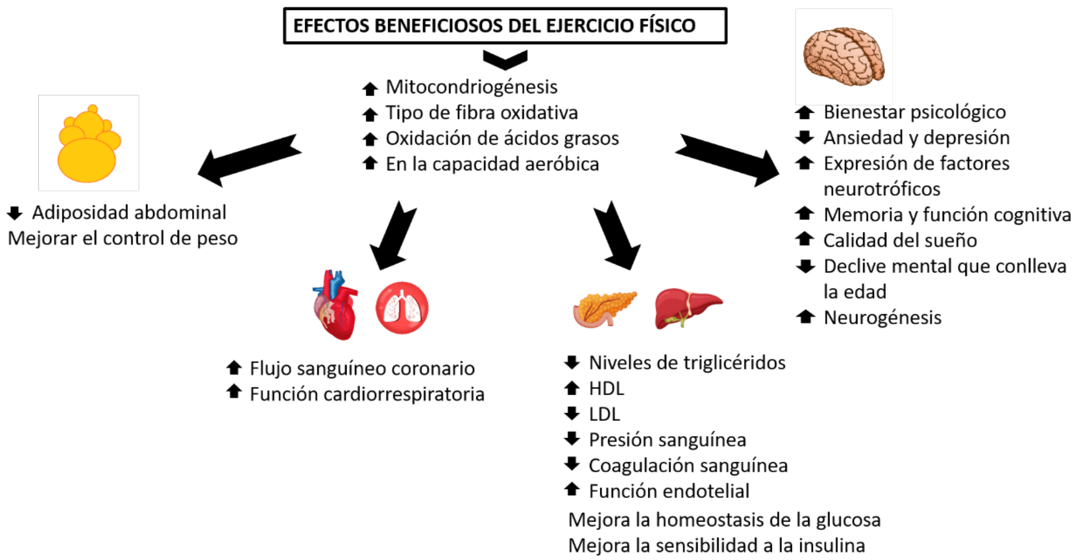
Los esfuerzos de la sociedad actual deben ir enfocados hacia la promoción del ejercicio físico para luchar contra la obesidad y en definitiva para mejorar la salud de la población. Tanto potencial tiene el ejercicio físico de mejorar la salud de las personas, que como bien dice el Dr. Robert Neil Butler, médico gerontólogo, psiquiatra, ganador de un Premio Pulitzer y primer director del National Institute on Aging de Estados Unidos, "“If exercise could be packaged in a pill, it would be the single most widely prescribed and beneficial medicine in the nation”. Esta idea de que el ejercicio es medicina es la que defiende la iniciativa de salud global “Exercise is Medicine”, administrada por el American College of Sports Medicine (ACSM), cuyo objetivo es que la evaluación y promoción de la AF sea un estándar en la atención sanitaria, conectando la atención médica con la AF basada en evidencia científica, lo que se traduce en una promoción del trabajo multidisciplinar entre el personal sanitario y el profesional de la AF o educador físico-deportivo (66). Con esta iniciativa se apoya la idea o creencia de que la AF promueve una salud óptima y es parte integral de la prevención y el tratamiento de muchas afecciones médicas. En España, EXERNET, Red de Ejercicio Físico y Salud, pretende unir los esfuerzos de todos los grupos de investigación españoles en AF y salud, con el objetivo de coordinar, armonizar y divulgar la investigación en diferentes grupos de población y ha sido la impulsora de la introducción de “Exercise is Medicine” en España (67).

1.3.1 Beneficios

El entrenamiento concurrente combinando ejercicio aeróbico y ejercicio de fuerza es el más efectivo para producir numerosos beneficios en niños/as y adolescentes con sobrepeso u obesidad (63). De hecho, el efecto negativo para la salud de la obesidad infantil puede contrarrestarse con el ejercicio físico (65). El ejercicio físico con el entrenamiento concurrente produce mejoras en la CF, incluyendo la composición corporal, que es uno de los aspectos más debilitados en niños/as y adolescentes con sobrepeso u obesidad (68,69) y por tanto uno de los que más necesita una mejora, debido a su estrecha relación con la salud (63,64).

Otros parámetros fisiológicos muy relacionados con la salud, que se muestran en la Figura 18, también son susceptibles de mejora con el ejercicio físico, por ejemplo con una reducción de la insulina en ayunas y de los marcadores inflamatorios y una mejora del perfil lipídico con una disminución del LDL y triglicéridos y un aumento del HDL (63,64), disminuyendo de esta manera los factores de riesgo cardiometabólicos y cardiovasculares (49,65).

Figura 18. Beneficios del ejercicio físico en tejidos y órganos en niños/as y adolescentes con sobrepeso u obesidad.



Fuente: La figura está adaptada de una figura del artículo «Exercise acts as a drug; the pharmacological benefits of exercise». (70) Licencia: by Elsevier and Copyright Clearance Center (License Number: 5460921267788).

1.3.1.1 Mejora de la condición física

Los niños/as y adolescentes con sobrepeso u obesidad muestran un peor rendimiento en las pruebas de valoración de la CF, ya que existe una relación inversa entre el porcentaje de grasa corporal y la CF, siendo esta relación mayor que entre una baja CF y los comportamientos sedentarios o la dieta (59). Este peor rendimiento se muestra claramente en la condición cardiorrespiratoria (57,71) pero también en la fuerza muscular (58,59).

El ejercicio, concretamente el entrenamiento multicomponente (62), es eficaz para mejorar tanto la condición cardiorrespiratoria como la fuerza muscular, además de la composición corporal (64). Sin embargo, el principal reto es asegurar la adherencia al ejercicio en niños/as y adolescentes con sobrepeso y obesidad (72), por lo que se necesitan nuevas formas de hacer ejercicio que sean más atractivas y motivadoras para esta población.

1.3.1.1.1 Composición corporal

La composición corporal, y especialmente la excesiva grasa corporal es la característica principal de los niños/as y adolescentes con sobrepeso u obesidad. Uno de los objetivos clave en este grupo poblacional es mejorar la composición corporal normalizando los niveles de grasa corporal e incrementar o mantener los niveles de masa magra y masa ósea.

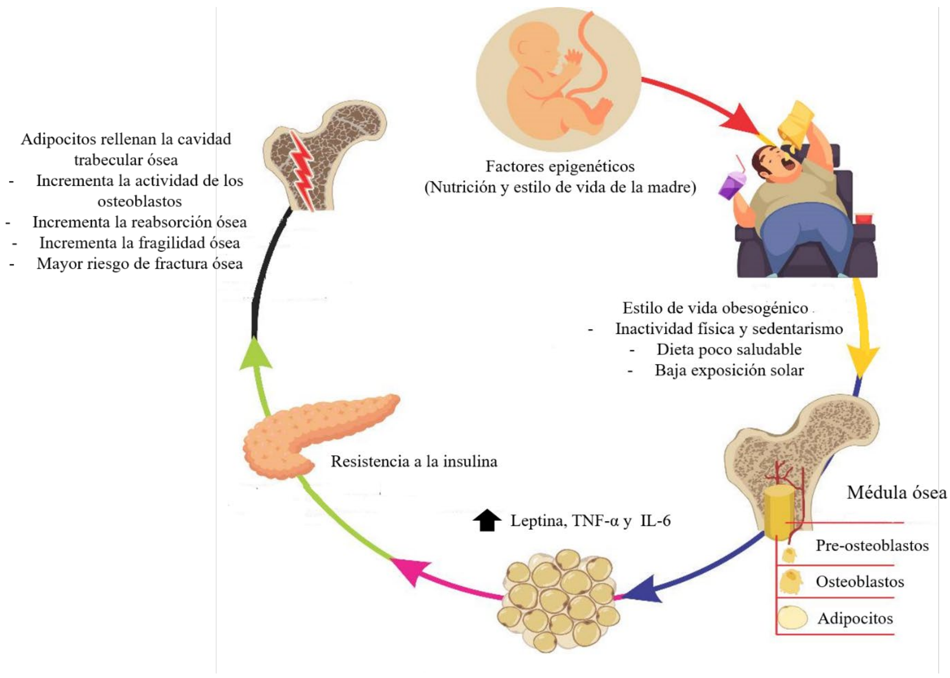
Como se ha mencionado anteriormente la evidencia científica actual ha mostrado mejoras en la composición corporal de niños/as y adolescentes con sobrepeso u obesidad producidas por un programa de ejercicio físico que combine entrenamiento aeróbico y de fuerza (63,64). El efecto principal que reportó el meta-análisis realizado por Stoner y col. (49) fue una reducción del IMC, el peso corporal (-3,7 kg), el porcentaje de grasa (-3,1%) y la circunferencia de la cintura, además de un incremento de la masa de tejido magro (+1,6 kg). Los resultados del meta-análisis llevado a cabo por García-Hermoso y col. (63) mostraron un efecto positivo del ejercicio físico con entrenamiento que se tradujo en una reducción de la masa corporal (-2,3 kg), el porcentaje de grasas (-3,5%) y masa grasa (-4,3 kg), además de un incremento de masa marga (+2,2 kg). Lee (64) también reportó en su meta-análisis reducciones de IMC y porcentaje de grasa, y aumentos en masa magra. Los incrementos de masa magra son especialmente importantes ya que parece ser la variable más influyente en el crecimiento del corazón (73).

Cada vez hay más pruebas que sugieren que los niños con obesidad experimentan deficiencias neuro-musculo-esqueléticas y complicaciones físicas, como un aumento del dolor, una reducción de la fuerza muscular, un deterioro del equilibrio y la habilidad motora, desviaciones de la marcha, una mala alineación postural, una mayor fatiga y una posible reducción de la flexibilidad y una salud ósea subóptima. Estas pruebas apoyan la necesidad de examinar, evaluar y optimizar la salud neuro-musculo-esquelética como parte del tratamiento de la obesidad pediátrica (74).

La obesidad también afecta a la salud ósea debido al impacto de los parámetros metabólicos clínicos y biológicos. Los niños obesos parecen estar excesivamente afectados por fracturas óseas y evidencias recientes sugieren que la grasa puede ser perjudicial para la acumulación de hueso en los niños, lo que puede ser especialmente importante durante la adolescencia dado el rápido crecimiento del esqueleto, por lo que en esta etapa vital hay que prestar especial atención a las alteraciones inducidas por la grasa en los factores hormonales y las citoquinas que pueden producir una alteración de la acumulación ósea durante la etapa de adquisición del pico de masa ósea. Por un lado, la obesidad parece proteger contra las fracturas de cadera y vertebrales, pero es un factor de riesgo para las fracturas de húmero y tobillo (75). No obstante, Julian y col. (76), mostraron un empeoramiento del hueso trabecular en la zona lumbar y una menor densidad mineral ósea de la cadera en niños/as con obesidad severa. Por otro lado, la incidencia de las fracturas durante la adolescencia está aumentando, por lo que comprender los efectos de la masa grasa en el hueso durante el crecimiento y el inicio de la edad adulta es importante (75).

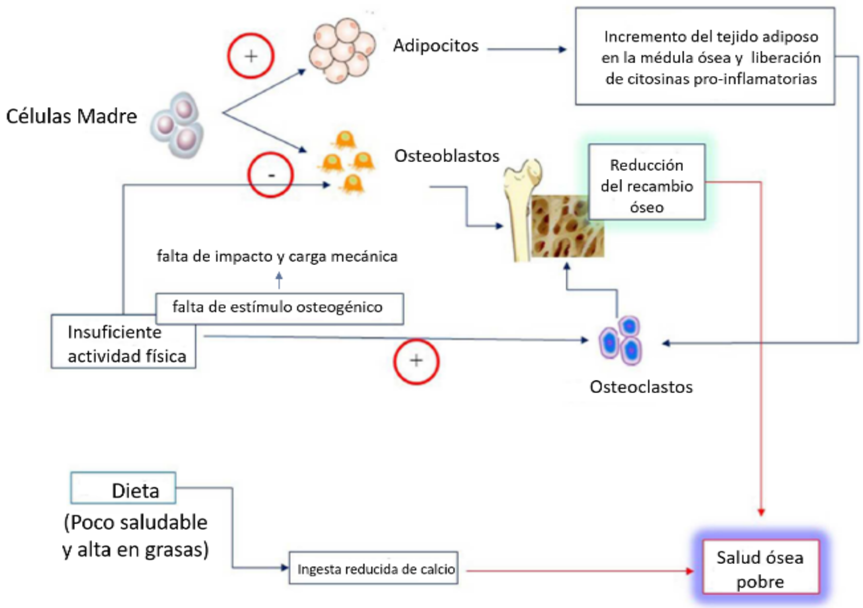
Este riesgo incrementado de fractura que ha evidenciado la literatura científica podría estar relacionado con las consecuencias de la obesidad, como la inflamación, la resistencia a la insulina, la diabetes de tipo 2 y la dislipidemia (76). El incremento de grasa estimula la secreción de biomarcadores de inflamación tales como la leptina, que incrementa la producción de factor de necrosis tumoral, interleucina-6 y proteína C-reactiva, lo que a su vez da lugar a una reducción de los osteoblastos y a un aumento de la actividad de los osteoclastos, como se puede visualizar en la Figura 19. La salud ósea de los niños con obesidad se ve afectada por diferentes estímulos humorales, especialmente por las adipoquinas y las mioquinas, aunque también su hueso también está sometido a una carga de trabajo mecánica que es beneficiosa para la acumulación y la geometría del hueso, carga que no es lo suficientemente aprovechada como estímulo osteogénico debido a la AF reducida de este grupo poblacional que a su vez empeora la salud ósea, como se puede ver en la Figura 20 (77). La mayoría de los estudios apuntan a las consecuencias negativas del exceso de peso (principalmente de la adiposidad visceral) sobre la salud y la fragilidad ósea, por la producción de citoquinas proinflamatorias, el aumento de la reabsorción ósea y el daño a la formación del hueso (78). Es por ello que se recomienda incluir una evaluación bioquímica y una valoración de la presión arterial en la etapa de la pubertad en los exámenes rutinarios de salud de los niños y adolescentes, especialmente de aquellos con exceso de grasa corporal (78), además de una evaluación de la salud musculoesquelética (74).

Figura 19. Beneficios del ejercicio físico en tejidos y órganos en niños/as y adolescentes con sobrepeso u obesidad.



Fuente: La figura pertenece al artículo «Adiposity Metabolic Consequences for Adolescent Bone Health». Licencia: Creative Commons (CC-BY 4.0).

Figura 20. Mecanismos que empeoran la salud ósea de juveniles con sobrepeso u obesidad.



Fuente: La figura pertenece al artículo «The Bones of Children With Obesity». (77). Licencia: Creative Commons (CC-BY 4.0).

Otro aspecto relevante es comprobar los niveles séricos de vitamina D, ya que la hipovitaminosis D es un problema de salud pública que afecta negativamente a parámetros metabólicos como la salud ósea. En general, la mayoría de los adolescentes son sedentarios y no realizan AF al aire libre. De hecho, la síntesis cutánea es un factor relevante para conseguir unos niveles adecuados de vitamina D, por lo que se recomienda estimular a los adolescentes para que realicen AF al aire libre (78).

La promoción de hábitos saludables es crucial para fomentar la salud, especialmente la alimentación y los estilos de vida saludables, y para prevenir enfermedades, como la osteopenia/osteoporosis. Además, hay que mejorar la vigilancia alimentaria y la nutrición durante el periodo de gestación y la lactancia, ya que las modificaciones epigenéticas afectan a la salud de los descendientes (78).

1.3.1.1.2 Condición cardiorrespiratoria

La condición cardiorrespiratoria es un componente de la CF especialmente importante debido a su relación inversa con la mortalidad, relación que es incluso más fuerte que entre la AF y la mortalidad (79). La mejor manera de medir esta condición cardiorrespiratoria es a través de una prueba de esfuerzo máxima en la que además no se requiere un plateau para ser considerado un esfuerzo máximo en niños/as y adolescentes (80).

La condición cardiorrespiratoria de los niños/as y adolescentes con sobrepeso u obesidad está empeorada (81), además de que muestran un cociente respiratorio menor durante la prueba (82), por lo que hay que ser cauto a la hora de considerar el cociente respiratorio por encima de 1 como un criterio de maximalidad (83). Una mayor condición cardiorrespiratoria en la infancia y la adolescencia se asocia con un menor IMC, grasa corporal y síndrome metabólico al menos 2 años más tarde (84).

El ejercicio físico muestra gran efectividad para aumentar el consumo máximo de oxígeno ($VO_{2máx}$) en niños/as con sobrepeso u obesidad (64). Además, incrementos en la condición cardiorrespiratoria están asociados a una reducción de la grasa corporal (85), concretamente las intervenciones de ejercicio mostraron que un aumento de al menos 0,38 mL/kg/min en condición cardiorrespiratoria podría obtener una reducción clínicamente importante de al menos un 2,3% en el porcentaje de grasa en niños/as y adolescentes con sobrepeso y obesidad (86). Las evidencias sugieren que la adiposidad incrementa el riesgo de ECV pero una buena aptitud física y especialmente una buena condición cardiorrespiratoria protege de este riesgo aumentado (87).

1.3.1.1.3 Condición muscular

La condición muscular es un componente de la CF muy relacionado con la salud, mostrando una asociación inversa con la adiposidad y los factores de riesgo cardiovascular y metabólico y una asociación directa con la participación deportiva y la AF (88), así como con la salud ósea, la competencia motriz real y percibida y con la calidad de vida (89). Parece ser que el exceso de peso en niños/as y adolescentes produce adaptaciones musculares como consecuencia del estímulo crónico que lleva a un incremento de fuerza (90), mostrando un mejor rendimiento en los test de fuerza que requieren fuerza absoluta aunque con peor rendimiento en los test de fuerza que requieren el movimiento del propio cuerpo (91,92). Sin embargo, parece ser que un mayor porcentaje de grasa corporal, que generalmente va acompañado de niveles bajos de AF, se asocia con un peor rendimiento neuromuscular (93). Siguiendo esta idea, Herda y col. (94) concluyó que los niños/as con sobrepeso u obesidad tenían una peor composición del tejido muscular, deficiencias en cuanto a la potencia muscular y peor reclutamiento de unidades motoras, lo que haría a los niños/as y adolescentes con exceso de grasa corporal susceptibles de sufrir la triada pediátrica de la inactividad (36). El entrenamiento de fuerza en niños/as y adolescentes es importante y necesario para una óptima condición muscular consiguiendo ganancias de fuerza principalmente debido al mecanismo neurológico de aumento de reclutamiento de neuronas motoras (95), pero es especialmente importante en juveniles con sobrepeso u obesidad. Se han investigado asociaciones entre la baja fuerza muscular y una sensibilidad reducida a la insulina (96,97), un peor perfil lipídico y mayor riesgo de dislipidemia (98), una presión sanguínea más alta y con factores de riesgo metabólico y cardiovascular (89,97). Además, niveles elevados de condición muscular pueden atenuar los efectos adversos del factor de crecimiento endotelial vascular A y del factor de necrosis tumoral-α sobre el contenido mineral óseo subtotal del cuerpo, por lo que niveles adecuados de fuerza muscular pueden preservar la salud ósea normal en niños/as con sobrepeso u obesidad (99). Es por eso que los niños/as y jóvenes con sobrepeso u obesidad deben incrementar sus niveles de fuerza, ya que muestran peor rendimiento. Además, uno de los beneficios más directos de una condición muscular alta o una mejora de la misma es el incremento de la salud psicológica (100).

1.3.1.2 Mejora de la salud cardiometabólica

La obesidad infantil conlleva perjuicios en la salud, tales como un empeoramiento del perfil lipídico, dislipidemia, aterosclerosis coronaria acelerada, hipertensión, resistencia a la insulina y desarrollo de diabetes tipo II, disfunción endotelial y la inflamación (14,15), que tiene como resultado un incrementado riesgo de ECV.

El ejercicio físico produjo una mejora en la sensibilidad a la insulina, en la presión arterial sistólica y en el perfil lipídico (49), disminuyendo el riesgo de ECV y mejorando la salud cardiometabólica.

1.3.1.3 Mejora de la habilidad motriz

La habilidad motriz se correlaciona negativamente con un mayor IMC, circunferencia de la cintura o de porcentaje de grasa corporal (101,102) y positivamente con la condición cardiorrespiratoria y la condición muscular (102–104), además de con la AF (103,105). Es por ello que los niños/as con sobrepeso u obesidad tienen menor habilidad motriz en comparación con los normopeso (106). De hecho, a pesar de que los niños/as con mayor condición cardiorrespiratoria, la fuerza muscular de extremidades inferiores, la velocidad y la agilidad mostraron mayor calidad de movimiento funcional, el estatus de peso parece ser más determinante que la CF en cuanto a la calidad de movimiento funcional, aunque estar en forma parece atenuar la influencia negativa del exceso de grasa corporal (107). La evidencia científica también muestra que, debido a la estrecha relación entre la habilidad motriz y la CF, incrementos o mejoras de habilidad motriz pueden conducir a mejoras en la CF, y por ende mejoras en la salud en jóvenes (102).

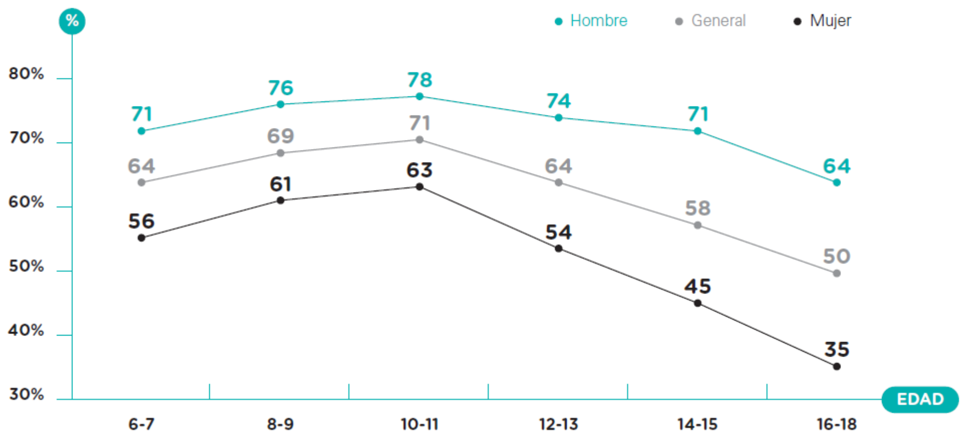
La importancia de una buena habilidad motriz en la infancia reside en su estrecha relación con la habilidad motriz percibida y la participación deportiva (103,108). De este modo, las intervenciones con ejercicio físico son efectivas para mejorar la habilidad motriz a través de actividades con gran variedad de movimientos y en los que se desarrolle la agilidad, la coordinación y el equilibrio para producir una mejora en este grupo de población vulnerable que rompa con el círculo vicioso de la obesidad que promueve la inactividad ante la percepción de incompetencia motriz (106). Es reseñable que no solo la mejora de la habilidad motriz debe ser el objetivo principal, sino también la habilidad motriz percibida, la cual incrementará la autoestima y autopercepción de capacidad, lo que conllevará un incremento de la motivación para practicar ejercicio físico y actividades deportivas (108).

1.3.2 Limitaciones del ejercicio

El ejercicio físico es tan eficaz para mejorar la calidad de vida, mejorar el cuadro clínico de muchas enfermedades y en definitiva promover la salud, que podría considerarse un tratamiento farmacológico, siempre prestando atención a la dosis y las características de cada individuo (70). Sin embargo, de nada sirve el beneficioso efecto del ejercicio físico si existe un problema de adherencia al ejercicio (72). Este problema de adherencia está relacionado con otra limitación en el área de la investigación del ejercicio físico como es la falta de transferencia de los resultados desde el laboratorio y el entorno controlado que se da en una investigación al mundo real (72). En el ámbito infantil y de la adolescencia, los factores más influyentes en la adherencia al ejercicio físico a nivel intrapersonal fueron el género, la edad, la etnia y el autoconcepto; a nivel interpersonal y organizativo, el apoyo de los amigos, los padres y los profesores fueron predictores positivos de la adherencia, especialmente la disponibilidad de tiempo por parte de los padres de niños y niñas; y por último, la accesibilidad de las instalaciones y la seguridad de los barrios fueron factores cruciales (109).

Concretamente en España, se puede observar un progresivo abandono de la práctica de actividad físico-deportiva organizada, abandono que es más acusado en niñas que en niños, como se puede observar en la Figura 21.

Figura 21. Práctica de actividad físico-deportiva organizada según sexo y edad.



Fuente: La figura pertenece al «Estudio PASOS (Physical Activity, Sedentarism and Obesity of Spanish youth) - Resultados principales del estudio PASOS

2019 sobre la actividad física, los estilos de vida y la obesidad de la población española de 8 a 16 años». (9)

Por mucho que una herramienta funcione, si no es lo suficientemente motivante o atractiva como para ser aplicada de forma continua, esa herramienta no será efectiva. Por otro lado, es bien conocida la predilección de los jóvenes por las nuevas tecnologías y el ocio de pantalla. Bajo el más que justificado logo "si no puedes con tu enemigo, únete a él", nació la propuesta de utilizar videojuegos para promover la AF e intentar sustituir tiempo de pantalla sedentario. De esta manera, se pretende una alianza con las nuevas tecnologías para la lucha contra la obesidad infantil en vez de intentar luchar contra esas nuevas tecnologías intentando imponer la práctica de ejercicio físico.

1.4 Videojuegos Activos

1.4.1 Definición

Los exergames o VJA son un tipo de videojuegos que requieren que el jugador se mueva, con el consiguiente mayor gasto energético, de modo que el dispositivo usado capta ese movimiento (110). De esta manera, parecen ser dispositivos que promueven la AF y por tanto la salud (111).

1.4.2 Efectos en el gasto energético y actividad física

La literatura científica ha demostrado el potencial de los VJA para aumentar el gasto energético y sustituir las conductas sedentarias mediante la promoción de la AF ligera a moderada (112–118). Una revisión sistemática muy reciente ha mostrado que los VJA son eficaces para alcanzar niveles de AF moderada y/o vigorosa y para reducir el IMC y la grasa corporal entre niños y adolescentes (119). De esta manera, algunos artículos proponen los VJA como una estrategia o herramienta para alcanzar las recomendaciones de AF diaria

(120–122). Los VJA también parecen ser una herramienta estratégica interesante para fomentar un estilo de vida activo y saludable como alternativa a las conductas sedentarias (114,123,124). Una revisión sistemática mostró que las sesiones estructuradas de VJA tenían el potencial de aumentar la AF en los niños, pero no había pruebas de los beneficios de realizarlas en el entorno doméstico de forma autónoma (125).

1.4.3 Efectos en la condición física: composición corporal, condición muscular y condición cardiorrespiratoria

La evidencia científica muestra efectos positivos de intervenciones con VJA en la composición corporal, especialmente en niños/as y adolescentes con sobrepeso u obesidad. La gran mayoría de estudios coinciden en encontrar que las intervenciones con VJA disminuyen el peso o el IMC (126–129) y la grasa corporal (126), aunque hay algún estudio que no reporta efectos (130–132) o incluso reporta incrementos en el IMC (133). Atendiendo al grupo poblacional más necesitado, los niños/as y adolescentes con sobrepeso u obesidad, los efectos de las intervenciones con VJA son incluso mejores. Muchos estudios han reportado reducciones de peso, IMC, grasa corporal o porcentaje de grasa corporal en este grupo poblacional tras una intervención con VJA (134–144) frente a los pocos artículos cuyos resultados no muestran efectos significativos (111,145–147). Esta mejora de la composición corporal, en concreto del IMC y la masa grasa parece ser independiente de la etnia, sexo y nivel de condición cardiorrespiratoria. Además, entre los diferentes modos de juego, parece que el modo cooperativo funciona mejor que el competitivo en niños/as con sobrepeso u obesidad (140).

Por otro lado, las intervenciones supervisadas muestran un gasto energético mayor (148), así como las intervenciones a domicilio muestran ser menos efectivas (124).

Los resultados son menos claros y hay más controversia en cuanto al efecto de los VJA en la condición cardiorrespiratoria, con estudios mostrando efectos positivos (134) frente a otros estudios que no reportan efectos significativos (111,147,149). Lo mismo ocurre en juveniles con sobrepeso y obesidad, con estudios evidenciando un efecto beneficioso de los VJA (127,133,150) y estudios evidenciando una ausencia de efecto tras una intervención con VJA (126,130,151). Esta poca claridad en los efectos positivos puede deberse al diseño de las intervenciones, tanto a la duración como a la intensidad alcanzada. Es por eso que la propuesta de combinar una intervención de VJA con ejercicio multicomponente puede ser interesante a la hora de provocar un mayor efecto en los componentes de la CF.

La evidencia científica tampoco aclara los efectos de los VJA en la fuerza muscular. Algunos artículos han reportado mejoras en la fuerza muscular después de una intervención con VJA (127,152), mientras que otros no reportan efecto alguno (153,154). Los artículos que han investigado las mejoras en la fuerza muscular en niños/as con sobrepeso u obesidad con VJA encontraron efectos positivos (143,144,149), exceptuando un estudio cuyo programa de entrenamiento podría no haber sido lo suficiente intenso o con la suficiente duración (155). De la misma manera, combinar los VJA con ejercicio multicomponente incluyendo el entrenamiento de fuerza puede proporcionar el estímulo suficiente para mejorar este componente de la CF.

1.4.4 Efectos en la habilidad motriz

Los VJA parecen ser una estrategia efectiva para mejorar la habilidad motriz en niños y niñas, e incluso se podría proponer la inclusión de esta estrategia en el contenido curricular escolar (156). Hay varios artículos que, aunque no específicamente en niños/as con sobrepeso u obesidad, muestran efectos positivos de los VJA en la habilidad motriz (157–163), mientras que unos pocos no muestran efectos positivos (127,164,165). En definitiva, parece que se puede mejorar la competencia motriz a través de los VJA (166,167).

1.4.5 Efectos en la motivación y el bienestar psicológico

Los VJA parecen ser una herramienta eficaz para mejorar el autoconcepto, la autoeficacia, el interés y la motivación situacional, el disfrute y el bienestar psicológico y social (168,169). En concreto, los VJA pueden tener efectos positivos sobre los aspectos psicológicos y la salud mental de los niños y adolescentes con sobrepeso u obesidad (170,171).

2. Hipótesis

Una intervención con videojuegos activos combinados con ejercicio multicomponente producirá incrementos de gasto energético y mejoras significativas en la condición física y la habilidad motriz de niños/as prepuberales con sobrepeso u obesidad.

El incremento de la condición cardiorrespiratoria, la fuerza muscular y la habilidad motriz junto con la mejora de la composición corporal usando videojuegos activos como una alternativa más atractiva al ejercicio físico convencional supondrá una ruptura con el estilo de vida obesogénico en niños/as con sobrepeso u obesidad.

2. Hypotheses

Active video games will be an effective tool to improve physical fitness and motor skills in both healthy-weight and overweight/obese children and adolescents and could be a strategy to fight childhood obesity.

The improvement of cardiorespiratory endurance, muscular strength and motor skills together with the decrease of fat mass and the increase or maintenance of lean mass and bone mass using active video games as a more attractive alternative to conventional physical exercise may represent a break with the obesogenic lifestyle, with the consequent improvement of health.

3. Objetivos

El *objetivo general* de la presente Tesis Doctoral es evaluar la efectividad de una intervención de ejercicio físico con videojuegos activos combinados con ejercicio multicomponente para aumentar el gasto energético y mejorar la condición física y habilidad motriz en niños/as prepuberales con sobrepeso u obesidad.

Los *objetivos específicos* enmarcados en cada uno de los cinco artículos que componen esta Tesis Doctoral son:

Artículo I. Resumir y evaluar críticamente la investigación existente sobre los efectos de los videojuegos activos en la condición física relacionada con la salud y la competencia motora en niños/as y adolescentes con sobrepeso y obesidad y extraer conclusiones sobre su efectividad.

Artículo II. (I) Identificar y valorar críticamente los resultados de las investigaciones actuales a partir de los datos obtenidos y agrupar los resultados de los estudios publicados en un meta-análisis para determinar el potencial de los videojuegos activos para mejorar la salud en niños/as y adolescentes con peso saludable y para promover un estilo de vida más sano.

Artículo II. (II) Actualizar la evidencia científica existente sobre los videojuegos activos para promocionar la salud, mejorar la condición física e incrementar la habilidad motriz, dado que el avance tecnológico de los videojuegos activos ha hecho que ofrezcan más posibilidades para incrementar el gasto energético.

Artículo III. (I) Investigar el gasto energético de las sesiones con videojuegos activos combinados con ejercicio multicomponente, así como analizar el gasto energético de cada uno de los dispositivos de videojuegos activos utilizados: Nintendo Wii®, Xbox Kinect®, esterillas de baile, BKOOL® ciclosimulador y Nintendo Ring Fit Adventures®, siendo este último innovador y muy actual.

Artículo III. (II) Examinar las diferencias de género en el gasto energético durante las sesiones y entre los diferentes videojuegos activos.

Artículo IV. Examinar el efecto de una intervención de videojuegos activos combinada con ejercicio multicomponente sobre la condición muscular, la actividad física y las habilidades motoras en niños/as prepuberales con sobrepeso u obesidad.

Artículo V. Investigar los efectos de una intervención con videojuegos activos combinada con un entrenamiento multicomponente en la condición cardiorrespiratoria a intensidades máximas y submáximas en niños/as prepuberales con sobrepeso u obesidad.

3. Aims

The *general aim* of this Doctoral Thesis is to evaluate the effectiveness of a physical exercise intervention with active video games combined with multicomponent exercise to improve physical fitness and motor skills in prepuberal children with overweight or obesity. The *specific aims* of each of the five articles that compose this Thesis are:

Manuscript I. To summarize and critically evaluate existing research on the effects of active video games on health-related physical fitness and motor skills in overweight and obese children and adolescents and get conclusions about their effectiveness.

Manuscript II. (I) Identify and critically appraise current research findings from the data obtained and pool the results of published studies in a meta-analysis to determine the potential of active video games to improve health in children and adolescents with healthy weight and to promote a healthier lifestyle.

Manuscript II. (II) To update the existing scientific evidence on active video games to promote health, improve physical fitness and increase motor skills, given that the technological advancement of active video games has made them offer more possibilities to increase energy expenditure.

Manuscript III. (I) To investigate the energy expenditure of sessions with active video games combined with multicomponent exercise, as well as to analyse the energy expenditure of each of the active-videogame devices used: Nintendo Wii®, Xbox Kinect®, dance mats, BKOOL® cyclosimulator and Nintendo Ring Fit Adventures®, the latter being innovative and trendy.

Manuscript III. (II) To examine gender differences in energy expenditure during sessions and between different active video games.

Manuscript IV. To examine the effect of an intervention using active video games combined with multicomponent exercise on muscular fitness, physical activity and motor skills in prepuberal overweight or obese children.

Manuscript V. To investigate the effects of an intervention using active video games combined with multicomponent training on cardiorespiratory fitness at maximal and submaximal intensities in prepuberal children who are overweight or obese.

4. Material y métodos

En este apartado se detallarán los procedimientos generales utilizados para obtener los resultados que dan lugar a la presente Tesis Doctoral. Esta consta de dos artículos de tipo revisión sistemática con meta-análisis y de tres artículos originales derivados del proyecto de investigación. La metodología concreta de cada estudio individual puede consultarse en el manuscrito correspondiente en la sección de *Resultados y Discusión* de este documento.

4.1 Revisión sistemática en niños/as y adolescentes con sobrepeso u obesidad

La revisión sistemática que forma parte de la presente Tesis Doctoral fue elaborada siguiendo los criterios y la metodología establecidos por el Manual Cochrane para Revisiones Sistemáticas de Intervenciones (versión 5.1.0 y 6.2) (172), y siguiendo las indicaciones detalladas en la guía PRISMA (*Preferred reporting ítems for systematic reviews and meta-analyses*) (173).

El protocolo de la revisión fue establecido de manera previa al comienzo del proceso de revisión de la literatura científica y se registró en el Registro Internacional Prospectivo de Revisiones Sistemáticas (PROSPERO), obteniendo el código CRD42020189138.

4.1.1 Fuentes de datos y estrategia de búsqueda

Para la elaboración del estudio se revisaron sistemáticamente las bases de datos de PubMed, MEDLINE, Web of Science, y SPORTDiscus, con el objetivo de identificar y recopilar todas las investigaciones de interés publicadas hasta el 1 de marzo del 2021.

La estrategia de búsqueda utilizada en las diferentes bases de datos se realizó a través de la combinación de diferentes términos indexados y de texto libre:

- PubMed y MEDLINE: "exergam* OR active video gam* OR active videogam* OR active gam* OR interactive video gam* OR interactive videogam* OR Wii OR Xbox OR Kinect OR PlayStation", y se aplicaron los filtros "Especies: Humanos" e "Idioma: Inlgés".
- SportDiscus: "TX=(exergam* OR active gam* OR active video gam* OR active videogam* OR interactive video gam* OR interactive videogam* OR Wii OR Xbox OR Kinect OR PlayStation)" y se aplicaron los filtros "Tipo de documento: artículo" e "Idioma: Inlgés".
- Web of Science: "TS=(exergam* OR active gam* OR active video gam* OR active videogam* OR interactive video gam* OR interactive videogam* OR Wii OR Xbox OR Kinect OR PlayStation)" y se aplicaron los filtros "Tipo de documento: artículo" e "Idioma: Inlgés".

Además, se verificaron las referencias de los artículos incluidos para encontrar estudios potencialmente relevantes. Dos revisores independientes (CCC, AGA) examinaron los títulos y resúmenes de los artículos y decidieron cuál de ellos necesitaba un examen más detenido del texto completo.

4.1.2. Criterios de inclusión y de exclusión

Para elaborar la revisión solo se recopilaron estudios originales, excluyendo todo tipo de informes de simposios, protocolos, cartas al editor, resúmenes de conferencias, libros, opiniones de expertos y revisiones de cualquier tipo.

Se examinaron los títulos y los resúmenes, y se obtuvieron y evaluaron los artículos de interés utilizando los criterios de inclusión y exclusión.

Los criterios de inclusión se utilizaron siguiendo el formato PICOS (Población, Intervención, Comparación, Resultados y Estudio) (174), y fueron que los estudios trataran el tema de interés de la revisión con niños/as y adolescentes con sobrepeso u obesidad, que fueran ensayos controlados aleatorizados o no aleatorizados de diseño longitudinal que estudiaran los efectos de una intervención de VJA en los componentes de CF relacionados con la salud y en la habilidad motriz, con un grupo control que no realizara ninguna intervención o que realizara una intervención con ejercicio físico convencional, que midieran variables de habilidad motriz o componentes de la CF relacionados con la salud tales como condición cardiorrespiratoria, condición muscular o composición corporal, y que estuvieran publicados en inglés. Los ensayos no controlados se consideraron en la discusión del artículo con la consideración de la gran limitación que supone la falta de un grupo control en la interpretación de los resultados, pero no se incluyeron en las evaluaciones del riesgo de sesgo ni en el meta-análisis.

4.1.3. Evaluación del riesgo de sesgo

Se utilizaron dos herramientas en función del diseño de cada estudio incluido para evaluar el riesgo de sesgo de los estudios incluidos. Se utilizó el Risk of Bias-2 (175) para evaluar los ensayos controlados aleatorizados, y el ROBINS-I (Risk of Bias in Nonrandomised Studies of Interventions) (176) para evaluar los ensayos controlados no aleatorizados.

Risk of Bias-2 utiliza 5 criterios para evaluar la calidad metodológica de los estudios para obtener una valoración global de “bajo riesgo”, “algunos problemas” o “alto riesgo”. Cada uno de esos cinco criterios evalúa un aspecto del estudio: el proceso de aleatorización, cambios respecto a la intervención prevista, falta de datos de los resultados, medición de los resultados y selección de los resultados reportados. Cada criterio tiene sub-apartados en los que se debe contestar “si” o “no”, y en función de esa respuesta se evaluará un apartado como “bajo riesgo”, “algunos problemas” o “alto riesgo”, para finalmente obtener la valoración global.

Por otro lado, el ROBINS-I se estructura en tres partes, evaluando el riesgo de sesgo tanto en la parte de pre-intervención, durante la intervención y post-intervención y utiliza 7 criterios. En la parte de pre-intervención se evalúan las variables de confusión y en el reclutamiento y selección de participantes, en la parte de intervención se valora la aplicación de esa intervención y en la parte post-intervención se evalúan cambios respecto a la intervención prevista y datos o resultados no reportados. Las posibilidades de respuesta son “sí”, “probablemente sí”, “no”, “probablemente no”, “no aplica” o “sin información”. En función de las respuestas, se clasificará el riesgo de sesgo de alto, medio, bajo o crítico.

4.2 Revisión sistemática en niños/as y adolescentes con normopeso

La revisión sistemática que forma parte de la presente Tesis Doctoral fue elaborada siguiendo los criterios y la metodología establecidos por el Manual Cochrane para Revisiones Sistemáticas de Intervenciones (versión 5.1.0 y 6.2) (172), y siguiendo las indicaciones detalladas en la guía PRISMA (*Preferred reporting ítems for systematic reviews and meta-analyses*) (173).

El protocolo dela revisión fue establecido de manera previa al comienzo del proceso de revisión de la literatura científica y se registró en el Registro Internacional Prospectivo de Revisiones Sistemáticas (PROSPERO), obteniendo el código CRD42020222831.

4.2.1 Fuentes de datos y estrategia de búsqueda

Para la elaboración del estudio se revisaron sistemáticamente las bases de datos de PubMed, MEDLINE, Web of Science, y SPORTDiscus, con el objetivo de identificar y recopilar todas las investigaciones de interés publicadas hasta el 1 de marzo del 2021.

La estrategia de búsqueda utilizada en las diferentes bases de datos se realizó a través de la combinación de diferentes términos indexados y de texto libre:

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- SportDiscus: "TX=(exergam* OR active gam* OR active video gam* OR active videogam* OR interactive video gam* OR interactive videogam* OR Wii OR Xbox OR Kinect OR PlayStation)" y se aplicaron los filtros "Tipo de documento: artículo" e "Idioma: Inlgés".
- Web of Science: "TS=(exergam* OR active gam* OR active video gam* OR active videogam* OR interactive video gam* OR interactive videogam* OR Wii OR Xbox OR Kinect OR PlayStation)" y se aplicaron los filtros "Tipo de documento: artículo" e "Idioma: Inlgés".

4.2.2 Criterios de inclusión y de exclusión

Para elaborar la revisión solo se recopilaron estudios originales, excluyendo todo tipo de informes de simposios, protocolos, cartas al editor, resúmenes de conferencias, libros, opiniones de expertos y revisiones de cualquier tipo.

Se examinaron los títulos y los resúmenes, y se obtuvieron y evaluaron los artículos de interés utilizando los criterios de inclusión y exclusión

Los criterios de inclusión se utilizaron siguiendo el formato PICOS (Población, Intervención, Comparación, Resultados y Estudio) (174) y fueron que los estudios trataran el tema de interés de la revisión con niños/as y adolescentes con sobrepeso u obesidad, que fueran ensayos controlados aleatorizados o no aleatorizados de diseño longitudinal que estudiaran los efectos de una intervención de VJA en los componentes de CF relacionados con la salud y en la habilidad motriz, con un grupo control que no realizara ninguna intervención o que realizara una intervención con ejercicio físico convencional, que midieran variables de habilidad motriz o componentes de la CF relacionados con la salud tales como condición cardiorrespiratoria, condición muscular o composición corporal, y que estuvieran publicados en inglés. Los ensayos no controlados se consideraron en la discusión del artículo con la consideración de la gran limitación que supone la falta de un grupo control en la interpretación de los resultados, pero no se incluyeron en las evaluaciones del riesgo de sesgo ni en el meta-análisis.

4.2.3 Evaluación del riesgo de sesgo

Se utilizaron dos herramientas en función del diseño de cada estudio incluido para evaluar el riesgo de sesgo de los estudios incluido. Se utilizó el Risk of Bias-2 (175) para evaluar los ensayos controlados aleatorizados, y el ROBINS-I (Risk of Bias in Nonrandomised Studies of Interventions) (176) para evaluar los ensayos controlados no aleatorizados.

Risk of Bias-2 utiliza 5 criterios para evaluar la calidad metodológica de los estudios para obtener una valoración global de "bajo riesgo", "algunos problemas" o "alto riesgo". Cada uno de esos cinco criterios evalúa un aspecto del estudio: el proceso de aleatorización, cambios respecto a la intervención prevista, falta de datos de los resultados, medición de los resultados y selección de los resultados reportados. Cada criterio tiene sub-apartados en los que se debe contestar "si" o "no", y en función de esa respuesta se evaluará un apartado como "bajo riesgo", "algunos problemas" o "alto riesgo", para finalmente obtener la valoración global.

Por otro lado, el ROBINS-I se estructura en tres partes, evaluando el riesgo de sesgo tanto en la parte de pre-intervención, durante la intervención y post-intervención y utiliza 7 criterios. En la parte de pre-intervención se evalúan las variables de confusión y en el reclutamiento y selección de participantes, en la parte de intervención se valora la aplicación de esa intervención y en la parte post-intervención se evalúan cambios respecto a la intervención prevista y datos o resultados no reportados. Las posibilidades de respuesta son "sí", "probablemente sí", "no", "probablemente no", "no aplica" o "sin información". En función de las respuestas, se clasificará el riesgo de sesgo de alto, medio, bajo o crítico.

4.3 Proyecto VIDEOACTIVO

VIDEOACTIVO, un proyecto con el título "Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva" es un estudio longitudinal que comenzó en 2018, cuyo investigador principal es José Antonio Casajús Mallén y coordinado también por el doctor Alejandro González de Agüero Lafuente. Los objetivos generales son evaluar la efectividad de un programa de VJA sobre los factores de riesgo cardiometabólico, marcadores de inflamación y parámetros de CF en niños y niñas con sobrepeso/obesidad, además de estudiar la adherencia a la práctica de AF y los cambios en parámetros de hábitos saludables que les permitan alcanzar las recomendaciones diarias de AF.

4.3.1 Muestra y diseño del estudio

Se trata de un estudio de carácter longitudinal, concretamente es un ensayo controlado aleatorizado y cruzado que investiga la efectividad de una intervención de ejercicio físico con VJA combinados con ejercicio multicomponente para mejorar la CF y habilidad motriz en niños/as prepuberales con sobrepeso u obesidad. Aunque el diseño original planificaba un desarrollo de la intervención de un año para que el proyecto durara 2 años como se puede ver en el diseño ideal en el Anexo 1, debido a la dificultad encontrada en el reclutamiento, se planificaron dos años de desarrollo de programa, un primer año con los participantes reclutados y un segundo año para incrementar la muestra del estudio. Al ser un estudio aleatorizado y cruzado, el proceso de desarrollo del proyecto se planificó para tres años, sin embargo, el segundo año fue interrumpido por la COVID-19. Esta situación provocó la paralización del proyecto debido a las restricciones decretadas por el Gobierno de España.

Se calculó el tamaño de la muestra teniendo en cuenta el objetivo principal del estudio y la magnitud del cambio en la variable de efecto de la intervención. Este proyecto cuenta con bastantes variables de interés, por lo que se realizó una simulación del cálculo del tamaño muestral en referencia a tres variables de interés: HOMA, VO_{2max} e insulina en ayunas. Para el error tipo I, α (la probabilidad de rechazar incorrectamente la hipótesis nula), se simularon valores en un rango desde α=0,01 hasta α=0,1. Para el error tipo II, β (la probabilidad de aceptar incorrectamente la hipótesis alternativa) asumiremos un valor frecuente del 20%; β=0,2 y, por tanto, un poder estadístico de 0,8. También se asumió que en cada grupo independiente tenemos un tamaño de muestra igual n1 (intervención) = n2 (control). De esta forma, el tamaño de muestra total será N = n1+n2. Para realizar los cálculos se utilizó la herramienta G*Power (versión 3.1.9.2 para Mac) aplicando el test de tamaño muestral para pruebas t de Student para dos muestras independientes, ya que el objetivo era comparar diferencias entre grupos. En el diseño del estudio se consideran para cada sexo, principalmente, dos grupos independientes: intervención y control; y en cada grupo se realizan medidas basales (pre) y posteriores al periodo de intervención (post), de forma que se pueden calcular diferencias pre-intervención y post-intervención. Para realizar el cálculo muestral, se utilizaron los valores de α y β, previamente definidos, y del tamaño del efecto, en este caso el valor *d* de *Cohen* para cada una de las variables de estudio. Para ello, se revisaron estudios previos en los que se observa que las diferencias pre-post intervención alcanzan tamaños del efecto (*d* de *Cohen*) de 0,85 para HOMA (Nemet y col. 2013), 1,01 para VO_{2max} (Murphy y col. 2009) y 1,08 para insulina en ayunas (Murphy y col. 2009). En la Tabla 1 se muestra la simulación para el rango de valores de α, para las distintas variables, asumiendo el valor fijo de β=0,2.

Tabla 1. Tamaño muestral para las diferentes variables, con un valor fijo de β = 0,2, para un rango de α.

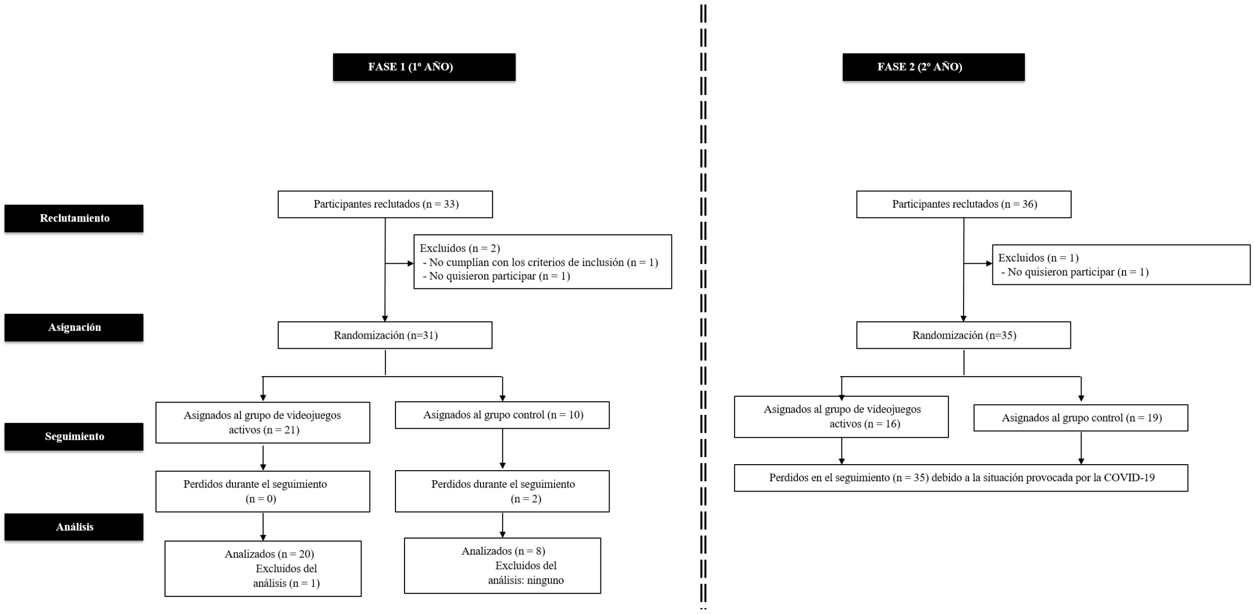
	N total		
Valor α	VO_{2max}	HOMA	Insulina en ayunas
0,01	41,9	53,1	43,5
0,02	34,9	45,5	37,2
0,03	30,8	41,0	33,6
0,04	27,8	37,9	31,0
0,05	25,6	35,4	29,0
0,06	23,7	33,4	27,3
0,07	22,1	31,7	25,9
0,08	20,8	30,2	24,7
0,09	19,6	28,9	23,6
0,1	18,5	27,7	22,7

Fuente: Elaboración propia

A partir de este cálculo, se puede observar cómo los tamaños de la muestra varían considerablemente atendiendo a cada variable, desde N=25 para el VO_{2max}, hasta N=36 para HOMA. Tomando como referencia para el estudio el valor más alto de las tres variables, el tamaño total de la muestra sería de N=36; 18 participantes en cada grupo. Sin embargo, el número de sujetos a reclutar depende, además, de las posibles pérdidas o abandonos de los participantes: N'=N/(1-p), de forma que si las pérdidas se estimaran en un 20%, el número de participantes a reclutar sería N'=36/(1-0,2), N'=45, o 46 participantes para tener 23 participantes en cada grupo. Al tener que dividir a los participantes por sexo para realizar los análisis estadísticos, la N final del proyecto se duplica, con una muestra idealmente de 46 chicos y 46 chicas, es decir N=92.

El objetivo tras el cálculo muestral fue de 92 participantes. Sin embargo, como se ha comentado anteriormente, el proceso de reclutamiento fue difícil y no tan exitosos como estaba planificado. Es por eso que se priorizó el grupo intervención en el primer año de reclutamiento con el objetivo de completar el grupo control en el reclutamiento del segundo año, por lo que se hizo una aleatorización 2:1 en el primer año de proyecto. No obstante, ante la paralización del proyecto, el número de participantes asignados al grupo de intervención y al grupo control quedó desequilibrado al tener 21 niños que realizaron la intervención con VJA el primer año frente a 8 niños/as que compusieron el grupo control. La muestra final fue de 66 niños/as con sobrepeso u obesidad, de los cuales 31 tienen mediciones pre-intervención y post-intervención, con 2 abandonos en el grupo control, 21 niños en el grupo intervención y 8 niños en el grupo control. En la Figura 22 se puede ver un diagrama de flujo explicativo del número de participantes y la asignación aleatoria a cada grupo.

Figura 22. Diagrama de flujo explicativo del número de participantes y la asignación aleatorizada



Fuente: Elaboración propia

4.3.2 Comité de ética del estudio

Este estudio se llevó a cabo siguiendo las Normas Deontológicas reconocidas por la Declaración de Helsinki de 1975 (revisada en la 64 Asamblea General, Fortaleza, Brasil, octubre 2013), las Normas de Buena Práctica Clínica y cumpliendo la legislación y la normativa legal española que regula la investigación clínica en humanos (Real Decreto 223/2004 sobre regulación de ensayos clínicos).

El proyecto fue aprobado por el Comité de Ética de Investigación Clínica de Aragón (CEICA), recibiendo el dictamen favorable de dicho Comité (18/2008) tanto para la realización de las mediciones previas y posteriores a la intervención como para la propia intervención (Anexo 2). Todos los participantes del estudio tuvieron que firmar un consentimiento informado (Anexo 3) de manera previa a su participación en el estudio, y recibieron información tanto oral como escrita sobre el proyecto, las mediciones que se iban a realizar y la intervención con VJA.

4.3.3 Pruebas y valoraciones del estudio

La fase experimental de recogida de datos se llevó a cabo en el laboratorio del grupo de investigación Growth, Exercise, Nutrition and Development (GENUD) de la Universidad de Zaragoza. Cada participante realizo todas las valoraciones previas al inicio de la intervención durante una tarde después de la jornada escolar, al igual que las valoraciones posteriores a la intervención. La habilidad motriz se evaluó en las primeras sesiones de intervención o en el propio colegio durante el recreo o la clase de Educación Física en caso de los participantes del grupo control. Estas pruebas y valoraciones se realizaron siempre en un orden idéntico para evitar sesgos.

4.3.3.1 Mediciones antropométricas y valoración de la composición corporal

Todas las pruebas de composición corporal se realizaron por el mismo personal cualificado. Las mediciones antropométricas se llevaron a cabo según el protocolo que marca la Sociedad Internacional para el Avance de la Cineantropometría (ISAK) (177). Se midió la talla y la talla sentado con un estadiómetro con precisión 0,1 cm (SECA 225, SECA, Hamburgo, Alemania) y un cajón antropométrico, y el peso con una báscula de precisión 0,1 kg (SECA 861, SECA, Hamburgo, Alemania). También se midieron los perímetros de cintura y cadera con una cinta antropométrica (Holtain).

La masa grasa, magra y ósea se determinaron mediante absorciometría fotónica dual de rayos X (DXA) utilizando el software y los valores de referencia pediátricos (Hologic Explorer, Hologic Corp., Software versión más reciente, Waltham, MA). A partir del análisis regional y total del escáner completo del cuerpo se valoró: el porcentaje de grasa y la masa grasa y magra total, subtotal (total menos cabeza), troncal y extremidades. Se calculó el área total (cm^2) y contenido mineral óseo (CMO; g) y se obtuvo la densidad mineral ósea (DMO) siguiendo la fórmula DMO = CMO · área^{-1}. El DXA también reportaba el valor Z-Score, un dato que nos da información sobre cuanto se acerca o aleja un participante de la media según su edad y sexo. La masa grasa y magra subtotal (cuerpo total menos la cabeza), troncal, del tren inferior (calculada con la media de ambas piernas) y del tren superior (calculada con la media de ambos brazos) se obtuvo a partir de las exploraciones de cuerpo entero. Todos los análisis de DXA fueron realizados por el mismo investigador capacitado. El coeficiente de variación de la DXA en el laboratorio para el área ósea fue del 2,6%, para el contenido mineral óseo fue del 2,3% y para la densidad mineral ósea fue del 1,3% (178). Además, se calculó el índice de masa grasa y magra normalizado a la altura y se obtuvieron puntuaciones normalizadas basadas en los valores de referencia del estudio realizado por Weber y col. (179). Se entregó a cada participante un informe del análisis DXA.

Se midieron los índices de resistencia ósea, la morfometría ósea, el área ósea, los índices de resistencia y la microarquitectura del hueso trabecular en la tibia no dominante con la realización de una tomografía cuantitativa computerizada periférica utilizando un escáner Stratec XCT-2000 L pQCT (Stratec Medizintechnik, Pforzheim, Alemania). El dispositivo es un escáner de tomografía computerizada de rotación y traslación de pequeño calibre que obtiene una imagen trans-axial. El pQCT se calibró diariamente basándose en un fantoma de control de calidad proporcionado por el fabricante (Stratec Medizintechnik, Pforzheim, Alemania). Los coeficientes de variación para cada variable de la pQCT en nuestro laboratorio para cada variable ya han sido reportados (180).

La extremidad no dominante se determinó preguntando qué pierna se utilizaría para patear una pelota. Los participantes se sentaron en una silla ajustable a las proporciones corporales de cada participante. La longitud de la tibia se midió desde el borde medial superior de la tibia hasta el punto más alejado del maléolo medial de la tibia, y siempre fue determinada por el mismo técnico utilizando una regla de madera. La pierna evaluada se colocó en el centro del campo de imagen, y el pie y la rodilla se aseguraron para minimizar el movimiento. El escáner se colocó en el extremo distal de la tibia, y se realizó una radiografía computerizada coronal (vista de exploración) para localizar manualmente la línea de referencia en el punto medio de la placa terminal de la tibia distal.

Las mediciones óseas se realizaron al 4%, 38% y 66% de la longitud de la tibia. Siguiendo las recomendaciones de la Sociedad Internacional de Densitometría Clínica (ISCD) (181), las variables evaluadas en el 8% fueron el área ósea total, el área trabecular, la DMO total y la DMO trabecular. Las variables medidas en el 38% fueron el área ósea total, la DMO total, el grosor cortical (CRT_THK38), la circunferencia perióstica (PERI38), la circunferencia endóstica (ENDO38), el área ósea cortical, la densidad ósea cortical y el índice de deformación de la fuerza polar (SSIPOL38). En el lugar del 66% de la tibia, se obtuvieron el área ósea total, la DMO total, el grosor cortical (CRT_THK66), la circunferencia perióstica (PERI66), la circunferencia endóstica (ENDO66), el área ósea cortical, la densidad ósea cortical, el índice de tensión de resistencia polar (SSIPOL66) y la carga de fractura en el eje X (FRC_LDX66) y en el eje Y (FRC_LDY66). Las imágenes se analizaron con la versión 6.20 del software del fabricante. De esta manera se obtuvo un análisis selectivo del área y la densidad cortical y trabecular, la sección transversal, grosor cortical, circunferencias del endostio y periostio, así como de índices biomecánicos de tensión.

4.3.3.2 Condición cardiorrespiratoria

Para evaluar la condición cardiorrespiratoria se empleó un protocolo de marcha para evaluar la aptitud cardiovascular. La prueba se realizó en una cinta de correr (Quasar Med 4.0, h/p/cosmos) con una máscara facial. Se explicó la prueba a los participantes, y previo a la prueba de esfuerzo se realizó una evaluación basal con auscultación cardiaca y respiratoria, electrocardiograma basal y registro de la presión arterial basal. Un médico especialista en medicina deportiva supervisó toda la prueba y realizó un examen preclínico para determinar si el participante era apto para realizar la prueba de esfuerzo. Se colocaron electrodos a los participantes y se les midió la respuesta cardíaca y la frecuencia cardíaca (FC) en reposo antes de comenzar. Tras colocarles el arnés de seguridad, la prueba comenzó a un ritmo de marcha cómodo (3,2 km/h), y la velocidad se incrementó en 0,8 km/h cada 2 minutos hasta que los participantes caminaron rápidamente (5,6 km/h), que fue la velocidad máxima alcanzada durante la prueba. A continuación, se aumentó la pendiente en un 4% cada minuto hasta el agotamiento o hasta una pendiente máxima del 24%. Los datos de intercambio de gases respiratorios se midieron respiración a respiración mediante espirometría de circuito abierto (Oxycon Pro, Jaeger/Viasys Healthcare).

Los valores máximos de consumo de oxígeno y FC se definieron como los valores medios más altos obtenidos durante cualquier período continuo de 15 segundos. El analizador de gases se calibró diariamente con un gas y un volumen conocidos según las recomendaciones del fabricante.

La FC se registró de forma continua mediante un electrocardiograma de 12 derivaciones (H12+, Mortara Instrument) desde el principio hasta el final de la prueba de esfuerzo. El valor máximo de la FC fue el valor más alto de la FC registrado durante la última fase del ejercicio. También se midió la presión arterial con un monitor digital (M3, HEM-72OO-E, Omron Healthcare Europe), por razones de salud y seguridad, antes de la prueba de esfuerzo máximo con el participante tumbado en posición de inclinación, y durante el periodo de recuperación en posición de pie, ambos en el brazo derecho. Los manguitos se ajustaron a la circunferencia del brazo sometido a la prueba y la medición se realizó dos veces. Los participantes debían estar en reposo 5 minutos antes de la medición previa a la prueba.

Es importante remarcar la dificultad de los niños y niñas, especialmente aquellos con sobrepeso u obesidad, para cumplir con todos los criterios de maximalidad en la prueba de esfuerzo y demostrar una meseta en su consumo máximo de oxígeno (80). Para determinar si la prueba de esfuerzo fue máxima y si los datos de FC y VO_{2max} fueron válidos, se buscó que los participantes alcanzaran su FC máxima teórica al final de la prueba y una tasa de intercambio respiratorio ≥1.15 (182). Solo 4 de los 28 participantes en la prueba de esfuerzo de las mediciones iniciales y 3 de los 28 participantes en la prueba de esfuerzo posterior al periodo de intervención no alcanzaron el 90% de su FC máxima teórica al final de la prueba de esfuerzo máximo, pero lograron una tasa de intercambio respiratorio muy cercano, igual o superior a 1,15. Por lo tanto, se puede afirmar que las pruebas fueron máximas.

4.3.3.3 Condición muscular

Salto vertical con contramovimiento:

El salto vertical con contramovimiento o countermovement jump (CMJ) se evaluó utilizando una plataforma de fuerza Kistler 9260AA (Kistler Holding AG, Winterthur, Suiza). Los niños estaban en posición de pie con ambas manos en las caderas para aislar la acción de los miembros inferiores, sin acción de miembros superiores. Para la realización del contramovimiento, se pidió a los niños que realizaran una media sentadilla rápida antes de iniciar el salto, sin detenerse tras la bajada. Se permitieron tres intentos y se registró la mejor ejecución para su posterior análisis. Las puntuaciones normalizadas se obtuvieron basándose en los resultados del estudio realizado por Focke y col. (183). La altura del salto se calculó a partir del tiempo de vuelo mediante la siguiente ecuación: $h_t = \frac{g(t_v)^2}{8}$ (184).

Fuerza isométrica máxima de la extensión de la rodilla:

La fuerza isométrica máxima de la extensión de la rodilla se midió con la galga extensiométrica a través de un medidor de señalización (Universidad de Zaragoza, Zaragoza, España). Los niños partían de una posición sentada con las rodillas flexionadas 90º. La galga se colocó en el tercio distal anterior de la tibia, la cual está conectada al extensómetro, registrando los datos de fuerza durante el tiempo que el participante tenía que realizar la máxima extensión de rodilla hasta que la curva de fuerza comenzaba a disminuir. Se permitieron tres intentos para cada pierna, registrándose el mejor rendimiento de cada pierna y se obtuvo la media del mejor intento de cada pierna para cuantificar la fuerza de extensión isométrica de la rodilla. Las puntuaciones normalizadas se obtuvieron basándose en los valores de referencia del estudio realizado por Beenakker y col. (185).

Dinamometría manual:

La prueba de fuerza de agarre de la mano se midió utilizando un dinamómetro de agarre de la mano (TKK 5001, agarre A; Takei) (rango, 0-100 kg; precisión, 0,1 kg). Los niños se encontraban en posición de pie manteniendo el brazo del lado examinado recto hacia abajo con el hombro ligeramente abducido (~10° sin tocar el resto del cuerpo), el codo en 0° de flexión, el antebrazo en posición neutra y la muñeca en 0° de flexión. Se utilizó el mejor valor de tres intentos con cada mano y se obtuvo la media del mejor intento de cada brazo para cuantificar la fuerza de tren superior. Los percentiles de fuerza de agarre de la mano por edad y sexo se calcularon basándose en los valores normativos de niños y adolescentes de 9 a 17 años de edad que representaban a 24 países propuestos por Tomkinson y col. (79).

4.3.3.4 Actividad física

La AF y las conductas sedentarias se evaluaron objetivamente antes y después de la intervención utilizando los acelerómetros GENEActiv calibrados (ActivInsights Ltd., Kimbolton, Cambridgeshire, Reino Unido) (186). Todos los participantes llevaron el acelerómetro en la muñeca izquierda durante 7 días consecutivos (187). Los dispositivos se configuraron para registrar con una frecuencia de 30 Hz.

Se pidió a los participantes que llevaran los dispositivos durante todo el día durante 7 días, incluso durante el sueño y las actividades acuáticas. Se dieron instrucciones verbales a los padres junto con una hoja de registro en caso de que se retirara el dispositivo.

Los datos del acelerómetro se descargaron utilizando el software GENEActiv versión 3.2 y se agregaron en épocas de 15 s para su posterior análisis utilizando el software R. Los periodos en los que no se llevó el acelerómetro se detectaron siguiendo el método propuesto por van Hees y col. (188) y se eliminaron de los registros y los participantes con menos de 4 días válidos (<10 horas de tiempo de uso por día) fueron excluidos del análisis de la acelerometría. El tiempo durante las conductas sedentarias y de AF a diferentes intensidades fue registrado, clasificando una AF como ligera, moderada o vigorosa según los puntos de corte propuestos por Schaefer y col. (189) en 0,190 g, 0,314 g y 0,998 g, respectivamente. El tiempo de sueño no se incluyó en el tiempo de sedentarismo y la AF total se calculó como la suma de los minutos de intensidad ligera, moderada y vigorosa.

4.3.3.5 Gasto energético durante las sesiones

La duración y la intensidad de la AF de los niños se cuantificó objetivamente utilizando acelerómetros triaxiales (ActiGraph-GT3X + BT, ActigraphTM, LLC, Fort Walton Beach, FL, EE.UU.). Los niños llevaron los acelerómetros durante toda la sesión. Estos dispositivos se colocaron en la cadera izquierda, que ha demostrado ser la región que proporciona los datos más fiables utilizando esta técnica (190). Los acelerómetros se utilizaron para registrar la frecuencia cardíaca medida por el sensor de frecuencia cardíaca Polar H10 (Polar Electro Oy., Lake Success, NY, EE.UU.) y la correa torácica Pro, conectado a la aplicación a través de Bluetooth. Los niños llevaban el sensor de frecuencia cardíaca Polar H10 durante varias las sesiones, junto con el acelerómetro. Era importante asegurar la correcta colocación de la banda pectoral y evitar interferencias con otros participantes que también llevaban la banda y el acelerómetro. La persona encargada debía anotar la hora justa de inicio y de final de cada actividad, para posteriormente conocer en qué dispositivo de VJA o en qué actividad se había realizado ese gasto energético, ya que se exportaban los datos de la sesión completa.

Se registró la FC y el VO_2 de cada sujeto tanto en esfuerzos submáximos como en el esfuerzo máximo a través de una prueba de esfuerzo máxima. Para calcular el consumo de oxígeno durante todas las partes de la sesión a partir de la frecuencia cardíaca registrada, se calculó una ecuación de regresión lineal para cada participante a partir de los datos de frecuencia cardíaca y consumo de oxígeno durante todas las fases de la prueba en cinta rodante. A continuación, se estimó el gasto energético durante cada ejercicio y toda la sesión utilizando esta ecuación desarrollada para cada niño y los datos de frecuencia cardíaca obtenidos de los acelerómetros y del sensor de frecuencia cardíaca Polar H10. Los datos de aceleraciones obtenidos con los acelerómetros no se tuvieron en cuenta debido a que no son adecuados para cuantificar el gasto en ciertas actividades como el ejercicio en el ciclosimulador. No obstante, la estimación del gasto con la frecuencia cardíaca utilizando las frecuencias cardíacas obtenidas en la prueba de esfuerzo máxima es un método válido y fiable para medir el gasto energético (191,192), y es incluso más fiable que los datos de la acelerometría (193), teniendo en cuenta además que uno de los dispositivos utilizados consiste en un ciclosimulador, que podría no ser registrado de forma fiable por la acelerometría.

4.3.3.6 Habilidad motriz

La habilidad motriz fue evaluada en el grupo de intervención, utilizando el Test para el Desarrollo Motor Grueso-3ª Edición (TGMD-3 - The Test of Gross Motor Development–Third Edition), que evalúa 13 habilidades motoras fundamentales, subdivididas en dominios locomotores y de control de objetos (194). El TGMD-3 tiene dos partes: una parte en la que se valora la habilidad motriz gruesa locomotora que se centra en los diferentes desplazamientos que requieren coordinación, y otra parte en la que se valora la habilidad motriz gruesa que incluye un implemento que lanzar, golpear, recepcionar, botar o chutar. El TGMD-3 proporciona una puntuación global que nos informa sobre la habilidad motriz de los niños y niñas a través de una puntuación total. El TGMD-3 fue evaluado y codificado de acuerdo con el protocolo de administración y calificación estandarizada. Una explicación detallada de la administración y la codificación se puede encontrar en la página web de la TGMD-3 (195), con información general, una breve guía de administración, algunos vídeos útiles y cuatro vídeos de fiabilidad. Los investigadores que evaluaron las habilidades motoras con esta herramienta completaron la evaluación de los cuatro vídeos de fiabilidad para comprobar la consistencia de la administración y codificación, además de la variabilidad intra- e inter-observador. La puntuación de las pruebas, la codificación de los resultados y los percentiles se obtuvieron basándose en el manual del examinador (196).

4.3.3.7 Maduración sexual

Un médico experimentado, evaluó directamente los estadíos de Tanner (197) de los participantes. También se determinó en las muestras sanguíneas la hormona foliculoestimulante (FSH), hormona luteinizante (LH) y testosterona total. El desarrollo madurativo se calculó usando la talla sentado o la talla con la ecuación propuesta en la revisión de Koziel y col. (198).

4.3.3.8 Presión arterial

Se midió la frecuencia cardíaca, la tensión arterial sistólica y diastólica, por duplicado, en reposo con un tensiómetro (Omron M3). Esta medición se realizó después de la valoración del DXA dado que permanecían en tendido supino y relajados al menos 10 minutos. Esta medición se realizó en la arteria braquial del brazo izquierdo.

4.3.4 Pruebas y valoraciones del estudio que no fueron utilizados en la presente tesis

4.3.4.1 Parámetros bioquímicos

Las muestras de sangre en ayunas se extrajeron de la vena antecubital con una palomilla de extracción sanguínea y se colocaron en tubos de separación de suero con gel (5 mL) y en tubos con 18 mg de EDTA para el análisis hematológico (Becton, Dickinson and Company, Franklin Lakes, NJ, USA). A continuación, se codificaron los tubos de sangre, se centrifugaron las muestras en la centrífuga ORTOALRESA MICROCEN 24 a 350 RMP durante 10 minutos y se pipetearon para posteriormente ser almacenados a -80ºC.

Las extracciones se realizaron entre las 8:00 y las 9:00 horas y en ayunas. Se valoraron los siguientes parámetros: glucosa e insulina en ayunas, Péptido C, HbA1C, leptina, adiponectina, visfatina, ALT y AST, gamma-GT, hs-CRP, TNF-alfa, IL-6, fibrinógeno, perfil lipídico y perfil férrico.

4.3.4.2 Dieta y hábitos nutricionales

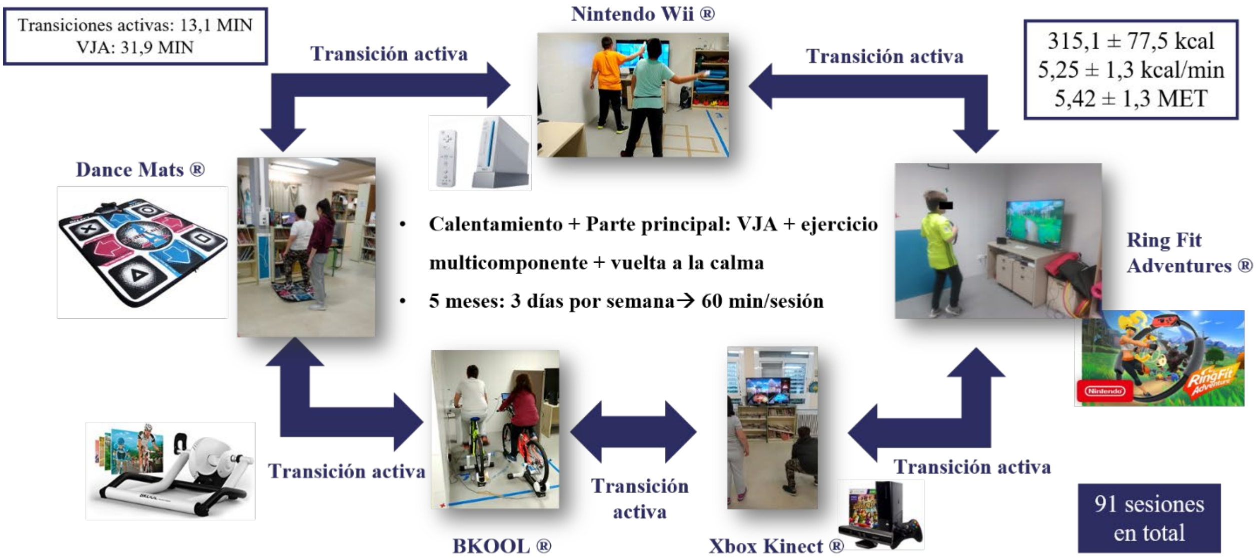
La dieta y los hábitos nutricionales de los participantes se valoraron utilizando tres cuestionarios. Por un lado, los participantes rellenaron un recuerdo de 24 horas de un día entre semana, concretamente el día anterior al día de la citación para la evaluación. Además, cumplimentaron dos cuestionarios, uno sobre frecuencia de consumo de alimentos, Children's Eating Habits Questionnaire (CEHQ) (199) y otro sobre el comportamiento alimentario infantil (Children Eating Behaviour Questionnaire - CEBQ) (200).

4.3.5 Intervención

El programa de ejercicio físico mediante VJA lo llevaron a cabo personas cualificadas del grupo de investigación y las sesiones se desarrollaron en dos sedes: pabellón universitario del Campus Plaza San Francisco de la Universidad de Zaragoza y en el colegio público San Braulio en Zaragoza, dependiendo de la disponibilidad geográfica y horaria de todos los participantes. El programa de intervención con VJA tuvo lugar de enero a mayo, coincidiendo con un curso escolar y una frecuencia de 3 sesiones por semana, contando con los meses de octubre-noviembre y con junio para las mediciones previas y posteriores a la intervención. La duración de cada sesión fue de aproximadamente 60 minutos y se controló la intensidad mediante acelerómetros y bandas de FC. Gracias a esta monitorización de la FC, se pudo adaptar las sesiones a este grupo poblacional e individualizar lo máximo posible, incrementando la intensidad progresivamente, con una intensidad de 2-3 MET en el periodo inicial del primer mes, de 3-6 MET en el periodo de progresión en el segundo y tercer mes, e intentando superar los 6 MET en el periodo de mantenimiento de los últimos meses de intervención.

De esta manera, se llevó a cabo una temporalización del programa de entrenamiento, teniendo en cuenta el nivel de CF inicial y habilidades motrices de los participantes, y una planificación del entrenamiento en función de los diferentes objetivos a lo largo del tiempo, que se puede observar en el Anexo 7. Además, se diseñó el programa de entrenamiento que combinaba ejercicio físico con un trasfondo lúdico enfocado a mejorar diferentes aspectos de la CF con VJA, es decir, que requieran movimiento corporal y esfuerzo físico, y concretamente se trabajó la mejora de la condición cardiorrespiratoria, resistencia muscular, fuerza muscular, equilibrio, agilidad, coordinación y la composición corporal. Se usaron 5 dispositivos, con las diferentes posibilidades que nos ofrecen la gran variedad de juegos y opciones de juego para cada dispositivo: Nintendo Wii® (Wii Sport®, Punch Out® y Mario y Sonic en los Juegos Olímpicos®), Xbox Kinect® (Kinect Adventures® y Kinect Sport®), esterillas de baile (Stepmania® y Mario y Sonic en los juegos olímpicos®), Nintendo Switch® con el juego Ring Fit® y el BKOOL®, un ciclosimulador conectado a una tablet. La dinámica de las sesiones de esta intervención de VJA combinados con ejercicio multicomponente fue una dinámica de circuito o estaciones, con diferentes estaciones de VJA y rotaciones con ejercicios de tipo convencional enfocados hacia la mejora de la CF con el objetivo de incrementar el estímulo de entrenamiento, intentando aumentar el efecto en los diferentes componentes de CF y aumentar el gasto energético buscando una mayor intensidad. En la Figura 23 se puede apreciar una imagen explicativa de la dinámica de la sesión, que se estructura como una sesión de ejercicio físico empezando con un calentamiento, seguido de un trabajo de estabilizadores, equilibrio o coordinación, tras lo cual se desarrollará la parte principal compuesta principalmente por los VJA con transiciones activas a través de diferentes ejercicios de tipo convencional, y terminando con una vuelta a la calma.

Figura 23. Dinámica de una sesión con videojuegos activos combinados con ejercicio multicomponente como transición activa



Fuente: Elaboración propia

4.4 Análisis estadísticos

Dado que algunos de los análisis estadísticos utilizados en los diferentes artículos que componen la presente Tesis Doctoral son comunes, se ha decidido optar por describir los diferentes análisis utilizados en un mismo apartado. No obstante, algunos de los métodos descritos a continuación solo se han utilizado en uno de los artículos, por ello, para conocer en mayor detalle los análisis estadísticos llevados a cabo en cada estudio, los mismos se pueden consultar en la siguiente sección de *Resultados y discusión*. En los artículos originales, el software utilizado para llevar a cabo los diferentes análisis estadísticos fue el Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc., Chicago, IL, USA). El nivel de significación estadística para todos los test se fijó en $p < 0{,}05$. En los meta-analisis, el software utilizado para llevar a cabo los diferentes análisis estadísticos fue el Open Meta [Analyst] (Windows 10, Rhode Island, RI, EE.UU.).

4.4.1 Meta-análisis

Merecen especial mención los artículos I y II, dado que son meta-análisis. En ambos se compararon los niños/as y adolescentes que realizaron una intervención de VJA con los controles que no participaron en ninguna intervención o en otro tipo de intervención de AF. Se calcularon los tamaños del efecto para cada resultado o variable. Se realizaron diferentes meta-análisis al estratificar los estudios por tipo de grupo de control (sin intervención o intervención de ejercicio sin VJA) y cuando el número de artículos lo hizo posible, se realizaron análisis por subgrupos dividiendo los estudios por la duración de la intervención.

Se calcularon las diferencias medias estandarizadas (DME) entre los participantes en las intervenciones de VJA y los grupos controles, y sus intervalos de confianza del 95% mediante un modelo de efectos aleatorios continuos (método de DerSimonian-Laird). Los tamaños de los efectos de las DME se interpretaron de la siguiente manera: <0,40 = pequeño, 0,40-0,70 = moderado, >0,70 = gran efecto (173). La heterogeneidad de los estudios se comprobó mediante el estadístico I^2 (201). Esta estadística describe la varianza entre los estudios como proporción de la varianza total y se interpretó de la siguiente manera: I^2 = 0-25% de no heterogeneidad, I^2 = 25-50% de heterogeneidad moderada, I2 = 50-75% de heterogeneidad alta, e I^2 = 75-100% de heterogeneidad muy alta.

4.4.2 Análisis descriptivos

En los tres artículos originales que componen la presente Tesis Doctoral se han llevado a cabo en primer lugar análisis estadísticos descriptivos de las principales variables. Los análisis descriptivos se han llevado a cabo para toda la muestra, y para diferentes subgrupos creados en cada caso en función de diferentes variables de interés. Las variables continuas se han presentado a través de su media y desviación estándar (SD), o a través de su media y error estándar (SE), las variables categóricas se han presentado a través de su porcentaje y número de participantes (N). Además, se estudió la normalidad en la distribución de las variables continuas mediante el test de Kolmogorov-Smirnov y la inspección visual de los histogramas.

4.4.3 Análisis estadísticos en los estudios longitudinales

En caso de los estudios longitudinales, las variables presentaron distribución no normal, probablemente debido a la poca muestra. Es por ello que, en los estudios longitudinales, las diferencias entre los grupos que realizó la intervención con VJA y el control fueron investigadas mediante las pruebas U de Mann-Whitney. Por otro lado, se utilizó la prueba de Wilcoxon para estudiar la evolución dentro del grupo, comparando las medidas previas y posteriores a la intervención, para saber si ha habido cambios significativos, tanto mejora como empeoramiento. El tamaño del efecto r se calculó para las pruebas U de Mann-Whitney y el test de Wilcoxon utilizando la fórmula de Fritz, Morris y Richler (202) para comparaciones no paramétricas. El tamaño del efecto de r puede ser pequeño (0,1-0,3), medio (0,3-0,5) o grande (>0,5) (203). Por último, el coeficiente de correlación de Spearman fue la prueba utilizada para estudiar relaciones entre variables.

4.4.4 Análisis estadísticos en el estudio transversal

En el estudio transversal en el que se calcula el gasto energético en los diferentes dispositivos de VJA y en las sesiones de esta intervención de VJA combinados con ejercicio multicomponente, las variables mostraron una distribución normal, por lo que se utilizó un análisis de varianza (ANOVA) para comparar el gasto energético de cada VJA y se utilizaron pruebas t para muestras independientes para examinar las diferencias de género y de IMC en el gasto energético de cada VJA. Se calcularon los tamaños del efecto *d* de Cohen (intervalos de confianza (IC) del 95%) y se interpretaron como pequeños (0,2-0,5), medianos (0,5-0,8) o grandes (>0,8). Se realizó una regresión lineal para cada participante con sus datos individuales de VO_2 y FC de la prueba máxima para calcular el gasto energético en cada VJA.

5. Resultados y discusión [Results and discussion]

5.1 Artículo I

Review

Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents With Overweight or Obesity: Systematic Review and Meta-Analysis

Cristina Comeras-Chueca[1,2,3], MSc[‡]; Jorge Marin-Puyalto[2,3,4,5], PhD; Angel Matute-Llorente[2,3,4,5,6], PhD; German Vicente-Rodriguez[2,3,4,5,6], PhD; Jose Antonio Casajus[1,2,3,5,6], PhD; Alex Gonzalez-Aguero[2,3,4,5,6], PhD

[1]Department of Physiatry and Nursing, Faculty of Health Science, University of Zaragoza, Zaragoza, Spain
[2]GENUD Research Group (Growth, Exercise, NUtrition and Development), University of Zaragoza, Zaragoza, Spain
[3]EXERNET, Red de Investigación en Ejercicio Físico y Salud para Poblaciones Especiales, Zaragoza, Spain
[4]Department of Physiatry and Nursing, Faculty of Health and Sport Science, University of Zaragoza, Huesca, Spain
[5]Instituto Agroalimentario de Aragón -IA2-, CITA, Universidad de Zaragoza, Zaragoza, Spain
[6]Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición (CIBERObn), Madrid, Spain
[‡]GENUD Research Group

Corresponding Author:
Alex Gonzalez-Aguero, PhD
Department of Physiatry and Nursing
Faculty of Health and Sport Science
University of Zaragoza
Despacho nº 8
Pabellón polideportivo río Isuela, Ronda de la misericordia 5
Huesca, 22001
Spain
Phone: 34 876553755
Email: alexgonz@unizar.es

Abstract

Background: Childhood obesity is one of the most important public health problems. Active video games (AVGs) have been proposed as an attractive alternative to increase energy expenditure and are being investigated to determine their effectiveness against childhood obesity.

Objective: The aim of this study is to summarize the existing research and draw conclusions about the effects of AVGs on health-related physical fitness and motor competence in children and adolescents with overweight and obesity.

Methods: The search strategy was applied to PubMed, MEDLINE, Web of Science, and SPORTDiscus, including randomized and nonrandomized controlled trials investigating the effects of AVG programs on health-related physical fitness and motor competence in children and adolescents with overweight and obesity. To measure the risk of bias in randomized and nonrandomized controlled trials, 2 different quality assessment tools were used. In total, 15 articles met the inclusion criteria, and the variables of interest were BMI, body fat percentage, cardiorespiratory fitness (CRF), waist circumference, fat-free mass, muscular fitness, and motor competence. A meta-analysis was performed.

Results: Positive effects were found for BMI and body fat percentage, favoring the AVG group compared with a control group with no intervention (mean difference −0.209; 95% CI −0.388 to −0.031 vs mean difference −0.879; 95% CI −1.138 to −0.602). Positive effects seem to be observed for CRF. The effects of AVG interventions on muscular fitness, fat-free mass, waist circumference, and motor competence are unclear.

Conclusions: AVG programs showed positive effects on BMI, body fat percentage, and CRF. AVG could be a good strategy to combat childhood obesity.

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KEYWORDS

active videogames; exergaming; BMI; body fat; motor skills; cardiorespiratory fitness; muscle

Introduction

Background

Childhood obesity is one of the most important public health problems in the 21st century in high-income societies [1]. The prevalence of overweight and obesity in childhood has acquired the status of an epidemic. The global prevalence of overweight and obesity among children and adolescents (aged 5-19 years) has risen dramatically from 4% in 1975 to over 18% in 2016. For instance, the prevalence of overweight was over 30%, and the prevalence of obesity was over 10% in European children and adolescents in 2016 [2]. Obesity has become a pandemic owing to an obesogenic environment that causes cardiovascular and cardiometabolic diseases and psychosocial problems [3,4]. Children with overweight and obesity are likely to remain obese during adulthood and are more likely to develop many other types of cardiovascular and metabolic pathologies [1]. Evidence shows that cardiovascular risk is inversely related to physical fitness [5] and the amount of physical activity (PA) [6] performed by youth. The components of health-related physical fitness are cardiorespiratory fitness (CRF), body composition, muscular strength, muscular endurance, and flexibility [7]. Childhood obesity is related to poor health-related physical fitness, such as CRF and muscular strength [8].

On the other hand, the recommendation of the World Health Organization indicates that a daily average of 60 minutes of moderate-to-vigorous PA provides any of the health benefits in young people, although daily average of beyond 60 minutes of moderate-to-vigorous PA provides additional benefits [9]. In 2016, a study including 1.6 million students aged 11-17 years showed that 81% of them did not meet this recommendation [10]. PA, especially at moderate-to-vigorous intensity, is associated with better physical fitness, independent of sedentary time [11,12].

In addition, one of the main sedentary behaviors of this population is playing electronic games, such as computer or console games [13]. The World Health Organization reported that 40.2% of children and adolescents spend at least 2 hours per day watching television or using electronic devices on weekdays, and this percentage rises to 75.8% during weekends, going further than the recommendations of maximum screen time [14]. This inactivity and excessive sedentary screen time are catastrophic for motor development in children and adolescents [15]. A recent systematic review performed by Han et al [16] showed that children and adolescents with overweight and obesity have a lower motor competence level than children and adolescents with healthy weight; therefore, low motor competence needs to be taken into consideration in children with overweight or obesity. Moreover, children with high actual and perceived motor competence will probably show higher PA and lower BMI status [17]. An improvement in motor competence may promote better perceived motor competence, which entails higher motivation and participation in extracurricular PA and sports [18,19]. In addition, evidence shows a relationship between motor competence and health-related physical fitness during childhood and adolescence [20]. Thus, improving motor skills in children with overweight and obesity is one of the main objectives.

It is well known that exercise is an effective tool to fight obesity [21], with all its associated benefits, such as improvements in BMI status or adiposity, cardiorespiratory and muscular fitness, or bone health [22]. However, the main challenge is to ensure adherence to exercise in children with overweight and obesity [23]. Therefore, the implementation of new types of exercise that are more attractive and motivational to this population is needed.

Active video games (AVGs) have been proposed as a suitable alternative to exercise and are being investigated to determine their effectiveness against childhood obesity. AVGs generally require full-body movement and therefore increase energy expenditure [24]. A systematic review showed that structured AVG sessions had the potential to increase PA in children, but there was no evidence of the benefits of conducting them in the home setting [25]. PA and energy expenditure during AVGs are a well-studied topic showing that AVGs elicit light-to-moderate PA, and also elevate energy expenditure to moderate-to-vigorous intensity, thus having a favorable influence on energy balance [26-28]. Nevertheless, energy expenditure has been found to be higher in structured programs [29]. AVGs seem to be an interesting strategic tool to encourage an active and healthy lifestyle as an alternative to sedentary behaviors [30-32]. However, according to the overview performed by Kari [33], additional high-quality research and systematic reviews concerning exergaming are needed. In addition, AVGs seem to be an effective tool for improving self-concept, self-efficacy, situational interest and motivation, enjoyment, and psychological and social well-being [34,35]. Specifically, AVGs may have positive effects on the psychological aspects and mental health of children and adolescents with overweight or obese [36,37].

Finally, AVGs may have a positive effect on motor competence and health-related physical fitness. Some studies have shown enhancements in children's motor competence and perceived competence [38-40] or improvements in health-related physical fitness, such as cardiorespiratory and muscular fitness [41-43] and body composition [44], after an AVG intervention.

Objective

Therefore, the main aim of this systematic review is to summarize and critically appraise the existing research on the effects of AVGs on health-related physical fitness and motor competence in children and adolescents with overweight and obesity and to extract conclusions from a fair comparison of the studies included.

Methods

Data Sources and Search Strategy

This review was performed following the criteria and methodology established by the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) [45]. This review was performed according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) 2020 statement [46]. The PRISMA checklist is shown in

Multimedia Appendix 1. The protocol was registered in the International Prospective Register of Systematic Reviews, PROSPERO (CRD42020189138).

Journal articles were identified by searching electronic databases, scanning reference lists of articles, and examining tables from previous systematic reviews. The search strategy was applied to PubMed, MEDLINE, Web of Science, and SPORTDiscus up to and including March 2021.

The search strategy used to identify the articles in PubMed and MEDLINE was as follows: exergam* OR *active video gam** OR *active videogam** OR *active gam** OR *interactive video gam** OR *interactive videogam** OR *Wii* OR *Xbox* OR *Kinect* OR *PlayStation*, and *Species: Humans* and *Language: English* filters were applied, along with *Journal Article* for MEDLINE. The search strategy applied in SPORTDiscus was as follows: TX=(exergam* OR *active gam** OR *active video gam** OR *active videogam** OR *interactive video gam** OR *interactive videogam** OR *Wii* OR *Xbox* OR *Kinect* OR *PlayStation*) and *document type: article* and *language: English* filters were applied. The search strategy used in Web of Science was as follows: TS=(exergam* OR *active gam** OR *active video gam** OR *active videogam** OR *interactive video gam** OR *interactive videogam** OR *Wii* OR *Xbox* OR *Kinect* OR *PlayStation*) and *document type: article* and *language: English* filters were applied.

Two reviewers (CCC and AGA) independently evaluated all studies. Titles and abstracts were examined, and relevant articles were obtained and assessed using the inclusion and exclusion criteria presented in Textbox 1. The inclusion criteria were used following the PICOS (Population, Intervention, Comparison, Outcomes and Study) format [47]. Interreviewer disagreements were resolved by consensus. A third reviewer (JAC) resolved these disagreements.

Textbox 1. Inclusion and exclusion criteria.

Inclusion criteria

- Types of participants were children and adolescents with overweight and obesity
- Trials studying the effects of active video game programs on health-related physical fitness and motor competence
- Control group with no intervention or with traditional exercise intervention
- Types of outcome measures included variables of health-related physical fitness, such as cardiorespiratory fitness, musculoskeletal fitness (muscular strength and muscular endurance), and body composition and variables related to motor competence
- Types of studies were randomized and nonrandomized controlled trials

Exclusion criteria

- Studies were conducted in languages other than English or Spanish
- Data were unpublished
- Studies were conducted with animals
- Studies included participants aged ≥18 years
- Studies included participants with disabilities, diseases, or disorders other than obesity
- Studies were conducted without pre- and postassessments of the variables of interest
- Studies were dissertations or abstracts from society proceedings or congresses
- Studies included participants with normal weight
- Noncontrolled trials were considered in the discussion of the article with the consideration of the great limitation of the lack of a control group in interpretation of the results
- Noncontrolled trials were not included in the risk of bias assessments or meta-analysis
- All the noncontrolled trials concerning the effects of active video games on motor competence and health-related physical fitness in children and adolescents with overweight and obesity are summarized in Multimedia Appendix 2

Risk of Bias

For assessing risk of bias proposed in the PRISMA 2020 statement, 2 risk of bias assessment tools were used—the Risk of Bias 2 in randomized controlled trials (RCTs) updated by Sterne et al [48] and the ROBINS-I (Risk of Bias in Nonrandomised Studies of Interventions) in nonrandomized controlled trials developed by Sterne et al [49].

Data Extraction

The following information was extracted from each included trial: name of first author, year of publication, sample size, participant characteristics including number of participants, age and sex, type of study, type of intervention, training characteristics including intervention length and frequency, variables and data sources, and outcomes. The reported variables were weight, BMI, z-score of BMI, fat mass, body fat percentage, CRF, waist circumference, fat-free mass, muscular fitness, and motor competence.

Meta-Analyses

Children and adolescents with overweight and obesity who underwent an AVG intervention were compared with a control group (ie, group with participants performing a PA intervention and with nonintervention participants). Effect sizes were calculated for each outcome (BMI, body fat percentage, CRF, waist circumference, fat-free mass, muscular fitness, and motor competence). Different meta-analyses were performed by stratifying the studies by type of control group (no intervention or exercise intervention without AVG). When the number of articles made it possible, analyses by subgroups were performed by dividing the studies by the length of the intervention. The free cross-platform software OpenMeta[Analyst] for advanced meta-analysis was used for data processing.

Mean differences (MD) between participants in AVG interventions and controls and their 95% CIs were calculated using a continuous random-effects model (DerSimonian-Laird method). The heterogeneity of the studies was tested using the I^2 statistic [48]. This statistic describes the variance between studies as a proportion of the total variance and was interpreted as follows: I^2=0%-25% no heterogeneity; I^2=25%-50% moderate heterogeneity; I^2=50%-75% high heterogeneity; and I^2=75%-100% very high heterogeneity. All analyses were performed using the OpenMeta[Analyst] software.

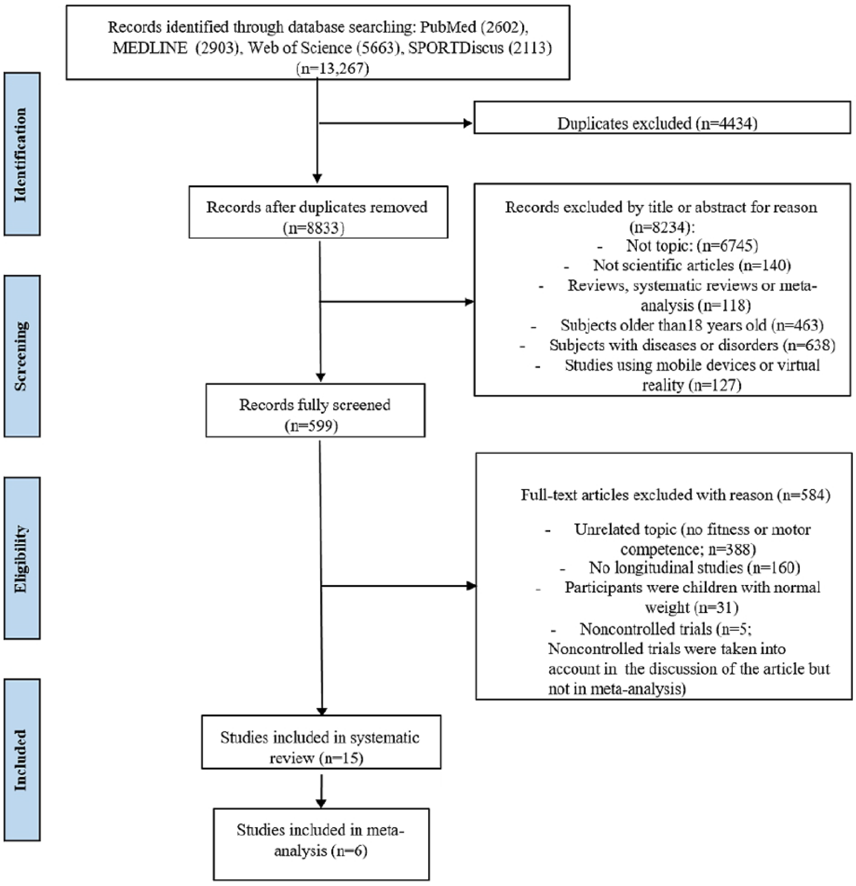
Results

Search Summary

A total of 13,267 relevant articles were identified using the abovementioned search strategies. Following a review of titles and abstracts and excluding duplicates, the total number of articles was reduced to 599. Of them, 15 articles met the inclusion criteria and were selected for this review. Articles were excluded for the following reasons: studies were cross-sectional (n=160); only psychological, cognitive, nutritional, and balance variables, PA, or energy expenditure were measured (n=388); participants were children with normal weight (n=31); and studies were noncontrolled trials (n=5; Figure 1).

The characteristics of each study included in this systematic review were summarized in different sections following the PICOS format [47].

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of articles that were selected.



Methodological Quality

Multimedia Appendix 3 summarizes the methodological quality assessment of RCTs. The risk of bias in the RCT was low.

The quality assessment for the only nonrandomized controlled trial shows a low risk of bias on preintervention, intervention and postintervention, and therefore, a low overall risk of bias [50].

AVG Interventions

There was a great deal of variety across the AVGs used. Interventions mostly ran during physical education lessons, during playtime or lunch time as extracurricular activities after school or at home. The most commonly used devices in AVG interventions were gaming consoles, such as Xbox 360 with Kinect, Nintendo Wii, Sony PlayStation 2, dance mats, and interactive video game cycling. Games included Just Dance, Wii Fit, Wii Sports, Kinect Adventures, Kinect Sport, Dance Central, Dance Dance Revolution (DDR), and EyeToy.

The length of AVG interventions ranged from 8 weeks to 6 months (mean 16.3, SD 6.7 weeks). The frequency of AVG sessions ranged from 1 day to 5 days per week (mean 126.3, SD 55.8 minutes per week). Sessions typically lasted between 30 and 90 minutes (mean 52.0, SD 11.1 minutes) and were delivered by teachers and research assistants. It is therefore complicated to establish a standard length, intensity, and duration of sessions or type of the AVG intervention.

The different control groups either performed another intervention without AVGs, such as physical education or exercise sessions, access to sedentary video games, and learning sessions or were only asked to continue their normal activities of daily life, the latter being the most used option for the control group.

AVG Effects

All the studies concerning the effects of AVG on motor competence and health-related physical fitness in children and adolescents with overweight and obesity are summarized in Multimedia Appendix 4.

A total of 15 randomized and nonrandomized controlled trials showed effects of AVGs on health-related physical fitness [42,44,51-62] and motor competence [50,61] in children and adolescents with overweight and obesity.

BMI, fat mass, or body fat percentage were measured in 14 studies using dual-energy x-ray absorptiometry [52,54] or bioelectrical impedance [51,58-60] to measure body fat. Waist circumference was measured in 4 studies [42,51,52,58]. CRF was evaluated in 8 studies using different tests, such as the 20-m shuttle run test [42,51,59,61], the 3-minute step test [57], and a submaximal test with a cycle ergometer [58,60]. Motor competence was only measured by Van Biljon et al [50] using the Bruininks-Oseretsky Test and by Bonney et al [61] using the Movement Assessment Battery for Children Test-Second Edition.

A quantitative analysis was performed for BMI, BMI z-score, body fat percentage, fat mass, fat-free mass, and waist circumference. Individual study results and global effects are presented in Figures 2-6, whereas a summary of the global results is presented in Table 1. Data from 2 studies [51,54] were included, taking into consideration when interpreting the data that the results obtained by these studies were adjusted for baseline outcome measures, age, and sex. Before including them, it was ascertained that the studies did not change the trend of the results without them.

Figure 2. BMI effect sizes for active video games compared with those for control group. AVG: active video game.

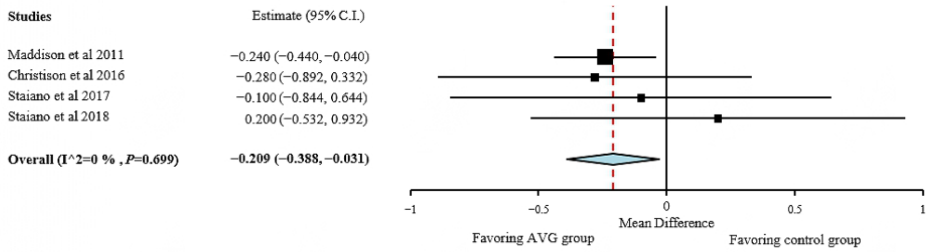


Figure 3. BMI z-score effect sizes for active video games compared with those for control group. Analysis by length of the intervention: subgroup 1: interventions lasting more than 12 weeks; subgroup 0: interventions lasting 12 weeks or less. AVG: active video game.

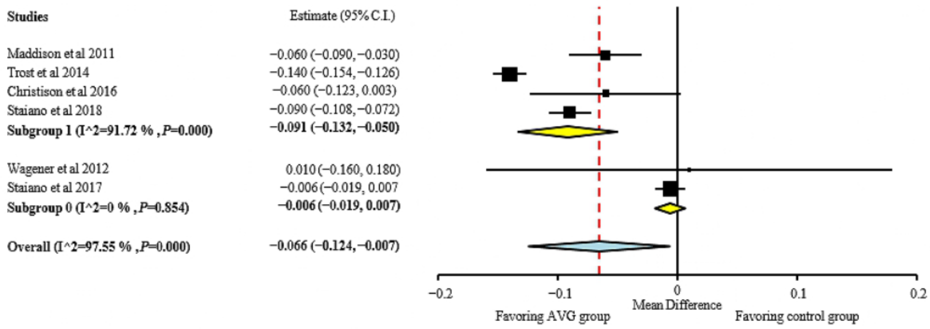


Figure 4. Body fat percentage effect sizes for active video games compared with those for control group. AVG: active video game.

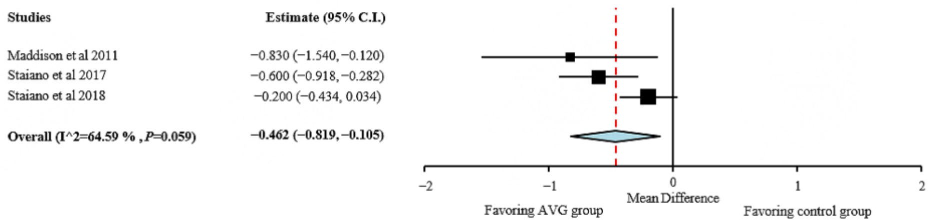


Figure 5. Waist circumference effect sizes for active video games compared with those for control group. AVG: active video game.

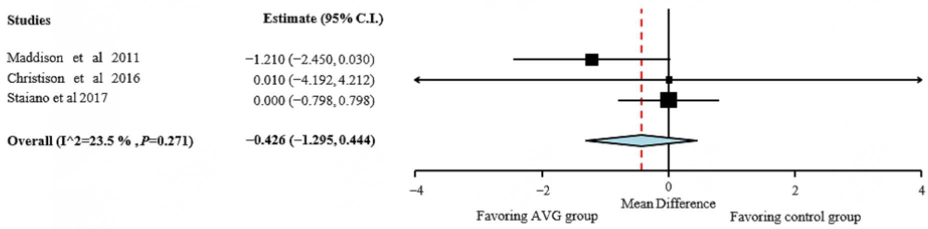


Figure 6. Fat-free mass effect sizes for active video games compared with those for control group. AVG: active video game.

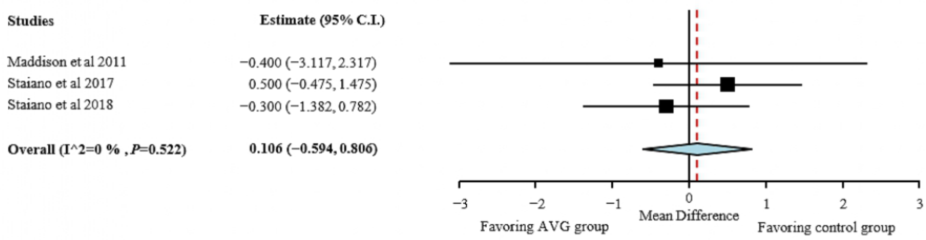


Table 1. Effect sizes and heterogeneity of findings for studies comparing active video game intervention versus control group (N=15).

Measures	Studies, n (%)	Hedge *g* effect size	Value, 95% CI	*P* value	I^2 (%)
BMI	4 (27)	−0.209	−0.388 to −0.031	.70	0
BMI z-score	6 (40)	−0.066	−0.124 to −0.007	<.001	97.55
Body fat percentage	3 (20)	−0.462	−0.819 to −0.105	.06	64.59
Fat-free mass	3 (20)	0.106	−0.594 to 0.806	.52	0
Waist circumference	3 (20)	−0.426	−1.295 to 0.444	.27	23.5

A quantitative analysis was not performed for CRF because of different measurement methods and articles with the same sample and for motor competence or muscular fitness because of the lack of articles. Some articles were excluded from the quantitative analyses given that the effect sizes could not be calculated from the information available in the papers [56,57], the sample was the same between studies [44,59], or the number of studies found was insufficient [50]. Another article was excluded from the quantitative analyses because of the control group exercised [58,60,61]. Noncontrolled trials [63-67] were considered in the discussion and are summarized in Multimedia Appendix 1.

Weight, BMI, and Body Fat

A total of 13 studies evaluated changes in weight, BMI, fat mass, or body fat percentage measured. Of the 13 studies, 9 reported positive effects of an AVG intervention on body weight, BMI, or body fat in children with overweight and obesity. The first study that investigated the effect of AVG on BMI status and body composition in adolescents with overweight and obesity was performed by Adamo et al [58], and they compared a 10-week AVG cycling intervention with a stationary bike music intervention. There were no significant group or group by time effects on body weight, BMI, fat mass, or fat-free mass, but a reduction in body fat percentage was found when groups were combined and compared with baseline. Nonsignificant results could be explained by the small sample size of the study and the shortness of the intervention period. The difference in effect sizes produced by the 2 types of training on BMI or body fat could be explained by the different energy expenditure, because AVG cycling intervention spent 576.2 kcal, whereas stationary bike music group spent 554.6 kcal.

Maddison et al [51] investigated the effect of the EyeToy of PlayStation on the body composition of 322 children. Participants in the intervention group were encouraged to meet the recommendations of 60 minutes per day and to substitute periods of traditional inactive video games, and they received a PlayStation 2 and the EyeToy to play at home. Differences between control and intervention groups were found for BMI (0.24 kg/m²; 95% CI −0.44 to −0.04; *P*=.02), BMI z-score (0.06; 95% CI −0.12 to −0.03; *P*=.03), body weight (0.72 kg; 95% CI −1.33 to −0.10; *P*=.02), fat mass (0.80 kg; 95% CI −1.36 to −0.24; *P*=.005), and body fat percentage (0.83%; 95% CI −1.54 to −0.12; *P*=.02), favoring the AVG group. A year later, derived from the previous study, the authors studied the mediating effect of CRF on body composition and concluded that an AVG intervention with EyeToy can have a positive effect on body composition in children with overweight or obesity and that this effect is most likely mediated through an improvement in CRF [59]. Foley et al [44] divided the analyses of the previous study by subgroups such as ethnicity, sex, and CRF level, and the results showed that AVG can be used to improve body composition regardless of ethnicity, sex, and CRF level.

Staiano et al [56] studied the effect of playing Nintendo Wii on school days on the weight of adolescents and compared the effects between co-operative and competitive AVGs versus a control group. The results showed that the co-operative AVG group lost more weight than the control group, whereas the competitive AVG group did not differ from the co-operative AVG group and control group. The authors studied the effect of psychological variables on weight loss and, as expected, those who had higher peer support at baseline lost marginally more weight over time, but, unexpectedly, initial self-efficacy did not affect weight change over time, nor did higher self-esteem cause more weight loss over time. The 2 studies by Staiano et al [52,54] investigated the effects of AVG interventions using Xbox Kinect. In the first study [52], a dancing AVG had no effects on or differences between the AVG and control groups. The small sample size and the short length of the intervention could explain the nonsignificant effects of AVG. In the other study by Staiano et al [54], a home-based AVG intervention led to a reduction in the BMI z-score (mean −0.06, SD 0.03) and the weight z-score (mean −0.09, SD 0.05) in the AVG group in comparison with the control group (mean 0.03, SD 0.03 and mean 0.07, SD 0.04 for BMI z-score and weight z-score, respectively) when one control outlier was excluded. There was a nonsignificant intervention effect for fat mass or body fat percentage. This could be influenced by the small sample size, in addition to the fact that the performance in the sessions with AVG at home showed lower or no benefits.

Trost et al [55] compared the effects of a 16-week weight management program with family-based theoretical sessions focused on lifestyle and the effects of the same program with AVG intervention. The overweight rate was reduced by 5.4% in the weight management program without PA and 10.9% in the AVG group, with significant pre-post and between-group differences. Both groups exhibited reductions in BMI z-score, but the AVG group showed greater reductions (mean −0.25, SD 0.03 vs mean −0.11, SD 0.03).

The most recent study was conducted by Irandoust et al [62], and the results showed reductions in weight and BMI in the AVG and exercise groups from pretest to posttest, resulting in lower weight and BMI at posttest measures in these groups in comparison with the control group after a 6-week intervention using Xbox Kinect and Nintendo Wii.

Of the 13 studies, 4 reported no positive effects of an AVG intervention on BMI or body fat in children with overweight and obesity [42,52,53,57]. Apart from Staiano et al [52], no other authors found effects after an AVG intervention. Christison et al [42] compared the effects of weight management didactic sessions with an AVG intervention with Nintendo Wii and DDR. The results showed a trend of reduction in the BMI z-score in the AVG group, whereas the BMI z-score among the control group was essentially unchanged (*P*=.07). Wagener et al [53] showed no pre-post differences in BMI within or between conditions after 10 weeks of an AVG intervention by playing dance-based AVGs. Probably, no benefits of AVGs and even nonsignificant worse results on BMI for the AVG group were found because of the small sample size and the short length of intervention. There were same limitations in the study performed by Maloney et al [57], which showed that there were no changes between pretest and posttest participant weight in the AVG group or control group after 12 weeks of intervention with AVGs.

Furthermore, 5 noncontrolled studies observed positive effects of an AVG intervention on BMI or body fat in children with overweight and obesity. The most recent study was performed by Argarini et al [67], and the results showed a significant decrease in weight, BMI, and body fat percentage after a 4-week AVG intervention with Xbox Kinect. Christison et al [66] evaluated the efficacy of an AVG intervention and the results showed a significant decrease in BMI (mean −0.48, SD 0.93 kg/m²) and BMI z-score (mean −0.07, SD 0.14) after 10 weeks of training (*P*=.002 and *P*<.001, respectively). Duman et al [64] investigated the effects of a combination of music-accompanied aerobics, callisthenic exercises, and AVGs, and the results showed decrease in BMI and triceps skinfold thickness. The percentage of obese children decreased from 72% to 40%; those children who were obese became children with overweight, so the percentage of overweight children increased from 28% to 46%; the percentage of children with normal weight increased from 0% to 14%. Calcaterra et al [65] demonstrated the effectiveness of a combination of circuit-based aerobics and strength and resistance exercises with AVGs, showing a significant decrease in BMI (from 32.9 to 31.9 kg/m²; *P*=.002) and body fat percentage (from 39.3% to 36.0%; *P*=.001). A very interesting result of this study was that 27.2% of the participants reported a previous negative experience with exercise, so a reduced drop-out rate during activity may be achieved with a playful aspect and adapted activities such as AVGs. Finally, Huang et al [63] investigated the effect of AVGs using Nintendo Wii and Xbox Kinect, with no effects on the percentage of body fat, probably because of the short length of the intervention and the reduced number of participants.

Systematic reviews have been performed on the effects of AVG on BMI or body fat, but they are mostly not focused on children or adolescents with overweight or obesity and including studies with children with normal weight; some limitations can be found in these studies, such as the inclusion of noncontrolled trials. The results of these studies are in line with the results of this study. The latest systematic review was performed by Gao et al [68], who included noncontrolled trials and studies with children with normal weight. Reduction in BMI after AVG interventions was found in children and adolescents. Hernández-Jimenez et al [69] performed a meta-analysis that showed a significant effect in favor of AVGs on BMI in children and adolescents, with better results achieved when the AVG intervention was applied to children with overweight or obesity. Another systematic review [70] included 4 RCTs, which are also included in this systematic review, which reported decreases in BMI or body fat after an AVG intervention. A previous systematic review performed by Gao et al [31] concluded that AVGs were a promising tool to promote PA and health as long as the AVG intervention is not home based, but this review did not focus on children with overweight or obesity. Two systematic reviews [30,71] supported the findings, although being among the first reviews on the effects of AVGs, quantitative analyses were not conducted because of a lack of articles. Lamboglia et al [30] found that AVG led to increased PA and CRF and decreased body fat, with considerable potential to fight obesity. Leblanc et al [71] found that AVG attenuated weight gain in participants with overweight and obesity, including 3 articles that are included in this systematic review. The improvement of cardiometabolic health through AVG was inconclusive because of the small number of articles at the time.

Quality Assessment of BMI, Body Fat Percentage, and Fat Mass

As shown in Figure 2, positive effects of the interventions were found for BMI, favoring the AVG group compared with the control group with no intervention (MD −0.209; 95% CI −0.388 to −0.031). Heterogeneity among studies for BMI was low (I^2=0%; *P*=.70). AVG showed more positive effects on BMI z-score than on BMI (MD −0.066; 95% CI −0.124 to −0.01), but it also showed a very high heterogeneity (I^2=97.55%; *P*<.001; Figure 3). The results of the subgroup analysis by the length of the intervention showed that the decrease in BMI z-score was higher in the AVG interventions longer than 12 weeks.

As shown in Figure 4, positive effects of AVG interventions were found for body fat percentage, favoring the AVG group compared with the control group with no intervention (MD −0.462; 95% CI −0.819 to −0.105). Heterogeneity among studies for BMI was high (I^2=64.59%; *P*=.06).

These results clearly showed the influence of AVG intervention length on weight, BMI, and body fat percentage. Positive effects were observed for AVG interventions longer than 12 weeks. It seems that a combination of AVG with multicomponent exercises could have more benefits on BMI and body fat percentage in children and adolescents with overweight and obesity, but RCTs are needed to confirm this.

Waist Circumference

Changes in waist circumference were evaluated by 4 RCTs [42,51,52,58], and no effects were found. The first study was performed by Adamo et al [58] and showed no effects or differences between groups for waist circumference. Maddison et al [51] reported no changes in waist circumference after a 24-week AVG intervention with EyeToy performed at the participants' homes. Christison et al [42] performed a 6-month AVG intervention with Nintendo Wii and DDR; they also did not report positive effects or differences between groups. The most recent study on waist circumference in children and adolescents with overweight and obesity was performed by Staiano et al [52], who investigated the effects of Xbox Kinect and found no effect on waist circumference or differences between AVG and control groups.

The noncontrolled trial performed by Calcaterra et al [65] demonstrated a decrease in waist circumference (-5.9 cm) and waist circumference to height ratio (-0.08) after a 12-week training program combining traditional exercise with AVGs.

Quality Assessment of Waist Circumference

As shown in Figure 5, no overall effects were found on waist circumference after the AVG interventions (MD −0.426; 95% CI −1.295 to 0.444). Heterogeneity among studies for waist circumference was moderate (I^2=23.5%; *P*=.27). AVGs seem not to be effective in decreasing waist circumference in children and adolescents with overweight and obesity. It is necessary to look for a way to increase the demands of the activity.

Interventions with AVG do not seem to be effective in decreasing waist circumference in children and adolescents with overweight and obesity. This result may be because of the length of the interventions in the included articles. A reduction in the waist circumference in children with obesity seems to be possible with a combination of AVG with multicomponent exercise instead of AVG exclusively, but RCTs are needed to confirm this. Waist circumference is as important as BMI or body fat percentage because they are good predictors of cardiovascular disease risk factors in children and adolescents, even better than BMI [72]. Therefore, the main aim is to decrease waist circumference of children and adolescents with overweight and obesity. However, the results suggest that AVG interventions do not seem to be effective in decreasing waist circumference in children and adolescents with overweight and obesity.

Fat-Free Mass

The effects of AVG on fat-free mass were reported in 4 articles [51,52,54,58]. To measure fat-free mass, bioelectrical impedance [51,58] or dual-energy x-ray absorptiometry [52,54] were used. Maddison et al [51] did not find any effects or differences between groups for fat-free mass. Similar results were reported by Adamo et al [58], with no changes or differences between groups. In contrast, Staiano et al [52,54] reported no effects on lean mass after an AVG intervention. Evidence on the effect of AVGs on fat-free mass is limited, and no effects have been shown.

Quality Assessment of Fat-Free Mass

As shown in Figure 6, no overall effects were found for fat-free mass after the AVG interventions (MD 0.106; 95% CI −0.594 to 0.806). Heterogeneity among studies for waist circumference was low (I^2=0%; *P*=.52).

Cardiorespiratory Fitness

CRF assessments following their AVG interventions were included by 5 studies, and 4 of them managed to find positive results. In general, CRF was improved after an intervention with AVG, such as Nintendo Wii, DDR, EyeToy, or a cycling AVG.

The first study that reported the effects of AVG on CRF in adolescents with overweight and obesity was the study by Adamo et al [58], who observed a significant training effect over time in both AVG cycling and stationary bike interventions. Both interventions produced significant improvements in peak heart rate, peak workload, and time to exhaustion, but no significant differences were found between the exercise groups. With this same intervention, Goldfield et al [60] observed that the psychological benefits of aerobic exercises were related to improved aerobic fitness. The abovementioned study by Maddison et al [51] did not find significant increases in CRF in the AVG group, but the positive effect of AVG on body composition in children with overweight or obesity is most likely mediated through improved aerobic fitness [59]. Maloney et al [57] showed no improvements in CRF in either the AVG or control group after playing DDR for 12 weeks. Christison et al [42] showed that the number of shuttle runs did not change after a 6-month AVG intervention. The most recent study was conducted by Bonney et al [61], who investigated the effect of Wii Fit in comparison with a task-oriented functional training on the performance of the shuttle run test and positive effects on CRF in both groups, but no differences were found between the AVG and control groups performing the task-oriented functional training.

The effects of AVG on CRF in children with overweight and obesity have been studied by 2 noncontrolled trials [63,65]. Calcaterra et al [65] demonstrated in their study an improvement in CRF (3.8 mL/kg/min; *P*<.001) measured by a walking test on a treadmill reaching 85% of the maximal heart rate. Huang et al [63] showed no effects of AVG using Nintendo Wii and Xbox Kinect on CRF, but the heart rate demonstrated that most participants were able to achieve moderate or vigorous intensity of exercise during most AVG sessions.

The effect of AVG interventions on CRF remains unclear. Probably, the limited effects of AVG interventions on CRF of children with overweight and obesity might be because of insufficient training volume in terms of either weekly frequency or overall duration of the interventions. As mentioned earlier, interventions performed at home could be ineffective for improving health-related physical fitness, such as CRF. As it occurs in children with normal weight, only Calcaterra et al [65] used a submaximal or maximal incremental cardiopulmonary exercise test with a gas analyzer, which is widely recognized as the best single index of aerobic fitness [73,74]. Once again, science-based evidence shows that a combination of AVG with multicomponent exercise could produce more benefits on CRF than AVG exclusively, probably because of a higher volume of training. Therefore, these results must be interpreted with caution because the studies that report results from interventions using AVGs with multicomponent exercise are noncontrolled trials. RCTs are needed to confirm this finding.

A systematic review performed by Zeng and Gao [70] included only 1 RCT, also included in this systematic review, which reported positive effects of an AVG intervention in comparison with the effects of an exercise group, but these results were unclear because of the inclusion of only 1 article.

Muscular Fitness

Only 1 RCT [61] and 3 noncontrolled trials [63-65] investigated the effects of an AVG intervention on the muscular fitness of children and adolescents with overweight and obesity. The only RCT about the effects of AVGs on muscle fitness showed that both the AVG group trained with Wii Fit and the control group that performed a task-oriented functional training for 14 weeks improved knee extensors and ankle plantar flexors to maximal isometric strength assessed with a handheld dynamometer.

Calcaterra et al [65] demonstrated an increase in muscular strength, improving from a mean of 29.6 kg (SD 9.3 kg) to 32.3 kg (SD 9.8 kg; *P*=.003) in a handgrip test. Duman et al [64] investigated the effects of an AVG intervention combined with traditional exercise on several physical performance tests that require muscle strength and endurance, such as time to ascend and descend 20 stairs, number of squats they can perform in 120 seconds, time to run 50 m, and rope jumps in 30 seconds. The results showed enhancements in all test performances. Finally, Huang et al [63] investigated the effect of AVG using Nintendo Wii and Xbox Kinect on the muscular strength of the quadriceps and hamstrings that were assessed using a handheld dynamometer and muscular endurance that were assessed by a 1-minute half-sit-up test consisting of completing as many half-sit-ups as possible within a minute. Nonsignificant changes in the muscular strength of the quadriceps or muscular endurance were observed. Low frequency and program duration may explain the lack of significant changes.

A combination of AVG with multicomponent exercise could enhance muscular fitness in children with overweight and obesity, but RCTs are required to confirm these results. A systematic review and meta-analysis [5] showed the importance of muscular fitness for children and adolescents and found associations between muscle fitness and bone health, total and central adiposity, and cardiovascular diseases, metabolic risk factors and self-esteem. In addition, according to Tomlinson et al [75], children and adolescents with overweight and obesity have a greater absolute maximum muscle strength than nonobese persons because increased adiposity induces a chronic overload stimulus on the antigravity muscles; however, when maximum muscular strength is normalized to body mass, individuals with obesity appear weaker, probably because of reduced mobility, neural adaptations, and changes in muscle morphology. Therefore, it is important to include exercises aimed at improving muscular fitness in programs for children and adolescents with overweight and obesity.

Motor Competence

Motor competence after an AVG intervention was reported in 2 articles. The first was performed by Van Biljon et al [50], and motor competence was evaluated in 30 individuals with overweight and obesity using the shorter version of the Bruininks-Oseretsky test for motor proficiency. The intervention group performed a 6-week AVG intervention for 3 days per week and 30 minutes per session using Wii; there were 2 control groups, one with access to traditional video games and the other continued with their everyday life activities with no intervention. The AVG group showed improvements in motor competence compared with both control groups, specifically in terms of agility and speed, co-ordination, and reaction time. Another more recent study by Bonney et al [61] showed that both the AVG group that trained with Wii Fit and the control group that performed a task-oriented functional training for 14 weeks improved motor co-ordination, as measured by the Movement Assessment Battery for Children Test-Second Edition. A notable difference between the controlled trials investigating the effect of AVG on motor competence is the length of the intervention; therefore, the study with the longest duration of the intervention [61] (14 weeks) showed positive effects, whereas the one with the shortest duration [50] (6 weeks) showed no effect after the AVG intervention. Another study with no control group showed an improvement in motor competence after 4 weeks of training with Xbox Kinect [67]. This scarcity of studies investigating the effect of AVG on the motor competence of children and adolescents with overweight and obesity is of great importance, given that evidence shows a relationship between motor competence and health-related physical fitness during childhood and adolescence [20], as mentioned earlier. Furthermore, low motor competence, denominated as *physical illiteracy*, is a component of the pediatric inactivity triad observed by Faigenbaum et al [76], together with exercise deficit disorder and pediatric dynapenia. These 3 components are closely related to each other. Children and adolescents who perceive themselves as having poor motor competence might feel less inclined to participate in PA or sports, which in turn will reduce their ability to improve their muscular fitness or motor competence. Motor competence is particularly important in children and adolescents with overweight and obesity, as they have a lower motor competence level than children and adolescents with a healthy weight [16]; this has health consequences because it is directly related to PA. Improving motor competence could increase PA, reduce sedentary behaviors, and positively impact health-related physical fitness [16,77]. Improvements in motor competence entail higher motivation and participation in extracurricular PA and sports [18,19]. AVGs could be a tool for improving motor competence, but randomized clinical trials are needed to corroborate this.

Interventions with AVG appear to be more effective in decreasing BMI and body fat in children and adolescents with overweight or obesity than in children with normal weight, but effectiveness in other health-related physical fitness parameters such as waist circumference or CRF is still unclear. Children and adolescents with overweight or obesity could benefit from AVGs to improve their motor competence, which seems to be a variable more susceptible to enhancement as improvements have been observed with shorter interventions, but further research is needed to confirm this hypothesis. Therefore, AVG programs could be a good strategy to combat childhood obesity.

Discussion

Principal Findings

This paper provides knowledge about the effects of AVG on health-related physical fitness and motor competence in children and adolescents by gathering previous scientific evidence, and it also provides the prospects for future studies.

Mental health can be considered as a major influencing variable and can undoubtedly influence the effects of AVG interventions on childhood obesity; however, this systematic review has focused on the effects of AVG interventions on health-related physical fitness and motor competence in children and adolescents with overweight and obesity, discarding the psychological aspects. However, a very recent overview [37] and a systematic review [36] found a positive effect of AVG on mental health, but it also showed the need for increasing scientific research in this area.

In contrast, the participants in the studies included in this review were from countries with a medium-to-high socioeconomic status; this leads to the limitation that such AVG interventions are difficult to implement or are not applicable in countries with a low socioeconomic status because of the lack of resources and lower purchasing power. It would be interesting to study the feasibility and possibilities of such interventions in societies with low socioeconomic status.

Furthermore, studies investigating the effects of AVG in children with obesity with some information from geohash dashboards related to the environment where the participants live and where the school is located can be useful to increase the strength of the hypothesis on how AVG affects the features addressed, as there are several features where weak correlation has been found with AVG use, as. As stated earlier, it is necessary to establish the guidelines for an effective intervention using AVGs. It seems that the most effective application of an AVG intervention is a sufficient duration and the structuring and planning of that intervention. In addition, most of the scientific evidence that has studied AVG interventions combined with traditional exercise lacked a control group to compare the effects; these AVG interventions seem to be promising, but RCTs are needed to investigate the effects of these AVG interventions.

Finally, few studies have examined the effects of an AVG intervention on muscular fitness and motor competence, which, as mentioned earlier, are components of the pediatric inactivity triad observed by Faigenbaum et al [76] together with exercise deficit disorder. The importance of these 2 variables lies in their close relationship with PA and sports participation, which can improve the physical fitness and body composition of children and adolescents, which is especially important in those who are overweight or obese. By improving the muscle strength and motor skill of these children and adolescents, we may make them more active and therefore healthier.

RCTs are needed to investigate the effects of AVG interventions on children's muscle strength and motor skills to learn about the possibilities of AVG interventions in stopping the vicious circle of pediatric inactivity triad.

Limitations

The limitations of this review should be acknowledged. A wide variety of AVG interventions have been included, with different devices and training interventions (duration, frequency, training setting or training dynamic, and type of AVG), which makes it difficult to analyze all the articles together and to obtain generalized results. In addition, the potential risk of bias of some studies was not considered when interpreting the results. Finally, some subgroup analyses were not performed because of the small number of controlled trials. Gender, demographics, or race influence were not deeply addressed because the studies did not show the results divided by these covariates. However, it would be interesting to investigate whether such interventions are more effective depending on them.

Strengths

This study also has several strengths. To the best of our knowledge, this is the first meta-analysis to summarize the existing research on the effects of AVG on health-related physical fitness and motor competence in children and adolescents with overweight and obesity. This analysis included not only the effects of AVG on BMI, but also those on body composition, CRF, muscular fitness, and motor competence. This study allowed us to realize that more RCTs reporting motor competence and muscular fitness results are needed.

Conclusions

AVGs could be a good strategy to fight childhood obesity. AVG programs showed positive effects on BMI and body fat percentage. Improvements in CRF have been observed after an AVG intervention. Children and adolescents could benefit from AVGs to improve motor competence, but further research is needed to confirm these results. The effects of AVG programs on muscular fitness or fat-free mass are also unclear.

In conclusion, AVGs seem to be an effective tool to improve health-related physical fitness and is a promising tool for improving motor competence in children and adolescents. AVGs can even be considered as a prospective alternative to traditional exercise for enhancing health status during childhood.

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Authors' Contributions

All authors have been actively involved in the planning and execution of this study. AGA and JAC were the main researchers in this study, and CCC is the first author. AML, JMP, and GVR were coresearchers. CCC and AGA independently evaluated all the studies. CCC drafted the document, and JMP, AML, GVR, JAC, and AGA critically reviewed the document. All authors read and approved the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 item Checklist.
[PDF File (Adobe PDF File), 231 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Descriptive characteristics of included noncontrolled trials.
[PDF File (Adobe PDF File), 195 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Quality assessment of randomized controlled trials.
[PDF File (Adobe PDF File), 13 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Descriptive characteristics of included studies with children with overweight and obesity.
[PDF File (Adobe PDF File), 29 KB-Multimedia Appendix 4]

References

1. Ahluwalia N, Dalmasso P, Rasmussen M, Lipsky L, Currie C, Haug E, et al. Trends in overweight prevalence among 11-, 13- and 15-year-olds in 25 countries in Europe, Canada and USA from 2002 to 2010. Eur J Public Health 2015 Apr;25 Suppl 2:28-32. [doi: 10.1093/eurpub/ckv016] [Medline: 25805783]
2. Nittari G, Scuri S, Petrelli F, Pirillo I, di Luca NM, Grappasonni I. Fighting obesity in children from European World Health Organization member states. Epidemiological data, medical-social aspects, and prevention programs. Clin Ter 2019;170(3):223-230 [FREE Full text] [doi: 10.7417/CT.2019.2137] [Medline: 31173054]
3. McCrindle BW. Cardiovascular consequences of childhood obesity. Can J Cardiol 2015 Feb;31(2):124-130. [doi: 10.1016/j.cjca.2014.08.017] [Medline: 25661547]
4. Gurnani M, Birken C, Hamilton J. Childhood obesity: causes, consequences, and management. Pediatr Clin North Am 2015 Aug;62(4):821-840. [doi: 10.1016/j.pcl.2015.04.001] [Medline: 26210619]
5. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. Sports Med 2014 Sep;44(9):1209-1223. [doi: 10.1007/s40279-014-0196-4] [Medline: 24788950]
6. Cesa CC, Sbruzzi G, Ribeiro RA, Barbiero SM, de Oliveira Petkowicz R, Eibel B, et al. Physical activity and cardiovascular risk factors in children: meta-analysis of randomized clinical trials. Prev Med 2014 Dec;69:54-62. [doi: 10.1016/j.ypmed.2014.08.014] [Medline: 25175591]
7. American College of Sports Medicine. Acsm's Health-related Physical Fitness Assessment Manual. 5th Ed. Philadelphia, Pennsylvania, United States: Lippincott Williams & Wilkins; 2013.
8. Casonatto J, Fernandes RA, Batista MB, Cyrino ES, Coelho-E-Silva MJ, de Arruda M, et al. Association between health-related physical fitness and body mass index status in children. J Child Health Care 2016 Sep;20(3):294-303. [doi: 10.1177/1367493515598645] [Medline: 26396021]
9. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med 2020 Dec;54(24):1451-1462 [FREE Full text] [doi: 10.1136/bjsports-2020-102955] [Medline: 33239350]
10. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc Health 2020 Jan;4(1):23-35 [FREE Full text] [doi: 10.1016/S2352-4642(19)30323-2] [Medline: 31761562]
11. Marques A, Santos R, Ekelund U, Sardinha LB. Association between physical activity, sedentary time, and healthy fitness in youth. Med Sci Sports Exerc 2015 Mar;47(3):575-580. [doi: 10.1249/MSS.0000000000000426] [Medline: 24977696]
12. Júdice PB, Silva AM, Berria J, Petroski EL, Ekelund U, Sardinha LB. Sedentary patterns, physical activity and health-related physical fitness in youth: a cross-sectional study. Int J Behav Nutr Phys Act 2017 Mar 04;14(1):25 [FREE Full text] [doi: 10.1186/s12966-017-0481-3] [Medline: 28259140]
13. Forde C, Hussey J. How children use active videogames and the association between screen time and physical activity. Games Health J 2015 Aug;4(4):312-317. [doi: 10.1089/g4h.2014.0135] [Medline: 26182219]
14. Childhood obesity surveillance initiative. World Health Organization. 2016. URL: https://www.euro.who.int/__data/assets/pdf_file/0006/372426/WH14_COSI_factsheets_v2.pdf [accessed 2021-01-04]
15. Hardy LL, Ding D, Peralta LR, Mihrshahi S, Merom D. Association between sitting, screen time, fitness domains, and fundamental motor skills in children aged 5-16 years: cross-sectional population study. J Phys Act Health 2018 Dec 01;15(12):933-940. [doi: 10.1123/jpah.2017-0620] [Medline: 30404565]
16. Han A, Fu A, Cobley S, Sanders RH. Effectiveness of exercise intervention on improving fundamental movement skills and motor coordination in overweight/obese children and adolescents: a systematic review. J Sci Med Sport 2018 Jan;21(1):89-102. [doi: 10.1016/j.jsams.2017.07.001] [Medline: 28728887]
17. De Meester A, Stodden D, Brian A, True L, Cardon G, Tallir I, et al. Associations among elementary school children's actual motor competence, perceived motor competence, physical activity and BMI: a cross-sectional study. PLoS One 2016;11(10):e0164600 [FREE Full text] [doi: 10.1371/journal.pone.0164600] [Medline: 27736964]
18. De Meester A, Maes J, Stodden D, Cardon G, Goodway J, Lenoir M, et al. Identifying profiles of actual and perceived motor competence among adolescents: associations with motivation, physical activity, and sports participation. J Sports Sci 2016 Nov;34(21):2027-2037. [doi: 10.1080/02640414.2016.1149608] [Medline: 26928601]
19. Bardid F, De Meester A, Tallir I, Cardon G, Lenoir M, Haerens L. Configurations of actual and perceived motor competence among children: associations with motivation for sports and global self-worth. Hum Mov Sci 2016 Dec;50:1-9. [doi: 10.1016/j.humov.2016.09.001] [Medline: 27620643]

20. Luz C, Rodrigues LP, Meester AD, Cordovil R. The relationship between motor competence and health-related fitness in children and adolescents. PLoS One 2017;12(6):e0179993 [FREE Full text] [doi: 10.1371/journal.pone.0179993] [Medline: 28658292]
21. Stoner L, Rowlands D, Morrison A, Credeur D, Hamlin M, Gaffney K, et al. Efficacy of exercise intervention for weight loss in overweight and obese adolescents: meta-analysis and implications. Sports Med 2016 May 2:1737-1751. [doi: 10.1007/s40279-016-0537-6] [Medline: 27139723]
22. The power of physical activity. Exercise is Medicine - American College of Sport Medicine. URL: https://www.exerciseismedicine.org/support_page.php/physical-activity-health-impact/ [accessed 2020-08-16]
23. Beedie C, Mann S, Jimenez A, Kennedy L, Lane AM, Domone S, et al. Death by effectiveness: exercise as medicine caught in the efficacy trap!. Br J Sports Med 2016 Mar;50(6):323-324 [FREE Full text] [doi: 10.1136/bjsports-2014-094389] [Medline: 25807166]
24. Oh Y, Yang S. Defining exergames and exergaming. In: Proceedings of the Meaningful Play 2010 Conference. 2010 Presented at: Meaningful Play 2010 Conference; Oct. 21-13, 2010; East Lansing, MI, USA URL: https://meaningfulplay.msu.edu/proceedings2010/
25. Liang Y, Lau PW. Effects of active videogames on physical activity and related outcomes among healthy children: a systematic review. Games Health J 2014 Jun;3(3):122-144. [doi: 10.1089/g4h.2013.0070] [Medline: 26196172]
26. Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: a systematic review. Arch Pediatr Adolesc Med 2010 Jul;164(7):664-672. [doi: 10.1001/archpediatrics.2010.104] [Medline: 20603468]
27. Bailey BW, McInnis K. Energy cost of exergaming: a comparison of the energy cost of 6 forms of exergaming. Arch Pediatr Adolesc Med 2011 Jul;165(7):597-602. [doi: 10.1001/archpediatrics.2011.15] [Medline: 21383255]
28. Comeras-Chueca C, Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, et al. Assessment of active video games' energy expenditure in children with overweight and obesity and differences by gender. Int J Environ Res Public Health 2020 Sep 15;17(18):6714 [FREE Full text] [doi: 10.3390/ijerph17186714] [Medline: 32942663]
29. De BJ, Perrier-Melo R, Melo DO, De SP, Da CC. Physical effort, energy expenditure, and motivation in structured and unstructured active video games: a randomized controlled trial. Hum Move 2016;17(3):198. [doi: 10.1515/humo-2016-0021]
30. Lamboglia CM, da Silva VT, de Vasconcelos Filho JE, Pinheiro MH, Munguba MC, Silva Júnior FV, et al. Exergaming as a strategic tool in the fight against childhood obesity: a systematic review. J Obes 2013;2013:438364 [FREE Full text] [doi: 10.1155/2013/438364] [Medline: 24319594]
31. Gao Z, Chen S. Are field-based exergames useful in preventing childhood obesity? A systematic review. Obes Rev 2014 Aug;15(8):676-691. [doi: 10.1111/obr.12164] [Medline: 24602072]
32. Gao Z, Chen S, Pasco D, Pope Z. A meta-analysis of active video games on health outcomes among children and adolescents. Obes Rev 2015 Sep;16(9):783-794. [doi: 10.1111/obr.12287] [Medline: 25943852]
33. Kari T. Can exergaming promote physical fitness and physical activity?: a systematic review of systematic reviews. Int J Gaming Comput Med Simulations 2014;6(4):77. [doi: 10.4018/ijgcms.2014100105]
34. Joronen K, Aikasalo A, Suvitie A. Nonphysical effects of exergames on child and adolescent well-being: a comprehensive systematic review. Scand J Caring Sci 2017 Sep;31(3):449-461. [doi: 10.1111/scs.12393] [Medline: 27862145]
35. Fu Y, Burns RD, Gomes E, Savignac A, Constantino N. Trends in sedentary behavior, physical activity, and motivation during a classroom-based active video game program. Int J Environ Res Public Health 2019 Aug 07;16(16):2821 [FREE Full text] [doi: 10.3390/ijerph16162821] [Medline: 31394855]
36. Andrade A, Correia CK, Coimbra DR. The psychological effects of exergames for children and adolescents with obesity: a systematic review and meta-analysis. Cyberpsychol Behav Soc Netw 2019 Nov;22(11):724-735. [doi: 10.1089/cyber.2019.0341] [Medline: 31697604]
37. Santos IK, Medeiros RC, Medeiros JA, Almeida-Neto PF, Sena DC, Cobucci RN, et al. Active video games for improving mental health and physical fitness-an alternative for children and adolescents during social isolation: an overview. Int J Environ Res Public Health 2021 Feb 09;18(4):1-13 [FREE Full text] [doi: 10.3390/ijerph18041641] [Medline: 33572159]
38. Fu Y, Burns RD, Constantino N, Zhang P. Differences in step counts, motor competence, and enjoyment between an exergaming group and a non-exergaming group. Games Health J 2018 Oct;7(5):335-340. [doi: 10.1089/g4h.2017.0188] [Medline: 29989430]
39. McGann J, Issartel J, Hederman L, Conlan O. Hop.Skip.Jump.Games: The effect of "principled" exergameplay on children's locomotor skill acquisition. Br J Educ Technol 2019 Nov 13;51(3):798-816. [doi: 10.1111/bjet.12886]
40. Gao Z, Zeng N, Pope ZC, Wang R, Yu F. Effects of exergaming on motor skill competence, perceived competence, and physical activity in preschool children. J Sport Health Sci 2019 Mar;8(2):106-113 [FREE Full text] [doi: 10.1016/j.jshs.2018.12.001] [Medline: 30997256]
41. Chen H, Sun H. Effects of active videogame and sports, play, and active recreation for kids physical education on children's health-related fitness and enjoyment. Games Health J 2017 Oct;6(5):312-318. [doi: 10.1089/g4h.2017.0001] [Medline: 28704072]

42. Christison AL, Evans TA, Bleess BB, Wang H, Aldag JC, Binns HJ. Exergaming for health: a randomized study of community-based exergaming curriculum in pediatric weight management. Games Health J 2016 Dec;5(6):413-421. [doi: 10.1089/g4h.2015.0097] [Medline: 27911621]
43. Fu Y, Burns RD. Effect of an active video gaming classroom curriculum on health-related fitness, school day step counts, and motivation in sixth graders. J Phys Act Health 2018 Sep 01;15(9):644-650. [doi: 10.1123/jpah.2017-0481] [Medline: 29741441]
44. Foley L, Jiang Y, Ni Mhurchu C, Jull A, Prapavessis H, Rodgers A, et al. The effect of active video games by ethnicity, sex and fitness: subgroup analysis from a randomised controlled trial. Int J Behav Nutr Phys Act 2014 Apr 03;11(1):46 [FREE Full text] [doi: 10.1186/1479-5868-11-46] [Medline: 24694082]
45. Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M. Cochrane handbook for systematic reviews of interventions version 6.2. Cochrane Training. 2021. URL: https://training.cochrane.org/handbook/current [accessed 2021-03-05]
46. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Br Med J 2021 Mar 29;372:n71 [FREE Full text] [doi: 10.1136/bmj.n71] [Medline: 33782057]
47. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. Br Med J 2015 Jan 02;350:g7647 [FREE Full text] [doi: 10.1136/bmj.g7647] [Medline: 25555855]
48. Sterne JA, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. Br Med J 2019 Aug 28;366:l4898. [doi: 10.1136/bmj.l4898] [Medline: 31462531]
49. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. Br Med J 2016 Oct 12;355:i4919 [FREE Full text] [doi: 10.1136/bmj.i4919] [Medline: 27733354]
50. Van Biljon A, Longhurst G. The influence of exergaming on the functional fitness in overweight and obese children. Afr J Phys Act Health Sci 2012;18(4):991 [FREE Full text]
51. Maddison R, Foley L, Ni MC, Jiang Y, Jull A, Prapavessis H, et al. Effects of active video games on body composition: a randomized controlled trial. Am J Clin Nutr 2011 Jul;94(1):156-163 [FREE Full text] [doi: 10.3945/ajcn.110.009142] [Medline: 21562081]
52. Staiano AE, Marker AM, Beyl RA, Hsia DS, Katzmarzyk PT, Newton RL. A randomized controlled trial of dance exergaming for exercise training in overweight and obese adolescent girls. Pediatr Obes 2017 Dec;12(2):120-128 [FREE Full text] [doi: 10.1111/ijpo.12117] [Medline: 26918815]
53. Wagener TL, Fedele DA, Mignogna MR, Hester CN, Gillaspy SR. Psychological effects of dance-based group exergaming in obese adolescents. Pediatr Obes 2012 Oct;7(5):68-74. [doi: 10.1111/j.2047-6310.2012.00065.x] [Medline: 22767495]
54. Staiano AE, Beyl RA, Guan W, Hendrick CA, Hsia DS, Newton RL. Home-based exergaming among children with overweight and obesity: a randomized clinical trial. Pediatr Obes 2018 Nov;13(11):724-733 [FREE Full text] [doi: 10.1111/ijpo.12438] [Medline: 30027607]
55. Trost SG, Sundal D, Foster GD, Lent MR, Vojta D. Effects of a pediatric weight management program with and without active video games a randomized trial. JAMA Pediatr 2014 May;168(5):407-413. [doi: 10.1001/jamapediatrics.2013.3436] [Medline: 24589566]
56. Staiano AE, Abraham AA, Calvert SL. Adolescent exergame play for weight loss and psychosocial improvement: a controlled physical activity intervention. Obesity (Silver Spring) 2013 Mar;21(3):598-601 [FREE Full text] [doi: 10.1002/oby.20282] [Medline: 23592669]
57. Maloney AE, Threlkeld KA, Cook WL. Comparative effectiveness of a 12-week physical activity intervention for overweight and obese youth: exergaming with "Dance Dance Revolution". Games Health J 2012 Apr;1(2):96-103. [doi: 10.1089/g4h.2011.0009] [Medline: 26193183]
58. Adamo KB, Rutherford JA, Goldfield GS. Effects of interactive video game cycling on overweight and obese adolescent health. Appl Physiol Nutr Metab 2010 Dec;35(6):805-815. [doi: 10.1139/H10-078] [Medline: 21164552]
59. Maddison R, Mhurchu CN, Jull A, Prapavessis H, Foley LS, Jiang Y. Active video games: the mediating effect of aerobic fitness on body composition. Int J Behav Nutr Phys Act 2012 May 03;9:54 [FREE Full text] [doi: 10.1186/1479-5868-9-54] [Medline: 22554052]
60. Goldfield GS, Adamo KB, Rutherford J, Murray M. The effects of aerobic exercise on psychosocial functioning of adolescents who are overweight or obese. J Pediatr Psychol 2012;37(10):1136-1147. [doi: 10.1093/jpepsy/jss084] [Medline: 23027721]
61. Bonney E, Ferguson G, Burgess T, Smits-Engelsman B. Benefits of activity-based interventions among female adolescents who are overweight and obese. Pediatr Phys Ther 2019 Oct;31(4):338-345. [doi: 10.1097/PEP.0000000000000636] [Medline: 31568378]
62. Irandoust K, Taheri M, H'mida C, Neto GR, Trabelsi K, Ammar A, et al. Exergaming and aquatic exercises affect lung function and weight loss in obese children. Int J Sports Med 2021 Jun;42(6):566-572. [doi: 10.1055/a-1289-9307] [Medline: 33176381]
63. Huang H, Cook L, Harrison J, O'Keefe N, Schultz K, Curtis D. Exercise by playing active video gaming in overweight and obese children. J Phys Ther Sport Med 2017;1(1):1000107. [doi: 10.35841/physical-therapy.1.1.25-31]

64. Duman F, Kokaçya MH, Doğru E, Katayıfcı N, Canbay O, Aman F. The role of active video-accompanied exercises in improvement of the obese state in children: a prospective study from Turkey. J Clin Res Pediatr Endocrinol 2016 Sep 01;8(3):334-340 [FREE Full text] [doi: 10.4274/jcrpe.2284] [Medline: 27087547]
65. Calcaterra V, Larizza D, Codrons E, De Silvestri A, Brambilla P, Abela S, et al. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. J Pediatr Endocrinol Metab 2013;26(3-4):271-276. [doi: 10.1515/jpem-2012-0157] [Medline: 23327787]
66. Christison A, Khan HA. Exergaming for health: a community-based pediatric weight management program using active video gaming. Clin Pediatr (Phila) 2012 Apr;51(4):382-388. [doi: 10.1177/0009922811429480] [Medline: 22157430]
67. Argarini R, Herawati L, Irwadi I, Arum CP, Meinar SG. Fundamental movement skill approach to combat childhood obesity in Surabaya, Indonesia: potential effects of video games based exercises (Exergaming). Talent Dev Excell 2020;12(1):3026-3034 [FREE Full text]
68. Gao Z, Zeng N, McDonough DJ, Su X. A systematic review of active video games on youth's body composition and physical activity. Int J Sports Med 2020 Aug;41(9):561-573. [doi: 10.1055/a-1152-4959] [Medline: 32375184]
69. Hernández-Jiménez C, Sarabia R, Paz-Zulueta M, Paras-Bravo P, Pellico A, Ruiz Azcona L, et al. Impact of active video games on body mass index in children and adolescents: systematic review and meta-analysis evaluating the quality of primary studies. Int J Environ Res Public Health 2019 Jul 08;16(13):2424 [FREE Full text] [doi: 10.3390/ijerph16132424] [Medline: 31288460]
70. Zeng N, Gao Z. Exergaming and obesity in youth: current perspectives. Int J Gen Med 2016;9:275-284 [FREE Full text] [doi: 10.2147/IJGM.S99025] [Medline: 27536158]
71. LeBlanc AG, Chaput J, McFarlane A, Colley RC, Thivel D, Biddle SJ, et al. Active video games and health indicators in children and youth: a systematic review. PLoS One 2013;8(6):e65351 [FREE Full text] [doi: 10.1371/journal.pone.0065351] [Medline: 23799008]
72. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000 Nov;24(11):1453-1458. [doi: 10.1038/sj.ijo.0801401] [Medline: 11126342]
73. Van Brussel M, Bongers BC, Hulzebos EH, Burghard M, Takken T. A systematic approach to interpreting the cardiopulmonary exercise test in pediatrics. Pediatr Exerc Sci 2019 May 01;31(2):194-203. [doi: 10.1123/pes.2018-0235] [Medline: 30691356]
74. Armstrong N, Welsman J, Winsley R. Is peak VO2 a maximal index of children's aerobic fitness? Int J Sports Med 1996 Jul;17(5):356-359. [doi: 10.1055/s-2007-972860] [Medline: 8858407]
75. Tomlinson DJ, Erskine RM, Morse CI, Winwood K, Onambélé-Pearson G. The impact of obesity on skeletal muscle strength and structure through adolescence to old age. Biogerontology 2016 Jun;17(3):467-483 [FREE Full text] [doi: 10.1007/s10522-015-9626-4] [Medline: 26667010]
76. Faigenbaum AD, Rebullido TR, MacDonald JP. Pediatric inactivity triad: a risky PIT. Curr Sports Med Rep 2018 Feb;17(2):45-47. [doi: 10.1249/JSR.0000000000000450] [Medline: 29420346]
77. Cheng J, East P, Blanco E, Sim EK, Castillo M, Lozoff B, et al. Obesity leads to declines in motor skills across childhood. Child Care Health Dev 2016 May;42(3):343-350 [FREE Full text] [doi: 10.1111/cch.12336] [Medline: 27059409]

Abbreviations

AVG: active video game
CRF: cardiorespiratory fitness
DDR: Dance Dance Revolution
MD: mean difference
PA: physical activity
PICOS: Population, Intervention, Comparison, Outcomes and Study
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial
ROBINS-I: Risk of Bias in Nonrandomized Studies-of Interventions

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5.2 Artículo II

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Review

The Effects of Active Video Games on Health-Related Physical Fitness and Motor Competence in Children and Adolescents with Healthy Weight: A Systematic Review and Meta-Analysis

Cristina Comeras-Chueca [1,2,3], Jorge Marin-Puyalto [2,3,4,5], Angel Matute-Llorente [2,3,4,5,6], German Vicente-Rodriguez [2,3,4,5,6], Jose A. Casajus [1,2,3,5,6] and Alex Gonzalez-Aguero [2,3,4,5,6,*]

1 Department of Physiatry and Nursing, Faculty of Health Science, Universidad de Zaragoza, 50009 Zaragoza, Spain; ccomeras@unizar.es (C.C.-C.); joseant@unizar.es (J.A.C.)
2 GENUD (Growth, Exercise, Nutrition and Development) Research Group, 50009 Zaragoza, Spain; jmarinp@unizar.es (J.M.-P.); amatute@unizar.es (A.M.-L.); gervicen@unizar.es (G.V.-R.)
3 EXERNET, Red de Investigación en Ejercicio Físico y Salud Para Poblaciones Especiales, 50009 Zaragoza, Spain
4 Department of Physiatry and Nursing, Faculty of Health and Sport Science (FCSD), Universidad de Zaragoza, 22001 Huesca, Spain
5 Instituto Agroalimentario de Aragón—IA2—(CITA-Universidad de Zaragoza), 50009 Zaragoza, Spain
6 Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición (CIBERObn), 50009 Zaragoza, Spain
* Correspondence: alexgonz@unizar.es

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Abstract: (1) Background: Poor levels of physical fitness and motor skills are problems for today's children. Active video games (AVG) could be an attractive strategy to help address them. The aim was to investigate the effects of AVG on health-related physical fitness and motor competence in children and adolescents with healthy weight. (2) Methods: Randomized and non-randomized controlled trials investigating the effects of AVG programs on health-related physical fitness and motor competence were included. Two different quality assessment tools were used to measure the risk of bias. Twenty articles met the inclusion criteria and the variables of interest were body mass index (BMI), body fat, cardiorespiratory fitness (CRF), muscular fitness and motor competence. (3) Results: AVG interventions seem to have benefits in BMI when lasting longer than 18 weeks (SMD, −0.590; 95% IC, −1.071, −0.108) and in CRF (SMD, 0.438; 95% IC, 0.022, 0.855). AVG seems to be a promising tool to improve muscular fitness and motor competence but the effects are still unclear due to the lack of evidence. (4) Conclusions: AVG seem to be an effective tool for improving some components of health-related physical fitness and motor competence in healthy-weight children and adolescents, but the effect on some fitness components needs further research. Therefore, AVG may be included as a strategy to improve health.

Keywords: exergames; fitness; motor competence; youth; Pediatric Inactivity Triad

1. Introduction

Childhood and adolescence are decisive periods because numerous physical, physiological and psychological changes take place [1]. In fact, lifestyle, understood as the habits and behaviors that, whether healthy or not, are acquired during these stages and have a clear influence on adult health [1,2]. Physical activity (PA) is generally considered a healthy lifestyle directly related to health but also to physical fitness [3,4]; being also true that although fitness has an important genetic component, it is also associated with active and sedentary behaviors [4,5].

Health-related physical fitness is currently considered one of the most important health markers [1,3]. The level of physical fitness is a predictor of morbidity and mortality for cardiovascular and metabolic disease and for all causes of death in life [1,4–6]. Improving health-related physical fitness, mainly cardiovascular and muscular fitness and body composition, is a means to improve health [2].

Children with a low cardiorespiratory fitness (CRF) level are more likely to exceed the healthy weight body mass index (BMI) status [2]. This is important because childhood obesity is one of the most important public health problems of the 21st century [7] and prevalence of childhood overweight and obesity has acquired the status of an epidemic; for instance, in 2016, the prevalence of overweight was over 30% and the prevalence of obesity was over 10% in European children and adolescents [8]. It therefore seems that a good early obesity prevention strategy could be to increase the levels of PA [9] and physical fitness [10] of young people, which are anyway interrelated and will also have an impact on each other [4].

PA is one of the most important factors in CRF [4] and it has a great influence on body composition [9]. PA has been widely and favorably associated with body fat, cardiometabolic biomarkers, physical fitness, bone health, motor competence and, in short, the quality of life; and insufficient PA is one of the main risk factors for non-communicable diseases and for premature death [11]. The recommendation of WHO indicates that an average of 60 min of moderate-to-vigorous PA daily provides benefits for health in young people, although PA beyond 60 min of moderate-to-vigorous PA daily provides additional benefits [12]. However, a large proportion of the children and adolescents do not meet the public health recommendations of PA, as showed in 2016, in a study of 1.6 million students aged 11–17 in which 81.0% of them did not meet this recommendation [13].

Physical inactivity in youth is a serious problem in today's society and is included in the Pediatric Inactivity Triad (PIT) by Faigenbaum et al. [14], which comprised three interrelated components: exercise deficit disorder, pediatric dynapenia, and physical illiteracy. The exercise deficit disorder is the term used to describe those children and adolescents that do not meet the current public health recommendations of PA and this term pretend "to highlight the gravity of this clinical condition" [14]. This exercise deficit disorder often leads to an excessive increase in body fat and a low fitness level [11].

The PIT notes the importance of muscular endurance and strength. Scientific evidence shows a trend of decline in muscle fitness compared to previous years [15–17]. Therefore, global trends indicate that children have a poorer level of muscular fitness than previous generations, which is related to a lower level of motor skills, PA and organized-sports participation [18,19]. A systematic review about trends in muscular fitness between 1972 and 2015 showed small increases in the relative muscular strength and speed while proxies of muscle power declined [20]. Muscular fitness is important in the development of children because "strength is the staple that holds other fitness components together" [18], together with its relationship with motor competence [14,20].

Further, the PIT highlights highlight the relevance of motor competence [14], understand as motor skill proficiency. The primary school years are considered the key stage to develop motor competence and to adopt an active or inactive lifestyle [21]. Motor competence positively correlated with PA and health-related physical fitness [22–24], which reinforces the importance of including the improvement of motor competence in the main objectives of physical exercise interventions for children and adolescents [25].

The decreased levels of PA and health-related physical fitness in children and adolescents are associated with adverse consequences on their health such as obesity, type II diabetes, cardiovascular and metabolic diseases, etc. [6] It is well known that exercise is an effective tool to obtain all the holistic benefits of exercise, such as improvements in BMI status or adiposity, in cardiorespiratory and muscular fitness or in bone health [26]. However, the main challenge is to ensure adherence to exercise [27], especially in the young population with particular possibilities of low practice.

Active-video games (AVG) have been proposed as a good alternative aiming to motivate those (young or not) who find sport less interesting, partly due to their body composition, poor performance or low motor skills. Scientific literature has shown the potential of AVG to increase the energy expenditure and to replace sedentary behaviors by promoting light-to-moderate PA [28–34]. Although some studies have reported the benefits of AVG on body composition [35], CRF [36], and motor competence [37,38], the effects of AVG on health-related physical fitness need further investigation because of the importance it can have for their present and future health.

It is therefore necessary to ascertain the potential of AVG for improving health in children and adolescents with healthy weight and for promoting a healthier lifestyle. As well, this update of the evidence is necessary as AVGs have been updated, offering more and more possibilities and increasing the physical demands in exercise sessions through AVG [34]. Consequently, this systematic review aims to identify and critically appraise current research results from the data obtained and to pool the results of published studies in a meta-analysis. This will allow us to provide a clear answer on the effects of AVG on health-related physical fitness and motor competence in children and adolescents with healthy weight. To define children with a healthy weight, the BMI zscore values were from >-2 to ≤ 1 or the BMI percentile from >3rd percentile up to 85th percentile [39].

2. Materials and Methods

This review has been performed following the criteria and methodology established by Cochrane Handbook for Systematic Reviews of Interventions (Version 5.1.0) [40]. The writing of this review was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement [41]. PRISMA 2020 item Checklist has been included as a supplementary file (Table S1). A protocol was registered in the International Prospective Register of Systematic Reviews, PROSPERO (CRD42020222831).

2.1. Data Sources and Search Strategy

Journal articles were identified by searching electronic databases, scanning reference lists of articles and examining tables from earlier systematic reviews. The search strategy was applied to PubMed, Medline, Web of Science and SPORTDiscus up to and including March 2021.

The search strategy used to identify the articles in PubMed and Medline was as follows: exergam* OR "active video gam*" OR "active videogam*" OR "active gam*" OR "interactive video gam*" OR "interactive videogam*" OR "Wii" OR "Xbox" OR "Kinect" OR "PlayStation", and "Species: Humans" and "Language: English" filters were applied, along with "Journal Article" for Medline. The search strategy applied in SPORTDiscus was as follows: TX = (exergam* OR "active gam*" OR "active video gam*" OR "active videogam*" OR "interactive video gam*" OR "interactive videogam*" OR "Wii" OR "Xbox" OR "Kinect" OR "PlayStation") and "document type: article" and "language: English" filters were applied. The search strategy used in Web of Science was as follows: TS = (exergam* OR "active gam*" OR "active video gam*" OR "active videogam*" OR "interactive video gam*" OR "interactive videogam*" OR "Wii" OR "Xbox" OR "Kinect" OR "PlayStation") and "document type: article" and "language: English" filter was applied.

Two reviewers (C.C.C. and A.G.A.) independently evaluated all studies. Titles and abstracts were examined, and relevant articles were obtained and assessed using the inclusion and exclusion criteria described below. Inter-reviewer disagreements were resolved by consensus. A third reviewer resolved disagreements.

2.2. Inclusion Criteria

The following inclusion criteria were used following PICOS format [42]: (P) participants: under 18 years old without overweight or obesity; (I) trials studying the effects of AVG programs on health-related physical fitness and motor competence; (C) control group with no intervention or with traditional exercise intervention; (O) types of outcome measures: variables of health-related physical fitness such as CRF, musculoskeletal fitness (muscular strength and muscular endurance) and body composition, and variables related with motor competence; (S) types of study: randomized and non-randomized controlled.

2.3. Exclusion Criteria

The following exclusion criteria were applied: (1) studies in languages aside from English or Spanish; (2) unpublished data; (3) studies with animals; (4) studies including participants with disabilities, diseases or disorders; (5) studies without pre- and post-assessments of the variables of interest (6) dissertations or abstracts from society proceedings or congresses.

2.4. Search Summary

A total of 13267 relevant articles were identified using the search strategies. Following a review of titles and abstracts, and excluding duplicates, the total number of articles was reduced to 599. Then, 20 articles met the inclusion criteria and were selected to be included in this review. Articles were excluded because of the following reasons: (1) cross-sectional studies (n = 160), (2) only psychological, cognition, nutrition, balance variables, PA or energy expenditure were measured (n = 388), (3) studies that included children and adolescents with overweight and obesity (n = 26), (4) and non-controlled trials (n = 5) (Figure 1).

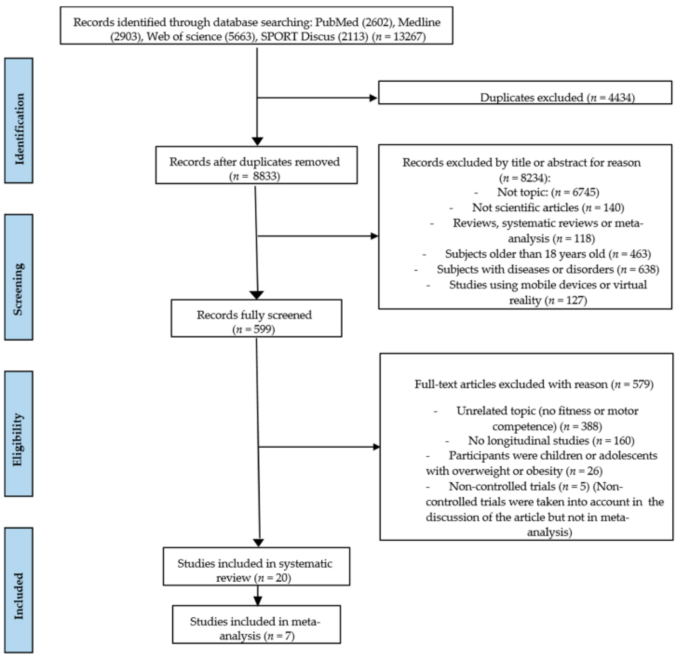

Figure 1. PRISMA flow diagram of articles that were selected.

The characteristics of each study included in this systematic review were summarized in different sections following PICOS format [42]: participants (P), intervention (I), comparison between groups or control group (C), outcomes (O), and study design (S).

2.5. Risk of Bias

Two risk-of-bias assessment tools were used for assessing risk of bias proposed in the PRISMA 2020 statement, the RoB 2 in randomized controlled trials updated by

Sterne et al. [43] and the ROBINS-I ("Risk of Bias in Non-randomized Studies—of Interventions") in non-randomized controlled trial developed by Sterne et al. [44].

2.6. Data Extraction

The following information was extracted from each included trial: name of first author, year of publication, sample size, participant characteristics including age, sex and BMI status, type of study, type of intervention, training characteristics including intervention length and frequency, variables and data sources and outcomes. From this point in the manuscript onwards, when not specifying the activity performed by the control group, this will imply that the control group continued with their normal routine.

2.7. Meta-Analyses

Children and adolescents who performed an AVG intervention were compared with controls who participated in no intervention or in another type of PA intervention. Effect sizes were calculated for each outcome (BMI, body fat percentage, CRF, waist circumference, fat-free mass, muscular fitness and motor competence). Different meta-analyses were performed stratifying by type of control group (no intervention or PA intervention without AVGs).

Standardized mean differences (SMD) between participants in AVG interventions and controls and their 95% confidence intervals were calculated using a continuous random-effects model (DerSimonian–Laird method). SMD effects sizes were interpreted as follows: <0.40 = small, 0.40–0.70 = moderate, >0.70 = large effect [40]. The heterogeneity of the studies was tested using the I^2 statistic [45]. This statistic describes the variance between studies as a proportion of the total variance and was interpreted as follows: I^2 = 0–25% no heterogeneity, I^2 = 25–50% moderate heterogeneity, I^2 = 50–75% high heterogeneity, and I^2 = 75–100% very high heterogeneity. All analyses were performed using the Open Meta [Analyst] software (Windows 10, Rhode Island, RI, USA).

3. Results and Discussion

Table 1 summarizes the details of the methodological quality assessment for randomized controlled trials. The risk of bias for randomized controlled trial was low.

Table 1. Quality assessment of randomized controlled trials.

Study, Year	R	D	Mi	Me	S	O
Medeiros et al., 2020 [46]	+	+	+	+	+	+
McGann et al., 2019 [47]	+	+	+	+	+	+
Gao et al., 2019 [48]	+	+	+	+	+	+
Coknaz et al., 2019 [49]	+	+	+	+	+	+
Ye et al., 2019 [50]	?	+	+	+	+	+
Fu et al., 2018 [37]	?	+	+	+	+	+
Lau et al., 2017 [51]	+	+	+	+	+	+
Vernadakis et al., 2015 [52]	+	+	+	+	+	+

Table 1. *Cont.*

Study, Year	R	D	Mi	Me	S	O
Johnson et al., 2015 [53]	+	+	+	+	+	+
Mombarg et al., 2013 [54]	+	+	+	+	+	+
Sheehan et al., 2013 [55]	+	+	+	+	+	+
Sheehan et al., 2012 [56]	+	+	+	+	+	+
Maloney et al., 2012 [57]	?	+	+	+	+	+
Graves et al., 2010 [58]	+	+	+	+	+	+
Maloney et al., 2008 [59]	+	+	+	+	+	+

R Bias arising from the randomisation process, D Bias due to deviations from intended interventions, Mi Bias due to missing outcome data, Me Bias in measurement of the outcome, S Bias in selection of the reported result, O Overall risk of bias.

Table 2 summarizes the details of the methodological quality assessment for the one non-randomized controlled trial, showing low risk of bias.

Table 2. Quality assessment of non-randomized controlled trials.

	Pre-Intervention		At Intervention		Post-Intervention			
Author, Year	**Bias Due to Confounding**	**Bias in Selection of Participants into the Study**	**Bias in Classification of Interventions**	**Bias Due to Deviations from Intended Interventions**	**Bias Due to Missing Data**	**Bias in Measurement of Outcomes**	**Bias in Selection of the Reported Result**	**Overall Risk of Bias**
Çifci et al., 2020 [60]	LOW	LOW	LOW	LOW	LOW	MODERATE	LOW	LOW
Gao et al., 2019 [61]	LOW	LOW	LOW	LOW	LOW	MODERATE	LOW	LOW
Fu et al., 2018 [36]	LOW	LOW	LOW	LOW	LOW	MODERATE	LOW	LOW
Ye et al., 2018 [38]	LOW	LOW	LOW	LOW	LOW	MODERATE	LOW	LOW
Azevedo et al., 2014 [35]	LOW	LOW	LOW	LOW	LOW	MODERATE	LOW	LOW

3.1. AVG Interventions

There was a great deal of variety across AVG used. Interventions mostly ran during Physical Education (PE) lessons, during playtime or lunchtime, or as an extracurricular activity after school. Most used devices in AVG interventions were gaming consoles such as Xbox 360 with Kinect®, Nintendo Wii®, Sony PlayStation 2®, dance mats, and also other games such as (GoNoodles®, "Adventure to Fitness" and "Cosmic Kids Yoga".

The length of AVG interventions ranged from 6 weeks to 12 months (mean: 16.1 $\pm$ 13.2 weeks). Frequency of AVG sessions ran from 2 to 7 days per week (mean: 3.8 $\pm$ 1.7 days per week), although some interventions were applied daily. Sessions typically lasted between 10 and 60 min (mean: 44.3 $\pm$ 26.0 min) and were delivered by PE teachers and research assistants or, in other cases, they were developed autonomously (Home-based AVG interventions). It is therefore complicated to establish a standard length, intensity, duration of sessions or type of AVG interventions.

The different control groups either were applied another intervention without AVG, like PE or exercise sessions, access to sedentary video games, learning sessions, or were just asked to continue their normal activities of daily life, the latter being the most used option for the control group.

3.2. AVG Effects

All the studies concerning the effects of AVG on health-related physical fitness and motor competence in children and adolescents with healthy weight are summarized in Table 3. A total of twenty randomized and non-randomized controlled trials showed effects of AVG on health-related physical fitness and motor competence in children and adolescents with healthy weight [35–38,46–61]. Although the non-controlled articles were not taken into account in the results, they were reviewed in the discussion and were summarized in Table S2.

Individual study results and global effects of quantitative effects of CRF are plotted in Figure 2, while a summary of the global result is presented in Table 4. Some articles were excluded from the quantitative analyses given that the effect sizes could not be calculated from the information available in the papers [48,50].

Table 3. Descriptive characteristics of included studies with children with healthy weight.

Study [Ref.]	Participants		Study Design	Intervention	Control	Training	Variables and Test Used	Outcomes
	n	Age						
Medeiros et al., 2020 [46]	*n* = 64 male (30) female (34)	9.09 ± 0.75 years	RCT	Xbox Kinect (*n* = 32)	CG: PE curriculum class (*n* = 32)	Period: 9 weeks Frequency: 2 days per week Duration: 45 min per session	MC (TGMD-2)	AVG and CG showed improvements in MC, but AVG showed improvements in more skills of TGMD-2
Çifci et al., 2020 [60]	*n* = 100 male (50) female (50)	12–15 years	Non-RCT	Xbox Kinect (*n* = 50)	No intervention (*n* = 50)	Period: 8 weeks Frequency: 40 min per week	MF (handgrip, leg dynamometry and vertical jump)	AVG improved MF. No differences on MF between AVG and CG were observed.
McGann et al., 2019 [47]	*n* = 40 male (21) female (19)	5–7 years	RCT	AVG focus on MC playing at Scratch with Kinect (*n* = 20)	Traditional AVG (*n* = 20)	Period: 8 weeks Frequency: Daily	MC (TGMD-2)	Improvements on MC for both AVG and CG, and group by time effect with significantly higher scores by AVG.
Gao et al., 2019 [48]	*n* = 32 male (16) female (16)	4.72 ± 0.73 years	RCT	Home-based AVG (LeapTV gaming console) (*n* = 18)	No intervention (*n* = 14)	Period: 12 weeks Frequency: 5 days per week Duration: 30 min per session	BMI CRF (3-Minute Step Test)	No effects for BMI and CRF
Coknaz et al., 2019 [49]	*n* = 106 male (46) female (60)	AVG group: 9.62 ± 1.02 years Control group: 10.31 ± 1.15 years	RCT	Nintendo Wii (*n* = 53)	No intervention	Period: 12 weeks Frequency: 3 days per week Duration: 50–60 min per session	BMI	AVG decreased BMI while CG increased

Table 3. *Cont.*

Study [Ref.]	Participants		Study Design	Intervention	Control	Training	Variables and Test Used	Outcomes
	n	Age						
Gao et al., 2019 [61]	*n* = 56 male (23) female (33)	4.5 ± 0.46 years	Non-RCT	Nintendo Wii and Xbox Kinect (*n* = 20)	No intervention (*n* = 36)	Period: 8 weeks Frequency: 5 days per week Duration: 20 min per session	MC (TGMD-2)	No group effect, but time effect for MC
Ye et al., 2019 [50]	*n* = 81 male (42) female (39)	9.23 ± 0.62 years	RCT	AVG during recess (Nintendo Wii and Xbox Kinect) (*n* = 36)	No intervention (*n* = 45)	Period: School year Frequency: 5 days per week during recess Duration: 50 min per session	CRF (Half-mile run test)	No effects for CRF
Fu et al., 2018 [36]	*n* = 65 male and female	11.6 ± 0.5 years	Non-RCT	AVG (GoNoodle, Adventure to Fitness, and Cosmic Kids Yoga) in regular school class time (*n* = 33)	Five 30-min of free-play sessions (*n* = 32)	Period: 18 weeks Frequency: 3 days per week Duration: 30 min per session	CRF (20-m PACER)	AVG showed a higher CRF than CG
Fu et al., 2018 [37]	*n* = 65 male (34) female (31)	4.9 ± 0.7 years	RCT	AVG (GoNoodles, Adventure to Fitness, and Cosmic Kids Yoga) in regular school class time (*n* = 36)	Five 30-min of free-play sessions (*n* = 29)	Period: 12 weeks Frequency: 5 days per week Duration: 30 min per session	MC (TGMD-3)	AVG showed higher increase in TGMD-3 score than CG

Table 3. *Cont.*

Study [Ref.]	Participants		Study Design	Intervention	Control	Training	Variables and Test Used	Outcomes
	n	Age						
Ye et al., 2018 [38]	*n* = 250 male and female	8.27 ± 0.70 years	Non-RCT	125 min of AVG (Nintendo Wii and Xbox Kinect) + PE (*n* = 135)	125 min of PE only (5 classes per week) (*n* = 115)	Period: 9 month Frequency: 3 PE classes and 2 exergaming sessions per week Duration: 125 min	BMI HRF (FITNESSGRAM protocols for PACER) MF (hand-grip dynamometry, push-ups and curl-ups) MC (speed for kicking and throwing, maximum standing long jump distance and hopping)	AVG improved BMI, CRF, MF and OCS, while CG improved CRF and object control skills but worsened MF and BMI.
Lau et al., 2016 [51]	*n* = 80 male (25) female (55)	9.23 ± 0.52 years	RCT	Xbox Kinect (*n* = 40)	No intervention (*n* = 40)	Period: 12 weeks Frequency: twice a week after school Duration: 60 min per day	BMI CRF (20-m shuttle run test)	BMI increased in AVG and CRF increased in AVG and CG, with higher improvements in AVG
Vernadakis et al., 2015 [52]	*n* = 66 males and females	6.35 ± 0.73 years	RCT	Xbox Kinect (*n* = 22)	EXE: traditional motor competence training program (*n* = 22) and no intervention (*n* = 22)	Period: 8 weeks Frequency and duration: Non-reported	MSC (OCS with TGMD-2)	AVG and EXE showed improvements in OCS. CG2 showed no improvements
Johnson et al., 2015 [59]	*n* = 36 male (53%) female (47%)	6–10 years	RCT	Xbox Kinect (*n* = 19; 7.9 ± 1.5 years)	No intervention (*n* = 17; 8.0 ± 1.2 years)	Period: 6 weeks Frequency: 5 days per week Duration: 50 min in lunchtime	MSC (OCS with TGMD-3)	No effects on OCS or differences between groups for AVG

Table 3. *Cont.*

Study [Ref.]	Participants		Study Design	Intervention	Control	Training	Variables and Test Used	Outcomes
	n	Age						
Azevedo et al., 2014 [35]	*n* = 497 male and female	11–13 years old	Non-RCT	Dance Mat Exergaming (*n* = 280; 11.2 ± 0.4 year; 63.9% female)	No intervention (*n* = 217, 11.3 ± 0.4 years; 64.5% female)	Period: 12 months Frequency: 2 h per week	BMI %BF (DXA) CRF (20-m shuttle run test)	AVG showed a positive effect on weight, BMI and %BF compared to CG, but not on CRF
Mombarg et al., 2013 [54]	*n* = 29 male (23) female (6)	7–12 years	RCT	Nintendo Wii (Wii-balance board with the Wii-fit-plus) (*n* = 15)	No intervention (*n* = 14)	Period: 6 weeks Frequency: 3 days per week Duration: 30 min per session	MC (movement assessment battery for children and Bruininks–Oseretsky Test)	Both AVG and CG showed improvements in MC. Balance scores of the AVG improved significantly, whereas those of the control group showed no significant progress. There were significant interaction effects on balance scores, favoring the AVG.
Sheehan et al., 2013 [55]	*n* = 61 male (33) female (28)	9–10 years	RCT	iDance^{TM}, XR Board^{TM} /Lightspace^{TM}, and Wii Fit^{TM} Plus. (*n* = 21)	CG1: PE curriculum class (*n* = 21) CG2: PE geared toward agility, balance, and coordination (ABC) improvement (*n* = 19)	Period: 6 weeks Frequency: 4–5 days per week Duration: 34 min per session	MC (balance test with the HUR BT4^{TM} platform)	AVG and the ABC PE (CG2) improved their postural stability significantly compared to those in the curricular PE class.

Table 3. *Cont.*

Study [Ref.]	Participants		Study Design	Intervention	Control	Training	Variables and Test Used	Outcomes
	n	Age						
Sheehan et al., 2012 [56]	*n* = 65 male (29) female (36)	9–10 years	RCT	Wii Fit+™ (*n* = 22)	CG1: PE curriculum class (*n* = 21) CG2: PE geared toward agility, balance, and coordination (ABC) improvement (*n* = 22)	Period: 6 weeks Frequency: 3 days per week Duration: 34 min per session	MC (balance test with the HUR BT4™ platform)	AVG and the ABC PE (CG2) improved the balance compared to those in the curricular PE class. Improvement were not significantly different from CG2.
Maloney et al., 2012 [57]	*n* = 58 male (71%) female (29%)	13.7 ± 0.6 years	RCT	Playstation 2 (In the Groove) (*n* = 29)	No intervention (*n* = 29)	Period: 10 and 20 weeks Frequency: 4–5 school days per week Duration: 10 min per session	BMI	AVG decreased BMI more than CG
Graves et al., 2010 [58]	*n* = 58 male (39) female (19)	9.2 ± 0.5 years	RCT	Nintendo Wii jOG (*n* = 29)	No intervention (*n* = 29)	Period: 6 and 12 weeks Frequency and duration: Non-reported home-based	BMI FM (DXA)	No effects for BF or BMI
Maloney et al., 2008 [59]	*n* = 60 male (30) female (30)	7.5 ± 0.5 years	RCT	DDR (*n* = 40)	No intervention (*n* = 20)	Period: 28 weeks Home-based	BMI	No changes in BMI

%BF body fat percentage, AVG active video games, BMI body mass index, CG control group, CRF cardiorespiratory fitness, DXA dual-energy X-ray absorptiometry, EXE exercise, FFM fat-free mass, FM fat mass, FPG free-play group, HRF health-related fitness, MF musculoskeletal fitness, min minutes, MSC motor skills competence, OCS object control skills, PACER progressive aerobic cardiovascular endurance run, PE physical education, RCT randomized controlled trial, TGMD test of gross motor development.

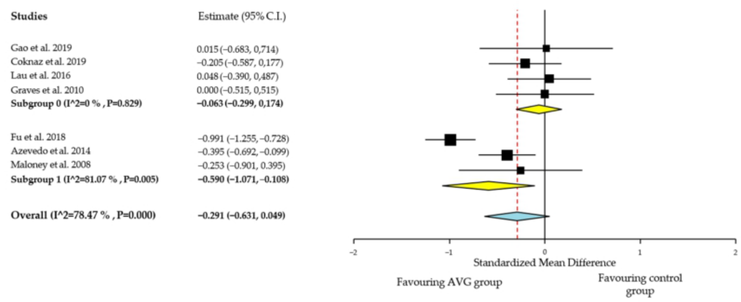

Figure 2. BMI effect sizes for AVG compared with control group. Subgroup analysis by AVG intervention's length; Subgroup 1: AVG interventions lasting less than 18 weeks; Subgroup 2: AVG interventions lasting 18 weeks or more.

Table 4. Effect sizes and heterogeneity of findings for studies comparing AVG intervention versus control group.

Variable	*N*	Hedges'g Effect Size	95 % CI	*p* Value	I^2
BMI	7	−0.291	−0.631; 0.049	0.000	78.47%
CRF	4	0.438	0.022; 0.855	0.001	82.9%

BMI body mass index, CRF cardiorespiratory fitness.

3.2.1. Body Mass Index and Percentage of Body Fat

BMI, fat mass or body fat percentage were evaluated by eight articles [35,38,48,49,51,57–59] and fat mass or body fat percentage were measured by dual-energy X-ray absorptiometry (DXA) [35,58]. Four out of eight studies reported that an AVG intervention decreased BMI in children with healthy weight [35,38,57]. Azevedo et al. [35] investigated the effect of an AVG with dance mats and the results showed a positive intervention effect on weight (−1.7 kg, 95% CI: −2.9 to −0.4) and BMI (−0.9 kg/m^2, 95% CI: −1.3 to −0.4) compared to a control group. A similar AVG was used by Maloney et al. [57], displaying a higher decrease in mean BMI percentile by children who participated in AVG in comparison with a control group (5.6 vs. 0.2 BMI percentile decrease, respectively). Coknaz et al. [49] investigated the effect of a 12-week AVG intervention with Nintendo Wii and positive intervention effects on BMI were observed. Ye et al. [38] examined the effectiveness of a combined AVG and PE program using Xbox Kinect and Nintendo Wii compared to PE only, across a school year with 125 min weekly, showing that AVG had positive effects on BMI (−0.3 kg/m^2), while PE control group increased it (1.28 kg/m^2).

On the other hand, four randomized controlled trials reported no effects [48,58,59] or negative effects [51], three of these were for non-supervised home-use [48,58,59] and another three of these lasted less than 12 weeks [48,51,58]. The first study on the effect of AVG on BMI was performed by Maloney et al. [59]. AVG group were provided with all equipment necessary to play DDR at home but there were no changes in BMI in neither AVG nor control groups. The same practice was followed by Graves et al. [58]. These authors reported no AVG effects on BMI after 12 weeks of non-supervised home-use Nintendo Wii. Gao et al. [48] showed no effects and no differences between AVG and control groups. Lau et al. [51] showed an increase in BMI ($p < 0.001$), while this increase was not shown in control group after a 12-week intervention with Xbox Kinect. Negative effects of the AVG group relative to control group were reported (0.22 kg/m^2, 95% CI: −0.46 to 0.90).

Only two studies reported effects of AVG on body fat in healthy-weight children. Azevedo et al. [35] showed a positive effect on body fat with a 1-year AVG intervention with dance mats compared to control group (−2.2%, 95% CI: −4.2 to −0.2). However, Graves et al. [58] reported no effects on body fat in AVG or control group after a home-based AVG intervention with Nintendo Wii over 12 weeks.

Non-supervised home-based AVG interventions do not seem to produce enough stimulus to have an effect on the BMI or percentage of body fat. De Brito-Gomes et al. [62] showed that higher energy expenditure was observed in structured interventions.

Two non-controlled studies also reported BMI and body fat changes after AVG intervention [63,64]. Bethea et al. [64] applied a 30-week AVG intervention with DDR and no changes were shown in BMI. These results were similar to those found in the article performed by Owens et al. [63] that evaluated the change in BMI and body fat percentage after a 3-month AVG intervention in which participants were provided with a Nintendo Wii to play at home, with no effects shown. It is worth noting that the intervention in this study was family-based and that they spent 12.6 min per day on average but that there was a significant reduction in Wii time between the first six and last six weeks of the intervention.

Some systematic reviews studied the effects of AVG on BMI or body fat, including studies of overweight or obese children or adolescents., but some limitations can be found, such as the inclusion of non-controlled trials, the inclusion of children and adolescents with diseases or disorders, or the search strategy, or differences in the inclusion and exclusion criteria such as including children and adolescents with overweight and obesity [31,65–71]. Our results are in line with theirs. The latest review, by Gao et al. [65], included studies in children with obesity or overweight, and the results showed improvements in body composition after AVG interventions. Hernández-Jimenez et al. [66] performed a meta-analysis showing a significant effect in favor of AVG on BMI in children and adolescents, with greater results when the AVG intervention was applied to overweight or obese children. Oliveira et al. [67] performed a systematic review focused on healthy-weight children and adolescents and the results showed that AVG were effective in reducing weight and BMI. Another systematic review [68] showed that most of the randomized controlled trials reported that AVG interventions had a positive effect on BMI, body composition, or body fat. A previous systematic review performed by Gao et al. [69] not focused on obesity, concluded that AVG were a promising tool to promote PA and health, as long as the AVG intervention is not home-based. In the systematic review by Norris et al. [70] which included some articles with obese children, half of the included articles assessing BMI or body composition reported positive effects following AVG intervention while the other half reported no effect, but all AVG interventions of the studies included were carried out at school. Two further systematic reviews [31,71] supported the findings, although being among the first reviews on the effects of AVGs, quantitative analyses were not conducted due to lack of articles. Lamboglia et al. [71] found that AVG led to an increased PA and cardiorespiratory function and a decreased body fat, with a considerable potential to fight obesity. Leblanc et al. [31] found that AVG helped to attenuate weight gain in overweight and obese participants, including three articles added in the present systematic review. The improvement of cardiometabolic health through AVG was inconclusive due to the small number of articles at the time.

The results seem to establish a positive effect of AVG interventions on BMI when the intervention was longer than 18 weeks and it was supervised and programmed. Home-based AVG interventions may not be appropriated, probably because the duration, frequency and even intensity were lower than that needed to improve BMI or body fat mass.

Quantitative Analysis of BMI

As shown in Figure 2, positive effects of the AVG interventions that lasted 18 weeks or more were found for BMI, favoring AVG group compared with control group with no intervention (SMD, −0.590; 95% IC, −1.071, −0.108), showing a moderate SMD effect size. These positive results were not observed for AVG interventions lasting less than 18 weeks

(SMD, −0.063; 95% IC, −0.299, 0.174). Heterogeneity among studies for BMI was very low (I^2 = 0%; $p < 0.424$).

Positive effects have been shown on BMI in favor of the AVG group when the interventions lasted 18 weeks or more, but not when the AVG interventions lasted less. No effects have been shown on percentage of body fat.

3.2.2. Cardiorespiratory Fitness

CRF were evaluated by six articles [35,36,38,48,50,51]. CRF was measured by different tests such as the progressive aerobic cardiovascular endurance run test (PACER) [36,38], the 20-m shuttle run test [35,51], the 3-min step test [48] and the half-mile run test [50]. Three out of six studies reported positive effects on CRF. In the first study reporting effects of AVG in CRF, Lau et al. [51] found improvements in CRF in the AVG group compared with a control group after an intervention with Xbox Kinect (1.58 mL·kg·min, 95% CI: 0.74 to 2.42; p = 0.001). Fu et al. [36] performed an 18-week AVG intervention. Authors found an improvement of 20.8 laps in CRF measured by PACER after the AVG intervention ($p < 0.001$), but not in the comparison group. Ye et al. [38] found an increase in CRF in both combined AVG and PE (6.63 laps) and PE only (3.95 laps) groups, with greater improvements for AVG group.

In three out of six studies, positive effects were not found after an AVG intervention. A recent study performed by Gao et al. [48] showed no effects on CRF, measured by 3-min step test, after a 12-week AVG intervention. The participants performed this intervention at home, which can be an explanation for non-significant results. In a study with a sample of 497 participants performed by Azevedo et al. [35], AVG group did not improve their performance in 20-m shuttle run test after a 1-year program with a dance mats AVG sessions in comparison with control group. Probably, more than two hours per week may be needed to obtain benefits in CRF. Ye et al. [50] investigated the change in CRF after an AVG intervention during a school year, where the participants played Xbox Kinect and Nintendo Wii during playtime. Results showed no improvements in CRF after the intervention in both AVG and control groups. These results could be due to a small sample or due to the chosen test for the assessment cardiorespiratory fitness (time to complete a half-mile run) which could be inaccurate.

Four non-controlled trials reported the effects of AVG interventions. Firstly, Owens et al. [63] observed an increase in CRF from 34.3 ± 9.6 to 38.4 ± 8.6 mL·kg·min, measured by the Bruce Ramp Protocol, after 3 months of an AVG intervention with Wii Fit in which participants were encouraged to play at home. Similar results were found by Bethea et al. [64], showing that CRF increased by 2.97 ± 4.99 mL·kg·min (p = 0.013), measured by 20-m shuttle run test, after an AVG intervention with DDR. On the other hand, George et al. [72], who used the 6-min walk test to evaluate CRF in 15 children who participated in a 6-week AVG intervention. No significant differences in the distance walked by participants after the AVG intervention was found, indicating that CRF did not change over the study duration. Probably a longer AVG intervention is needed to obtain benefits. Similarly, Gao et al. [73] investigated the effects of a 6-week AVG intervention, showing no effects on CRF after 6 weeks. The results from these four studies should be interpreted with caution as they are non-controlled trials and the sample was always small.

The conclusions of the present review are consistent with those of other reviews. Zeng and Gao [68] included two randomized controlled trials, also included in the present systematic review, which reported positive effects of an AVG intervention in comparison with an exercise group, but these results were unclear due to the lack of studies. Norris et al. [70], reported two studies with improvements in CRF after AVG interventions compared to a control group and one study found no difference between intervention groups. One of these three articles has not been included in this systematic review because the study was conducted in children with autism, being this an exclusion criterion. The interventions of the studies included in the review were carried out at school. In 2014, an overview of systematic reviews was performed by Kari [74] and the evidence did not support the AVG to increase CRF for significant health benefits. Two years later, this overview was updated, and the results were similar [75]. In this updated overview, it was noted that additional high-quality research and systematic reviews concerning AVG are needed, which supports and justifies the present systematic review with meta-analysis.

AVG seems to be a good strategy for improving CRF, but more randomized controlled trials are needed to confirm those benefits. Furthermore, this update of the evidence is necessary as AVGs have been updated, offering more possibilities and more physical demands in exercise sessions using AVG. Thus, in the older articles, AVG interventions used the DDR, the play station with the Eye Toy and the Nintendo Wii, and in the more recent articles, the Nintendo Wii and the Xbox with the Kinect are mainly used. Including AVG strategies into the curricular program such as playtime or PE classes would not be the best alternative. This may be because AVGs reduce the volume of PE rather than being a tool to increase the PA performed in daily life. Instead, AVG included in extracurricular activities could result most beneficial to improve CRF. It is also worth highlighting that no maximal or submaximal incremental cardiopulmonary exercise test with a gas exchange measurement has been performed for evaluating maximal oxygen uptake, despite this being widely recognized as the best single index of aerobic fitness [76,77].

Quantitative Analysis of Cardiorespiratory Fitness

Some articles [48,50] were excluded from meta-analysis due to the use of different measure tools, that reported CRF results in heart rate or time to perform a test, so improvements will be shown by a decrease in the time or heart rate when performing those tests. As shown in Figure 3, positive effects were found for CRF, favoring AVG group compared with control group (SMD, 0.438; 95% IC, 0.022, 0.855), with a moderate SMD effect size. Heterogeneity among studies for CRF was very high (I^2 = 82.9%; p = 0.001). The results also showed a trend towards greater effects when compared to a control group without any intervention (SMD, 0.585; 95% IC, −0.070, 1.240) than when compared to an intervention with exercise (SMD, 0.128; 95% IC, −0.121, 0.377) (Figure 3).

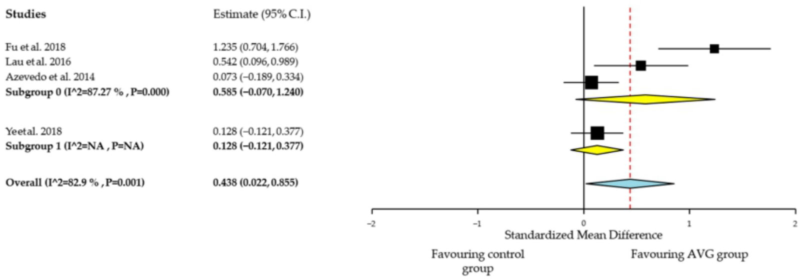

Figure 3. Cardiorespiratory fitness effect sizes for AVG compared with control group. Analysis by control group; Subgroup 1: control group with no intervention; Subgroup 2: exercise control group.

AVG interventions seem to have benefits in CRF but these results should be interpreted with caution because few articles have been included and two articles have not been included. More randomized controlled trials are needed to confirm those positive effects.

3.2.3. Muscular Fitness

From the nineteen controlled trials that focused on the effects of AVG on health-related physical fitness and motor competence in children or adolescents with healthy weight, only two articles evaluated muscular fitness. The first study that investigated the effects of AVG on compiled muscular fitness of children and adolescents with healthy weight was performed by Ye et al. [38] and muscular fitness was evaluated with three tests such as hand-grip dynamometry, push-ups and curl-ups after an AVG intervention using Nintendo Wii and Xbox Kinect during PE class compared with PE only. The between-group difference in the change scores of children's musculoskeletal fitness was significant, favouring the intervention group. The most recent study was conducted by Çifci et al. [60]. This study is a non-randomized controlled trial that investigated the effect of an 8-week intervention with Xbox Kinect on muscular fitness of adolescents, evaluated by handgrip, leg dynamometry and vertical jump. The children in the AVG group improved muscular fitness, but no differences were found between the AVG group and the control group. The difference between the effects in both studies could be due to two reasons: the length of the intervention (9 months vs. 8 weeks) and the design of the intervention, where the AVG intervention that showed positive effects included more AVG and was performed together with the PE classes in the curricular program of schools. In short, AVG could be useful to develop muscular fitness but positive effects of AVG on muscular fitness are unclear due to the lack of evidence.

Two non-controlled trials evaluated the effects of Nintendo Wii on muscular fitness [63,78]. Owens et al. [63] evaluated the effect of a 3-month AVG intervention using Nintendo Wii at home but results showed no effects on muscular fitness measured by push-ups test. Probably, longer and supervised interventions were needed to obtain benefits on muscular fitness because the time of use of Wii was significantly lower comparing the first six and last six weeks of the intervention, with an average of 12.6 $\pm$ 5.5 min per day of Wii use. Smits-Engelsman et al. [78] showed improvements in muscular fitness and in anaerobic fitness with several tests such as long jump, lateral step-up, sit to stand, 10 $\times$ 5-m sprint and 10 $\times$ 5-m slalom, after a 5-week AVG. In spite of the short duration, there were positive effects probably due to the supervision of professionals, which differentiates it from the previous study.

3.2.4. Motor Competence

Ten studies evaluated the effect of AVG on motor competence and those articles often evaluated also PA. Motor competence was reported by six articles using the TGMD-2 or TGMD-3 [37,46,47,52,53,61], by two articles using the Movement Assessment Battery for children and Bruininks–Oseretsky Test [54] and by three articles using the performance of motor skills such as speed for kicking and throwing, maximum standing long jump distance and hopping [38] or using a balance test with the HUR BT4TM platform [55,56].

Seven out of ten articles reported improvements in motor competence [37,46,47,52,54–56]. The most recent article about the effects of AVG in motor competence was performed by Medeiros et al. and the results showed that AVG and PE group improved motor competence, with the control group improving performance on more of the motor skills included in the TGMD-2 than PE group. Fu et al. [37] studied the effect of AVG such as GoNoodles, Adventure to Fitness, and Cosmic Kids Yoga performed in regular school class time on motor competence of preschool children. Children in the AVG group played 30 min of AVG with a frequency of 5 days per week, over 12 weeks while control group had free-play sessions instead of AVG sessions. The results showed that AVG group obtained higher overall TGMD-3 scores and higher step counts than control group (mean difference = 8.7, p = 0.019, d = 0.51). Another randomized controlled trial performed by McGann et al. [47] compared the effect of AVG and adapted AVG focused on motor competence improvement. A suite of purpose-built exergames with adaptable features were designed for the intervention group of this study. Four new games were developed using Scratch that was linked to the Kinect® via Kinect2Scratch, each targeting specific locomotor skills (hop, skip, jump and slide). There are three new games: Hop Ball, Jump Ball and Slide Ball; and an existing game: Alien Attack. Participants in both groups played AVG daily for 8 weeks and the results showed improvements in TGMD-2 scores, with a better performance of the group using adapted AVG focused on motor competence. Vernadakis et al. [52] investigated the effects of an 8-week AVG with 60 min per week of Xbox Kinect sessions on object control skills, a part of TGMD, in comparison with a group performing a traditional motor competence training program and in comparison with a no-intervention control group. Great improvements were found for AVG group and traditional motor competence training group but not for control group. Besides, AVG group showed higher enjoyment scores measured by PA enjoyment scale than traditional motor competence training group. Mombarg et al. [54] investigated the benefits of a 6-week intervention performing 5 days per week of 50-min sessions with Nintendo Wii on the motor competence, assessed by the Movement Assessment Battery for children and Bruininks–Oseretsky Test. The results showed that both AVG and the no-intervention control group showed improvements in motor competence. Balance scores of the AVG group improved significantly, whereas those of the control group showed no significant progress. There were significant interaction effects on balance scores, favoring the AVG group. Two articles written by Sheehan et al. [55,56] investigated the effectiveness of AVG on the improvement of balance, assessed by a balance test with the HUR BT4™ platform. One of the interventions of the articles included iDance™, XR Board™ /Lightspace™, and Wii Fit™ Plus [55], while the other article only included Wii Fit™ Plus in the intervention [56]. Both studies compared the AVG group with two control groups: a control group performing ordinal PE curriculum classes and a control group performing PE classes geared toward agility, balance, and coordination improvement. The period of intervention for AVG and control groups lasted 6 weeks and the classes were performed 3 days per week for 34 min each. In both studies, AVG group and the control group performing PE classes geared toward agility, balance, and coordination improvement improved their postural stability significantly compared to the control group performing the curricular PE classes.

Three out of ten articles reported no positive effects or no differences between groups in motor competence [38,53,61]. The first study that investigated the influence of AVG in motor competence in children with healthy weight was performed by Johnson et al. [53]. A 6-week AVG intervention with 5 days per week of 50-min Xbox sessions were performed and found no effects or differences between AVG and control groups. Gao et al. [61], previously described, showed a significant time effect for motor competence ($F(1, 52) = 15.61$, $p < 0.01$, $h^2p = 0.23$) and a significant group by time effect for MVPA ($F(1, 52) = 5.06$, $p < 0.02$, $h^2p = 0.09$). Ye et al. [38] reported results that showed improvements in object control skills in both AVG and PE groups, with PE group demonstrating greater improvements.

The importance of motor competence, together with muscular fitness, lies in their close bidirectional relationship with PA and sports participation, which can improve the physical fitness and body composition of children and adolescents. By increasing muscle strength and motor skills of children and adolescents it is possible that also they will become more physically active, and therefore healthier [11,14].

The use of different tests or batteries for measuring motor competence, the diverse types of control groups and the variety of interventions make it impossible to perform meta-analyses. However, AVG seems to be a promising option in order to help children developing motor skills. A limitation of the results of AVG for improving motor skills was the length of the AVG interventions. Most of the included AVG interventions lasted 8 weeks or less. Only two out of nine articles included an AVG intervention of longer duration, performed by Ye et al. [38] with an intervention´s length of 9 months and Fu et al. [37] with an intervention´s length of 12 weeks.

Two non-controlled trials investigated the effect of an AVG intervention with Nintendo Wii on motor competence assessed by the Movement Assessment Battery for Children [72] or the Bruininks–Oseretsky Test-2 [78]. George et al. [72] found non-significant effects on motor competence, higher in boys than in girls, after 6 weeks of an AVG intervention. Smits-Engelsman et al. [78] showed an improvement in motor competence, specifically in speed and agility (part of the Bruininks–Oseretsky test) but not in balance, after a 5-month AVG intervention with Nintendo Wii.

The results of the present systematic review are consistent with those of other previous reviews with different inclusion and exclusion criteria. The most recent systematic reviews [79,80] were performed including studies with non-typically developing children, developmental coordination disorders and other diseases; one of the reviews even includes adults. Some limitations can be found in these systematic reviews such as the inclusion of non-controlled trials or cross-sectional studies. The results of both systematic reviews were in agreement with the conclusions of the present systematic review and showed that AVG seem to have positive effects on motor skills and could be considered as a potential strategy to develop and improve motor skills. In addition, all 5 studies included in the Norris et al. [70] review reported improvements in motor competence following AVG intervention performed at school, but no studies found differences in motor skill improvements between AVG and other motor skill intervention programs. In the studies included in the review participated children and adolescents without disorders and students with balance disorders.

Overall, the results of AVG on motor competence in children and adolescents with healthy weight are still unclear, but AVG seems to be a promising tool for enhancing motor competence. PA could be a variable to take into account to improve motor competence, considering the direct relation between PA and motor competence [81,82]. AVG increase light-to-moderate PA and energy expenditure [28–33], which contributes to improving motor competence. Thus, AVG can be used to enhance motor competence, directly or indirectly through PA.

4. Limitations

Some limitations of this review should be recognized. A wide variety of AVG interventions have been included, with different devices and training interventions (duration, frequency, training setting or training dynamic and type of AVG). In addition, the potential risk of bias of some articles was not taken into account when interpreting the results. Lastly, some analyses by subgroups were not performed due to the small number of controlled trials. The present study has also several strengths. To the best of the authors' knowledge, this is the first meta-analysis to summarize the current research on the effects of AVG on health-related physical fitness and motor competence in healthy-weight children and adolescents. This analysis included not only the effects of AVG on BMI, but on body composition, CRF, muscular fitness and motor competence. This study allowed us to realize that more randomized controlled trials reporting motor competence and muscular fitness results are needed.

5. Perspectives

It is necessary to establish the guidelines for an effective intervention using AVGs. It seems that the most effective application of an AVG intervention is sufficient duration (at least 18 weeks) and a structuring and planning of that intervention, in fact, the optimal structure and overall training dose is still unknown being possibly the main factor affecting the effectivity of the AVG. In addition, most of the scientific evidence that has studied AVG interventions combined with traditional exercise lacked a control group to compare the effects, and these AVG interventions seem to be promising, but randomized controlled trials are needed to investigate the effects of these AVG interventions.

Finally, there are few articles studying the effects of an AVG intervention on muscular fitness and motor competence, which are components of the PIT observed by Faigenbaum et al. [14], together with exercise deficit disorder. Randomized controlled trials are recommended in order to investigate the effects of AVG interventions on muscle strength and motor skill to learn about the possibilities of these types of interventions for breaking the vicious circle of PIT.

6. Conclusions

AVGs could be a good strategy to control the BMI status and body fat percentage, and to enhance CRF provided that the AVG interventions are supervised and structured, and last at least 18 weeks. Children and adolescents with healthy weight could benefit from

AVG to improve motor competence and muscular fitness, but further research is needed to confirm these results because the effects are still unclear.

In conclusion, AVG seem to be an effective tool for improving some components of health-related physical fitness and look like a promising tool also for improvements in motor competence in children and adolescents with healthy weight, which could be important in combating the pediatric inactivity triad. AVGs can even be considered as a complementary alternative to traditional exercise for enhancing the health status during childhood.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18136965/s1, Table S1: PRISMA 2020 item Checklist, Table S2: Descriptive characteristics of included non-controlled trials.

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References

1. Ortega, F.B.; Ruiz, J.R.; Castillo, M.J.; Sjöström, M. Physical fitness in childhood and adolescence: A powerful marker of health. *Int. J. Obes.* **2008**, *32*, 1–11. [CrossRef]
2. Chen, W.; Hammond-Bennett, A.; Hypnar, A.; Mason, S. Health-related physical fitness and physical activity in elementary school students. *BMC Public Health* **2018**, *18*, 195. [CrossRef] [PubMed]
3. Pahkala, K.; Hernelahti, M.; Heinonen, O.J.; Raittinen, P.; Hakanen, M.; Lagström, H.; Viikari, J.S.A.; Rönnemaa, T.; Raitakari, O.T.; Simell, O. Body mass index, fitness and physical activity from childhood through adolescence. *Br. J. Sports Med.* **2013**, *47*, 71–77. [CrossRef] [PubMed]
4. Blair, S.N.; Cheng, Y.; Holder, J.S. Is physical activity or physical fitness more important in defining health benefits? *Sci. Sport. Exerc.* **2001**, *33*, 379–399. [CrossRef] [PubMed]
5. Tomkinson, G.R.; Carver, K.D.; Atkinson, F.; Daniell, N.D.; Lewis, L.K.; Fitzgerald, J.S.; Lang, J.; Ortega, F.B. European normative values for physical fitness in children and adolescents aged 9–17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *Br. J. Sports Med.* **2017**, *52*, 1445–1456. [CrossRef] [PubMed]
6. Micheli, L.; Mountjoy, M.; Engebretsen, L.; Hardman, K.; Kahlmeier, S.; Lambert, E.; Ljungqvist, A.; Matsudo, V.; McKay, H.; Sundberg, C.J. Fitness and health of children through sport: The context for action. *Br. J. Sports Med.* **2011**, *45*, 931–936. [CrossRef] [PubMed]
7. Ahluwalia, N.; Dalmasso, P.; Rasmussen, M.; Lipsky, L.; Currie, C.; Haug, E.; Kelly, C.; Damsgaard, M.T.; Due, P.; Tabak, I.; et al. Trends in overweight prevalence among 11-, 13- and 15-year-olds in 25 countries in Europe, Canada and USA from 2002 to 2010. *Eur. J. Public Health* **2015**, *25*, 28–32. [CrossRef] [PubMed]
8. Nittari, G.; Scuri, S.; Petrelli, F.; Pirillo, I.; Di Luca, N.M.; Grappasonni, I. Fighting obesity in children from European World Health Organization member states. Epidemiological data, medical-social aspects, and prevention programs. *La Clin. Ter.* **2019**, *170*, e223–e230. [CrossRef]
9. Westerterp, K.R. Changes in physical activity over the lifespan: Impact on body composition and sarcopenic obesity. *Obes. Rev.* **2018**, *19*, 8–13. [CrossRef]
10. García-Hermoso, A.; Alonso-Martinez, A.M.; Ramírez-Vélez, R.; Izquierdo, M. Effects of Exercise Intervention on Health-Related Physical Fitness and Blood Pressure in Preschool Children: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Sports Med.* **2019**, *50*, 187–203. [CrossRef]
11. Poitras, V.J.; Gray, C.; Borghese, M.M.; Carson, V.; Chaput, J.-P.; Janssen, I.; Katzmarzyk, P.; Pate, R.R.; Gorber, S.C.; Kho, M.; et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, 197–239. [CrossRef]

12. Bull, F.C.; Al-Ansari, S.S.; Biddle, S.; Borodulin, K.; Buman, M.P.; Cardon, G.; Carty, C.; Chaput, J.-P.; Chastin, S.; Chou, R.; et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* **2020**, *54*, 1451–1462. [CrossRef]
13. Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [CrossRef]
14. Faigenbaum, A.D.; Rial Rebullido, T.; MacDonald, J.P. Pediatric Inactivity Triad: A Risky PIT. *Curr. Sports Med. Rep.* **2018**, *17*, 45–47. [CrossRef]
15. Moliner-Urdiales, D.; Ruiz, J.R.; Ortega, F.B.; Jiménez-Pavón, D.; Vicente-Rodriguez, G.; Rey-López, J.P.; Martínez-Gómez, D.; Casajús, J.A.; Mesana, M.I.; Marcos, A.; et al. Secular trends in health-related physical fitness in Spanish adolescents: The AVENA and HELENA Studies. *J. Sci. Med. Sport* **2010**, *13*, 584–588. [CrossRef]
16. Cohen, D.; Voss, C.; Taylor, M.; Delextrat, A.; Ogunleye, A.; Sandercock, G. Ten-year secular changes in muscular fitness in English children. *Acta Paediatr. Int. J. Paediatr.* **2011**, *100*, e175–e177. [CrossRef]
17. Albon, H.M.; Hamlin, M.J.; Ross, J.J. Secular trends and distributional changes in health and fitness performance variables of 10-14-year-old children in New Zealand between 1991 and 2003. *Br. J. Sports Med.* **2010**, *44*, 263–269. [CrossRef]
18. Faigenbaum, A.D.; Bruno, L.E. A fundamental approach for treating pediatric dynapenia in kids. *ACSM Health Fit. J.* **2017**, *21*, 18–24. [CrossRef]
19. Smith, J.J.; Eather, N.; Weaver, R.G.; Riley, N.; Beets, M.W.; Lubans, D.R. Behavioral Correlates of Muscular Fitness in Children and Adolescents: A Systematic Review. *Sports Med.* **2019**, *49*, 887–904. [CrossRef]
20. Fühner, T.; Kliegl, R.; Arntz, F.; Kriemler, S.; Granacher, U. An Update on Secular Trends in Physical Fitness of Children and Adolescents from 1972 to 2015: A Systematic Review. *Sports Med.* **2021**, *51*, 303–320. [CrossRef]
21. Lai, S.K.; Costigan, S.A.; Morgan, P.J.; Lubans, D.R.; Stodden, D.F.; Salmon, J.; Barnett, L.M. Do School-Based Interventions Focusing on Physical Activity, Fitness, or Fundamental Movement Skill Competency Produce a Sustained Impact in These Outcomes in Children and Adolescents? A Systematic Review of Follow-Up Studies. *Sports Med.* **2014**, *44*, 67–79. [CrossRef]
22. Jaakkola, T.; Yli-Piipari, S.; Huotari, P.; Watt, A.; Liukkonen, J. Fundamental movement skills and physical fitness as predictors of physical activity: A 6-year follow-up study. *Scand. J. Med. Sci. Sports* **2016**, *26*, 74–81. [CrossRef]
23. Cattuzzo, M.T.; Henrique, R.D.S.; Ré, A.H.N.; de Oliveira, I.S.; Melo, B.M.; Moura, M.D.S.; de Araújo, R.C.; Stodden, D. Motor competence and health related physical fitness in youth: A systematic review. *J. Sci. Med. Sport* **2016**, *19*, 123–129. [CrossRef]
24. Milne, N.; Leong, G.M.; Hing, W. The relationship between children's motor proficiency and health-related fitness. *J. Paediatr. Child Health* **2016**, *52*, 825–831. [CrossRef]
25. Lubans, D.R.; Morgan, P.J.; Cliff, D.P.; Barnett, L.M.; Okely, A.D. Fundamental Movement Skills in Children and Adolescents Review of Associated Health Benefits. *Sport. Med.* **2010**, *40*, 1019–1035. [CrossRef]
26. American College of Sport Medicine Exercise is Medicine: The Power of Physical Activity. Available online: https://www.exerciseismedicine.org/support_page.php/physical-activity-health-impact/ (accessed on 10 April 2020).
27. Beedie, C.; Mann, S.; Jimenez, A.; Kennedy, L.; Lane, A.M.; Domone, S.; Wilson, S.; Whyte, G. Death by effectiveness: Exercise as medicine caught in the efficacy trap! *Br. J. Sports Med.* **2016**, *50*, 323–324. [CrossRef]
28. Peng, W.; Lin, J.-H.; Crouse, J. Is Playing Exergames Really Exercising? A Meta-Analysis of Energy Expenditure in Active Video Games. *Cyberpsychol. Behav. Soc. Netw.* **2011**, *14*, 681–688. [CrossRef]
29. Sween, J.; Wallington, S.F.; Sheppard, V.; Taylor, T.; Llanos, A.; Adams-Campbell, L.L. The Role of Exergaming in Improving Physical Activity: A Review. *J. Phys. Act. Health* **2014**, *11*, 864–870. [CrossRef]
30. Gao, Z.; Chen, S.; Pasco, D.; Pope, Z. A meta-analysis of active video games on health outcomes among children and adolescents. *Obes. Rev.* **2015**, *16*, 783–794. [CrossRef]
31. Leblanc, A.G.; Chaput, J.-P.; McFarlane, A.; Colley, R.C.; Thivel, D.; Biddle, S.J.H.; Maddison, R.; Leatherdale, S.T.; Tremblay, M.S. Active Video Games and Health Indicators in Children and Youth: A Systematic Review. *PLoS ONE* **2013**, *8*. [CrossRef]
32. Biddiss, E.; Irwin, J. Active Video Games to Promote Physical Activity in Children and Youth A Systematic Review. *Arch. Pediatr. Adolesc. Med.* **2010**, *164*, 664–672. [CrossRef] [PubMed]
33. Barnett, A.; Cerin, E.; Baranowski, T. Active Video Games for Youth: A Systematic Review. *J. Phys. Act. Health* **2011**, *8*, 724–737. [CrossRef] [PubMed]
34. Comeras-Chueca, C.; Villalba-Heredia, L.; Pérez-Llera, M.; Lozano-Berges, G.; Marín-Puyalto, J.; Vicente-Rodríguez, G.; Matute-Llorente, Á.; Casajús, J.A.; González-Agüero, A. Assessment of Active Video Games' Energy Expenditure in Children with Overweight and Obesity and Differences by Gender. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6714. [CrossRef] [PubMed]
35. Azevedo, L.B.; Watson, D.B.; Haighton, C.; Adams, J. The effect of dance mat exergaming systems on physical activity and health—related outcomes in secondary schools: Results from a natural experiment. *BMC Public Health* **2014**, *14*. [CrossRef]
36. Fu, Y.; Burns, R.D. Effect of an Active Video Gaming Classroom Curriculum on Health-Related Fitness, School Day Step Counts, and Motivation in Sixth Graders. *J. Phys. Act. Health* **2018**, *15*, 644–650. [CrossRef]
37. Fu, Y.; Burns, R.D.; Constantino, N.; Zhang, P. Differences in Step Counts, Motor Competence, and Enjoyment Between an Exergaming Group and a Non-Exergaming Group. *Games Health J.* **2018**, *7*, 335–340. [CrossRef]
38. Ye, S.; Lee, J.E.; Stodden, D.F.; Gao, Z. Impact of Exergaming on Children's Motor Skill Competence and Health-Related Fitness: A Quasi-Experimental Study. *J. Clin. Med.* **2018**, *7*, 261. [CrossRef]

39. De Onis, M.; Onyango, A.W.; Borghi, E.; Siyam, A.; Nishida, C.; Siekmann, J. Development of a WHO growth reference for school-aged children and adolescents. *Bull. World Health Organ.* **2007**, *85*, 660–667. [CrossRef]
40. Higgins, J.P.T.; Green, S. (Eds.) *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [Updated March 2011]*; Cochrane: London, UK, 2011.
41. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*. [CrossRef]
42. Moher, D.; Shamseer, L.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A.; Estarli, M.; Barrera, E.S.A.; et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Rev. Esp. Nutr. Hum. Diet.* **2016**, *20*, 148–160. [CrossRef]
43. Sterne, J.A.C.; Savović, J.; Page, M.J.; Elbers, R.G.; Blencowe, N.S.; Boutron, I.; Cates, C.J.; Cheng, H.-Y.; Corbett, M.S.; Eldridge, S.M.; et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ* **2019**, *366*. [CrossRef] [PubMed]
44. Sterne, J.A.; Hernán, M.A.; Reeves, B.C.; Savović, J.; Berkman, N.D.; Viswanathan, M.; Henry, D.; Altman, D.G.; Ansari, M.T.; Boutron, I.; et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* **2016**, *355*. [CrossRef] [PubMed]
45. Higgins, J.P.T.; Altman, D.G.; Gøtzsche, P.C.; Jüni, P.; Moher, D.; Oxman, A.D.; Savović, J.; Schulz, K.F.; Weeks, L.; Sterne, J.A.C.; et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* **2011**, *343*. [CrossRef] [PubMed]
46. Medeiros, P.; Felden, É.P.G.; Zequinão, M.A.; Cordeiro, P.C.; de Freitas, K.T.D.; dos Santos, J.O.L.; Cardoso, F.L. Positive effect of a motor intervation program with exergames: A blind randomized trial. *Int. J. Game Based Learn.* **2020**, *10*, 55–64. [CrossRef]
47. McGann, J.; Issartel, J.; Hederman, L.; Conlan, O. Hop.Skip.Jump.Games: The effect of "principled" exergameplay on children's locomotor skill acquisition. *Br. J. Educ. Technol.* **2019**, *51*, 798–816. [CrossRef]
48. Gao, Z.; Lee, J.E.; Zeng, N.; Pope, Z.C.; Zhang, Y.; Li, X. Home-Based Exergaming on Preschoolers' Energy Expenditure, Cardiovascular Fitness, Body Mass Index and Cognitive Flexibility: A Randomized Controlled Trial. *J. Clin. Med.* **2019**, *8*, 1745. [CrossRef] [PubMed]
49. Coknaz, D.; Mirzeoglu, A.D.; Atasoy, H.I.; Alkoy, S.; Coknaz, H.; Goral, K. A digital movement in the world of inactive children: Favourable outcomes of playing active video games in a pilot randomized trial. *Eur. J. Nucl. Med. Mol. Imaging* **2019**, *178*, 1567–1576. [CrossRef]
50. Ye, S.; Pope, Z.C.; Lee, J.E.; Gao, Z. Effects of school-based exergaming on urban children's physical activity and cardiorespiratory fitness: A quasi-experimental study. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4080. [CrossRef]
51. Lau, P.W.C.; Wang, J.J.; Maddison, R. A Randomized-Controlled Trial of School-Based Active Videogame Intervention on Chinese Children's Aerobic Fitness, Physical Activity Level, and Psychological Correlates. *Games Health J.* **2016**, *5*, 405–412. [CrossRef]
52. Vernadakis, N.; Papastergiou, M.; Zetou, E.; Antoniou, P. The impact of an exergame-based intervention on children's fundamental motor skills. *Comput. Educ.* **2015**, *83*, 90–102. [CrossRef]
53. Johnson, T.M.; Ridgers, N.D.; Hulteen, R.M.; Mellecker, R.R.; Barnett, L.M. Does playing a sports active video game improve young children's ball skill competence? *J. Sci. Med. Sport* **2016**, *19*, 432–436. [CrossRef]
54. Mombarg, R.; Jelsma, D.; Hartman, E. Effect of Wii-intervention on balance of children with poor motor performance. *Res. Dev. Disabil.* **2013**, *34*, 2996–3003. [CrossRef]
55. Sheehan, D.P.; Katz, L. The effects of a daily, 6-week exergaming curriculum on balance in fourth grade children. *J. Sport Health Sci.* **2013**, *2*, 131–137. [CrossRef]
56. Sheehan, D.P.; Katz, L. The impact of a six week exergaming curriculum on balance with grade three school children using the wii FIT+TM. *Int. J. Comput. Sci. Sport* **2012**, *11*, 5–22. [CrossRef]
57. Maloney, A.E.; Stempel, A.; Wood, M.E.; Patraitis, C.; Beaudoin, C. Can Dance Exergames Boost Physical Activity as a School-Based Intervention? *Games Health J.* **2012**, *1*, 416–421. [CrossRef]
58. Graves, L.E.F.; Ridgers, N.D.; Atkinson, G.; Stratton, G. The Effect of Active Video Gaming on Children's Physical Activity, Behavior Preferences and Body Composition. *Pediatr. Exerc. Sci.* **2010**, *22*, 535–546. [CrossRef]
59. Maloney, A.E.; Bethea, T.C.; Kelsey, K.S.; Marks, J.T.; Paez, S.; Rosenberg, A.M.; Catellier, D.J.; Hamer, R.M.; Sikich, L. A Pilot of a Video Game (DDR) to Promote Physical Activity and Decrease Sedentary Screen Time. *Obesity* **2008**, *16*, 2074–2080. [CrossRef]
60. Cifci, C.; Baspinar, S.G. The Effects of Active Video Games on Strength, Vertical Jumping and Flexibility in Children Aged 12 to 15 Years Old. *Int. J. Appl. Exerc. Physiol.* **2020**, *9*, 70–77. [CrossRef]
61. Gao, Z.; Zeng, N.; Pope, Z.C.; Wang, R.; Yu, F. Effects of exergaming on motor skill competence, perceived competence, and physical activity in preschool children. *J. Sport Health Sci.* **2019**, *8*, 106–113. [CrossRef]
62. De Brito-Gomes, J.L.; Perrier-Melo, R.J.; De Oliveira, S.F.M.; Guimarães, F.J.D.S.P.; Costa, M.D.C. Physical Effort, Energy Expenditure, and Motivation in Structured and Unstructured Active Video Games: A Randomized Controlled Trial. *Hum. Mov.* **2016**, *17*, 190–198. [CrossRef]
63. Owens, S.G.; Garner, J.C.; Loftin, J.M.; van Blerk, N.; Ermin, K. Changes in Physical Activity and Fitness after 3 Months of Home Wii Fit Use. *J. Strength Cond. Res.* **2011**, *25*, 3191–3197. [CrossRef]
64. Bethea, T.C.; Berry, D.; Maloney, A.E.; Sikich, L. Pilot Study of an Active Screen Time Game Correlates with Improved Physical Fitness in Minority Elementary School Youth. *Games Health J.* **2012**, *1*, 29–36. [CrossRef]

65. Gao, Z.; Zeng, N.; McDonough, D.J.; Su, X. A Systematic Review of Active Video Games on Youth's Body Composition and Physical Activity. *Int. J. Sports Med.* **2020**, *41*, 561–573. [CrossRef]
66. Hernández-Jiménez, C.; Sarabia, R.; Paz-Zulueta, M.; Paras-Bravo, P.; Pellico, A.; Azcona, L.R.; Blanco, C.; Madrazo, M.; Agudo, M.J.; Sarabia, C.; et al. Impact of Active Video Games on Body Mass Index in Children and Adolescents: Systematic Review and Meta-Analysis Evaluating the Quality of Primary Studies. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2424. [CrossRef]
67. Oliveira, C.B.; Pinto, R.Z.; Saraiva, B.T.C.; Tebar, W.R.; Delfino, L.D.; Franco, M.R.; Silva, C.C.M.; Christofaro, D.G.D. Effects of active video games on children and adolescents: A systematic review with meta-analysis. *Scand. J. Med. Sci. Sports* **2020**, *30*, 4–12. [CrossRef]
68. Zeng, N.; Gao, Z. Exergaming and obesity in youth: Current perspectives. *Int. J. Gen. Med.* **2016**, *9*, 275–284. [CrossRef]
69. Gao, Z.; Chen, S. Are field-based exergames useful in preventing childhood obesity? A systematic review. *Int. Assoc. Study Obes.* **2014**, *15*, 1–16. [CrossRef]
70. Norris, E.; Hamer, M.; Stamatakis, E. Active Video Games in Schools and Effects on Physical Activity and Health: A Systematic Review. *J. Pediatr.* **2016**, *172*, 40–46.e5. [CrossRef]
71. Lamboglia, C.M.G.F.; Da Silva, V.T.B.L.; Filho, J.E.D.V.; Pinheiro, M.H.N.P.; Munguba, M.; Júnior, F.V.I.S.; De Paula, F.A.R.; Da Silva, C.A.B. Exergaming as a Strategic Tool in the Fight against Childhood Obesity: A Systematic Review. *J. Obes.* **2013**, *2013*, 438364. [CrossRef] [PubMed]
72. George, A.M.; Rohr, L.E.; Byrne, J. Impact of Nintendo Wii Games on Physical Literacy in Children: Motor Skills, Physical Fitness, Activity Behaviors, and Knowledge. *Sports* **2016**, *4*, 3. [CrossRef]
73. Gao, Z.; Lee, J.E.; Pope, Z.; Zhang, D. Effect of Active Videogames on Underserved Children's Classroom Behaviors, Effort, and Fitness. *Games Health J.* **2016**, *5*, 318–324. [CrossRef] [PubMed]
74. Kari, T. Can Exergaming Promote Physical Fitness and Physical Activity? *Int. J. Gaming Comput. Simul.* **2014**, *6*, 59–77. [CrossRef]
75. Kari, T. Promoting Physical Activity and Fitness with Exergames. In *Transforming Gaming and Computer Simulation Technologies across Industries*; IGI Global: Hershey, PA, USA, 2016; pp. 225–245. [CrossRef]
76. Van Brussel, M.; Bongers, B.C.; Hulzebos, E.H.; Burghard, M.; Takken, T. A Systematic Approach to Interpreting the Cardiopulmonary Exercise Test in Pediatrics. *Pediatr. Exerc. Sci.* **2019**, *31*, 194–203. [CrossRef] [PubMed]
77. Armstrong, N.; Welsman, J.; Winsley, R. Is Peak VO2a Maximal Index of Children's Aerobic Fitness? *Int. J. Sport. Med.* **1996**, *17*, 356–359. [CrossRef]
78. Smits-Engelsman, B.C.; Jelsma, L.D.; Ferguson, G.D. The effect of exergames on functional strength, anaerobic fitness, balance and agility in children with and without motor coordination difficulties living in low-income communities. *Hum. Mov. Sci.* **2017**, *55*, 327–337. [CrossRef]
79. De Medeirosa, P.; Capistranoa, R.; Almeida, M.; Aparecida, S.; Silva, T.; Cardoso, F. Exergames as a tool for the acquisition and development of motor skills and abilities: A systematic review. *Rev. Paul. Pediatr.* **2017**, *35*, 464–471. [CrossRef]
80. Page, Z.E.; Barrington, S.; Edwards, J.; Barnett, L.M. Do active video games benefit the motor skill development of non-typically developing children and adolescents: A systematic review. *J. Sci. Med. Sport* **2017**, *20*, 1087–1100. [CrossRef]
81. De Meester, A.; Maes, J.; Stodden, D.; Cardon, G.; Goodway, J.; Lenoir, M.; Haerens, L. Identifying profiles of actual and perceived motor competence among adolescents: Associations with motivation, physical activity, and sports participation. *J. Sports Sci.* **2016**, *34*, 2027–2037. [CrossRef]
82. Bardid, F.; De Meester, A.; Tallir, I.; Cardon, G.; Lenoir, M.; Haerens, L. Configurations of actual and perceived motor competence among children: Associations with motivation for sports and global self-worth. *Hum. Mov. Sci.* **2016**, *50*, 1–9. [CrossRef]

5.3 Artículo III

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Article

Assessment of Active Video Games' Energy Expenditure in Children with Overweight and Obesity and Differences by Gender

Cristina Comeras-Chueca [1,2,3,†], Lorena Villalba-Heredia [2,3,4], Marcos Pérez-Llera [2,3], Gabriel Lozano-Berges [1,2,3], Jorge Marín-Puyalto [2,3], Germán Vicente-Rodríguez [1,2,3], Ángel Matute-Llorente [1,2,3], José A. Casajús [2,3,4] and Alejandro González-Agüero [1,2,3,*]

1 Faculty of Health and Sport Science (FCSD), Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain; ccomeras@unizar.es (C.C.-C.); glozano@unizar.es (G.L.-B.); gervicen@unizar.es (G.V.-R.); amatute@unizar.es (Á.M.-L.)
2 GENUD (Growth, Exercise, Nutrition and Development) Research Group, Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain; lvillalbaheredia@unizar.es (L.V.-H.); marcospelle21@gmail.com (M.P.-L.); jmarinp@unizar.es (J.M.-P.); joseant@unizar.es (J.A.C.)
3 EXERNET Red de Investigación en Ejercicio Físico y Salud para Poblaciones Especiales, Spain
4 Faculty of Health Science, Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain
* Correspondence: alexgonz@unizar.es
† EXERNET is a scientific society to which the authors of the paper belong, and does not have a physical headquarters.

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Abstract: (1) Background: Childhood obesity has become a main global health problem and active video games (AVG) could be used to increase energy expenditure. The aim of this study was to investigate the energy expenditure during an AVG intervention combined with exercise, differentiating by gender. (2) Methods: A total of 45 children with overweight or obesity (19 girls) performed an AVG intervention combined with exercise. The AVG used were the Xbox Kinect, Nintendo Wii, dance mats, BKOOL cycling simulator, and Nintendo Switch. The energy expenditure was estimated from the heart rate recorded during the sessions and the data from the individual maximal tests. (3) Results: The mean energy expenditure was 315.1 kilocalories in a one-hour session. Participants spent the most energy on BKOOL, followed by Ring Fit Adventures, Dance Mats, Xbox Kinect, and the Nintendo Wii, with significant differences between BKOOL and the Nintendo Wii. Significant differences between boys and girls were found, but were partially due to the difference in weight, VO_{2max}, and fat-free mass. (4) Conclusions: The energy expenditure with AVG combined with multi-component exercise was 5.68 kcal/min in boys and 4.66 kcal/min in girls with overweight and obesity. AVG could be an effective strategy to increase energy expenditure in children and adolescents with overweight and obesity.

Keywords: active video games; energy expenditure; gender differences; children; obesity

1. Introduction

Obesity has become a main global health problem because of the alarming increase in its prevalence [1]. The World Health Organization (WHO) even refers to obesity as a "global pandemic" [2,3]. Childhood obesity is considered an important public health issue of the 21st century [4,5], especially in developing countries but also in developed countries, with a prevalence of 18% of children and adolescents aged 5–19 with overweight or obesity in 2016 [6].

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Overweight and obesity involve serious consequences, including an increase in the risk of developing cardiovascular and cardio-metabolic diseases such as type 2 diabetes, hypertension, and metabolic syndrome; and psychosocial problems such as low self-esteem, low self-confidence, low self-efficacy, low motivation for physical activity, bullying, or difficulties in establishing relationships [7,8]. From an economic point of view, childhood obesity represents an economic expense for the health-care system [9]. In addition, overweight and obese children are likely to remain obese during adulthood and will be likely to develop all types of cardiovascular and metabolic pathologies [4].

According to the WHO, insufficient physical activity is one of the main risk factors for death worldwide and a key risk factor for non-communicable diseases such as cardio-metabolic and cardiovascular diseases and cancer [10]. Children and adolescents should participate in at least 60 min of moderate to vigorous intensity physical activity daily, and could expect additional benefits with a greater amount of physical activity [11]. Nevertheless, a large proportion of the children and adolescents do not meet the public health recommendations of physical activity [12]. Over 80% of the world's adolescent population is insufficiently physically active, with girls being less active than boys and inactivity rising with age [11,13], and the relationship between physical inactivity and obesity is well known [14].

The development of new technologies with the industrial revolution has led to a decline in physical activity and energy expenditure, but also to an increase in sedentary behavior among children and adolescents [13]. The American Academy of Paediatrics recommends not to exceed 2 h of screen time per day [15], but approximately a third of the European children included in IDEFICS study exceeded the recommendations [16]. Screen-based behaviors such as using smartphones, tablets, or computers; watching television; or playing videogames have become the preferred sedentary behaviors in free-time daily living among children and adolescents [17,18]. Gender differences have been shown for screen time, with boys spending more time in front of a screen and specifically playing video games [18].

The alarming increase in the prevalence of obesity and its dangerous consequences points out the need to confront it from childhood. It is well known that exercise is an effective tool to fight against obesity [19], but the main challenge is to ensure adherence to exercise in children with overweight and obesity [20]. Obesity prevention and treatment strategies have not been successful in the long term, and it is necessary to find new effective strategies to promote physical activity and to combat childhood obesity [10,18]. According to Ara et al. [21], interventions with children and adolescents with overweight or obesity are more likely to be effective and successful when working on reducing sedentary time and increasing moderate to vigorous physical activity rather than restricting dietary energy intake.

There is controversy about the influence of gender on energy expenditure. Drenowatz et al. [22] showed that the absolute and relative energy expenditure were higher in males compared with females. This could be due in part to the lower resting energy expenditure of females compared with males [23]. However, Geer et al. [24] reported similar resting energy expenditure in males and females when normalized to lean body mass. Other studies investigating differences in energy expenditure between males and females do not show significant differences. Klausen et al. [25] examined the effects of gender on energy expenditure independent of differences in body composition, showing that no significant differences between males and females for energy expenditure and basal metabolic rate were observed. These results were supported by Grund et al. [26], who concluded that gender had no significant effects on energy expenditure in prepubertal children. The results showed no gender differences in the resting energy expenditure, total energy expenditure, and activity-related energy expenditure, in addition to that resting energy expenditure and total energy expenditure were significantly related to fat-free mass [26].

Active-video games (AVG) have been proposed as a promising alternative, seeking to ally with new technologies rather than fighting against them [27,28]. AVG require body movement and the involvement of large muscle groups and, therefore, can be used to increase energy expenditure [27].

AVG interventions seems to be an effective strategy to promote the light-to-moderate physical activity among children and adolescents, being a good alternative to replace some sedentary behaviors [29,30]. AVG can be used to increase the energy expenditure to meet the daily recommendations of physical activity [31,32]. Some reviews show that AVG could contribute to promote a physically active lifestyle [32,33]. AVG interventions need to be structured and supervised. because no effects were found on physical activity or energy expenditure in home-based and/or unstructured AVG interventions [34,35].

Although scientific evidence seems to show the potential of AVG to increase energy expenditure and help children and adolescents achieve the daily physical activity recommendations to fight against obesity, the possibilities and effects of exercise sessions with AVG need to be investigated. It is unclear whether the intensity produced by AVG is enough to be considered a tool on which to base an intervention to prevent or treat obesity. In addition, it would be interesting to investigate the differences in energy expenditure when playing AVG between boys and girls. Gao et al. [33] pointed out the importance of taking gender differences into account, so an analysis of energy expenditure stratifying by gender is interesting.

A new AVG, the Ring Fit Adventures for Nintendo Switch, has been developed with the main objective of exercising. The Ring Fit Adventures is cutting-edge technology in AVG, and that is why it is necessary to study the potential of this AVG to fight against child obesity. What makes this AVG new and different is the use of a resistance ring to exert a resistance in the upper limb exercises and the use of a leg strap to control the movements of the lower extremities through a device with an accelerometer. The structure is like that of a conventional video game, with levels to overcome, with the difference that they are overcome with body movements and exercises. The intensity and difficulty of the exercises increases as the levels are surpassed. The detailed explanation of the exercises that are carried out, as well as a visual example, is noteworthy. In addition, it can be used by both adults and children.

Therefore, the aim of this study was to investigate the energy expenditure of combined sessions using several AVG, as well as to analyze the energy expenditure of each of the AVG used, especially the innovative AVG of Ring Fit Adventures. Furthermore, gender differences in energy expenditure during the sessions were examined.

2. Materials and Methods

This study was performed in accordance with the ethical guidelines of the Helsinki Declaration of 1964 (revised in Fortaleza, 2013), and were reviewed and approved by the Research Ethics Committee of the Government of Aragon (certificate numberº 11/2018, CEICA, Spain). All the participants and their parents or legal guardians were informed of the nature and possible risks of the experimental procedures before their written informed consent was obtained.

This is a cross-sectional study which is part of a larger randomized controlled trial which is registered in clinicaltrials.gov (identification number NCT04418713).

2.1. Participants

A total of 45 children with overweight or obesity met the inclusion criteria and participated in the study. The inclusion criteria were as follows: the participants had to be between the ages of 9 and 12 years, in Tanner I or II stage and not having had menarche, with overweight or obesity calculated by body mass index (BMI) and following the cut points of Cole et al. [36], without contraindications for the practice of physical exercise, and without pathologies that worsen with physical exercise. Tanner's stage was evaluated by a medical doctor. In addition, the exclusion criteria for the participants' daily lives were the following: participating in regular high-level or high-intensity extracurricular physical activities, following any special diet regime, and taking any medication that may interfere with the variables evaluated.

The participants were recruited from medical centers through their pediatricians or from schools of Zaragoza (Spain). The parents and pediatricians were informed about the development of the activity, the results, and the progress of the children.

2.2. Intervention

The participants were requested to attend to 3 sessions per week with a duration of 60 min each one. A total of 91 sessions were recorded. The sessions were composed of 10 min of warm-up, including joint mobility; dynamic flexibility; muscle activation; core, balance, and coordination exercises. This was followed by the main part, which consisted of 45 min of exercise with a combination of AVG and multicomponent exercise, following a circuit training dynamic where the participants were continuously rotating from AVG to exercises, and finally a 5 min cool-down part to lower the heart rate and end the session with static flexibility routines. In general, the sessions consisted of four AVG with an average duration of 8 min, and the multicomponent exercise was performed between the AVG. The multicomponent exercise lasted 13.1 min on average per session, divided into two or three activities with different objectives depending on the planning.

In the main part, the AVG included were the following: the Xbox 360® with the Kinect using "Kinect Adventures" and "Kinect Sport"; the Nintendo Wii® using "Wii Sports", "Just Dance", and "Mario and Sonic at the Olympic Games"; dance mats using "Dance Dance Revolution" and "Mario and Sonic at the Olympic Games" adapted from the Nintendo Wii to the dance mats; the BKOOL® interactive cycling simulator connected to a tablet HUAWEI MediaPad T5 AGS2-W09; and the Nintendo Switch® using "Ring Fit Adventures". It is noteworthy that the Ring Fit Adventures is a novel AVG that has not yet been studied. The intervention was carried out in two locations, the University of Zaragoza and the "San Braulio" public school in Zaragoza. All the AVG were provided through funding, and each site was equipped with the AVG necessary to develop the intervention. The sessions were different every day, following a progression of difficulty and intensity and fulfilling the objectives previously established in the planning. The participants did not play all the AVG in each session, so the number of sessions recorded for each AVG is different. The order in which the activities were carried out was different among the participants, as each participant started in an AVG and changed it after playing.

The AVG were combined with multicomponent exercises focused on enhancing health-related physical fitness, such as cardiorespiratory fitness, muscular endurance, and/or muscular strength, but also coordination and balance. This intervention design combining AVG with traditional exercise was selected due to a potentially greater energy expenditure [30]. The multicomponent exercise performed had a playful background to enhance motivation and enjoyment.

2.3. Outcomes

2.3.1. Physical Fitness

A walking-graded protocol was employed to assess cardiovascular fitness. Starting at a comfortable walking pace (3.2 km/h), speed was increased by 0.8 km/h every 2 min until the participants walked quickly (5.6 km/h), which was the maximum speed reached during the test. Then the slope was increased by 4% every minute until exhaustion (up to maximum of 20%). The test was performed on a treadmill (Quasar Med 4.0, h/p/cosmos, Nussdorf-Traunstein, Germany) with the mask fitted. A medical doctor, specialized in sports medicine, supervised the whole test. Respiratory gas exchange data were measured "breath-by-breath" using open circuit spirometry (Oxycon Pro, Jaeger/Viasys Healthcare, Hoechberg, Germany). Previously to maximal testing, an experienced physician examined each participant and gave permission to perform the cardiovascular fitness testing. The test was explained to the participants, who were fitted with electrodes and had their resting heart rate measured before starting.

Peak values of oxygen uptake and heart rate were defined as the highest average values obtained for any continuous 15 s period. The metabolic cart was calibrated with a gas of composition and volume previously known prior to the first test each day, as recommended by the manufacturer.

Electrocardiography (ECG) was used to record heart rate, utilizing a 12-lead system before and during the whole test. The maximal heart rate value was the highest value of heart rate recorded during the last stage of exercise. The blood pressure was also measured with a digital monitor (M3, HEM-72OO-E, Omron Healthcare Europe, Hoofddorp, Netherlands), for health and safety reasons, before the maximal effort test with the participant lying in a tilt, and during the recovery period in standing position, both on the right arm. The cuffs were adjusted to the circumference of the tested arm, and the measurement was taken twice. The participants had to be at rest 5 min before the pre-testing measurement.

2.3.2. Accelerometer and Heart Rate Monitor

The children's physical activity duration and intensity was objectively quantified using triaxial accelerometers (ActiGraph-GT3X + BT, ActigraphTM, LLC, Fort Walton Beach, FL, USA). The children wore the accelerometers during the whole session. These devices were placed on their left hip, which has been shown to be the region providing the most reliable data using this technique [37]. The accelerometers were used to record the heart rate measured by the Polar H10 (Polar Electro Oy., Lake Success, NY, USA) heart rate sensor and the Pro Chest Strap via Bluetooth. The children wore the Polar H10 heart rate sensor throughout the sessions, along with the accelerometer. It was important to ensure the correct placement of the chest strap and to avoid interference with other participants who were also wearing the band and the accelerometer.

2.3.3. Energy Expenditure Estimate

A maximal effort test was performed by all the participants. In order to estimate the oxygen consumption during all parts of the session based on the registered heart rate, a linear regression equation was calculated for each participant based on the heart rate and oxygen consumption data during all stages of the treadmill test. The energy expenditure during each exercise and the whole session was then estimated using this equation developed for each child and the heart rate data obtained from the accelerometers and the Polar H10 heart rate sensor. This method is valid and reliable to measure the energy expenditure [38,39], and is even more reliable than the accelerometry data [40], also taking into account that one of the devices used consists of a cyclosimulator, which might not be reliably registered by accelerometry.

2.4. Statistical Analyses

The Statistical Package for the Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA) was used to perform all the statistical analyses. Statistical significance was set at $p = 0.05$ in all tests. Data are presented as mean and standard deviation (SD). Kolmogorov–Smirnov tests were performed to verify the normal distribution of the variables, and the variables that did not show a normal distribution were transformed. A one-way analysis of variance (ANOVA) was used to compare the energy expenditure of each AVG. Independent t tests were used to examine the gender and BMI status differences in the energy expenditure of each AVG. Cohen's d effect sizes (95% confidence intervals (CI)) were calculated and interpreted as small (0.2–0.5), medium (0.5–0.8), or large (>0.8). A linear regression was performed for each participant with their individual oxygen consumption and heart rate data from the maximal test to calculate the energy expenditure when playing AVG.

3. Results

A total of 45 children and adolescents (10.1 ± 1.0 years) were included in this study. The participant characteristics are detailed in Table 1. Boys weighed more than girls, were taller, and had a higher BMI (all $p < 0.05$; Table 1).

Table 1. Participant characteristics.

Divided by Gender					
Variable	All (N = 45) Mean ± SD	Boys (n = 26) Mean ± SD	Girls (n = 19) Mean ± SD	d	p Value
Age (years)	10.1 ± 1.0	10.3 ± 1.0	9.8 ± 1.0	0.20	0.116
Weight (kg)	56.3 ± 10.7	60.1 ± 10.9	51.0 ± 8.1 *	0.36	0.004
Height (cm)	146.6 ± 7.6	149.1 ± 6.0	143.1 ± 8.4 *	0.37	0.008
BMI [a] (kg/m^2)	26.0 ± 3.2	26.9 ± 3.6	24.8 ± 2.3 *	0.26	0.030
BMI percentile	97.22 ± 2.4	97.6 ± 2.1	96.7 ± 2.7	0.39	0.201
VO_{2peak} (mL·kg·min)	32.5 ± 5.4	32.8 ± 6.1	32.1 ± 4.4	0.06	0.650
Divided by BMI status					
		Overweight (n = 19) Mean ± SD	Obesity (n = 26) Mean ± SD	d	p Value
Age (years)	-	10.6 ± 0.7	10.1 ± 1.0	0.49	0.117
Weight (kg)	-	49.9 ± 6.9	60.9 ± 10.7 †	1.22	0.000
Height (cm)	-	145.5 ± 7.2	147.3 ± 8.0	0.24	0.438
BMI [a] (kg/m$_2$)	-	23.4 ± 1.5	27.9 ± 2.9 †	1.94	0.000
BMI percentile	-	95.4 ± 2.7	98.58 ± 0.5	1.65	0.000
VO_{2peak} (mL·kg·min)	-	34.0 ± 5.3	31.4 ± 5.2	0.50	0.106

[a] BMI: Body Mass Index; * indicates a statistically significant difference between boys and girls (p < 0.05); † indicates a statistically significant difference between children with overweight and obesity (p < 0.05); Cohen's d can be small (0.2–0.5), medium (0.5–0.8), or large (>0.8).

The results showed 19 children with overweight (42.2%) and 26 children with obesity (57.8%) according to Cole et al. [36].

3.1. Energy Expenditure by Device

The energy spent in kcal/min and the metabolic equivalent (METs) for the whole session for each AVG and traditional exercise are reported in Table 2. The results showed an average energy expenditure of 315.1 ± 77.5 kilocalories for a one-hour session of this intervention, including AVG and exercises. Significant differences in energy expenditure were found between BKOOL and the Nintendo Wii (5.38 ± 1.2 vs. 4.38 ± 1.0 kcal/min; $p < 0.05$; Table 2). All the AVG included required a moderate intensity of between 3 and 6 METs [41].

Table 2. Energy expenditure for the whole session, each AVG [a], and exercise without AVG [a].

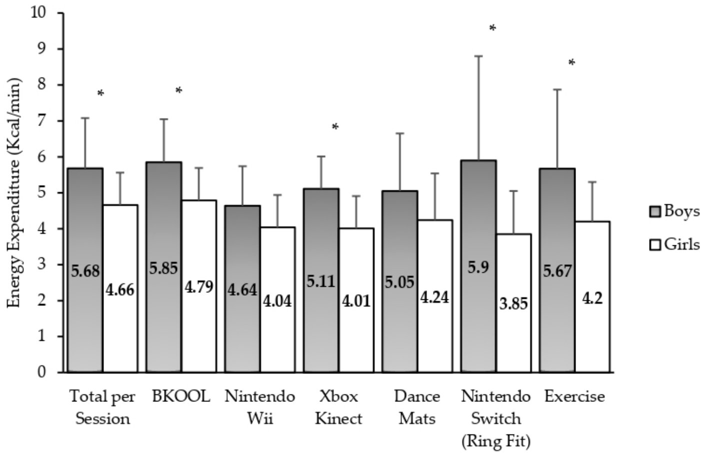
Variable	N	Kcal/min (n = 45)	METs [a]	Average Heart Rate
Complete session	45	5.25 ± 1.3	5.42 ± 1.3	134.52 ± 14.4
BKOOL	43	5.38 ± 1.2	5.61 ± 1.2	145.7 ± 12.0
Nintendo Wii	40	4.38 ± 1.0 *	4.63 ± 1.2 *	133.76 ± 10.9 *
Xbox Kinect	44	4.64 ± 1.0	4.83 ± 1.1	135.20 ± 13.5 *
Dance Mats	40	4.70 ± 1.5	4.83 ± 1.3	136.59 ± 12.2 *
Nintendo Switch (Ring Fit)	23	4.88 ± 2.0	4.80 ± 1.5	137.57 ± 14.8
Exercise	44	4.68 ± 1.2	4.81 ± 1.3	132.94 ± 12.2 *

[a] AVG: active video game; METs: metabolic equivalents; * indicates a statistically significant difference with BKOOL (p < 0.05).

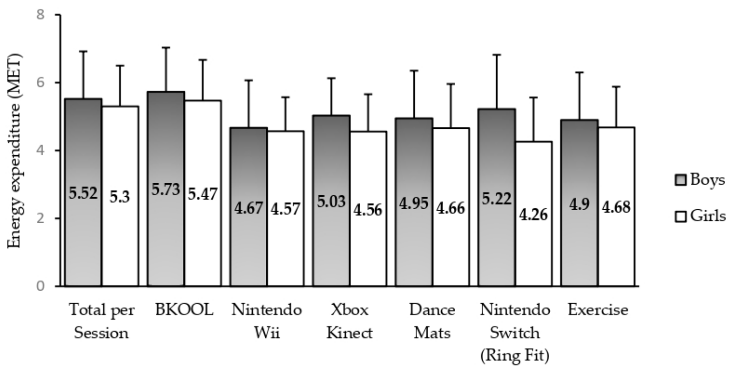
3.2. Gender Differences

Significant differences in energy expenditure between boys and girls were found for the average of the sessions and for some AVG (Figure 1). Boys had a higher energy expenditure than girls when playing Ring Fit Adventures (5.90 ± 2.9 vs. 3.85 ± 1.2 kcal/min), Xbox Kinect (5.11 ± 0.9 vs. 4.01 ± 0.9 kcal/min), and BKOOL (5.85 ± 1.2 vs. 4.79 ± 0.9 kcal/min) (all $p < 0.05$; Figure 1a).

These differences disappeared when using weight-independent metrics (METs), as shown in Figure 1b. This suggests that the differences shown in kcal/min were largely due to the difference in weight between boys and girls. Further analyzing the differences in the kcal/min spent between boys and girls, these differences in kcal/min disappeared when the VO_{2max} and fat-free mass mas were introduced as covariates, except for Xbox Kinect. No significant differences were found between boys and girls in the average heart rate recorded when playing each AVG.



(a)

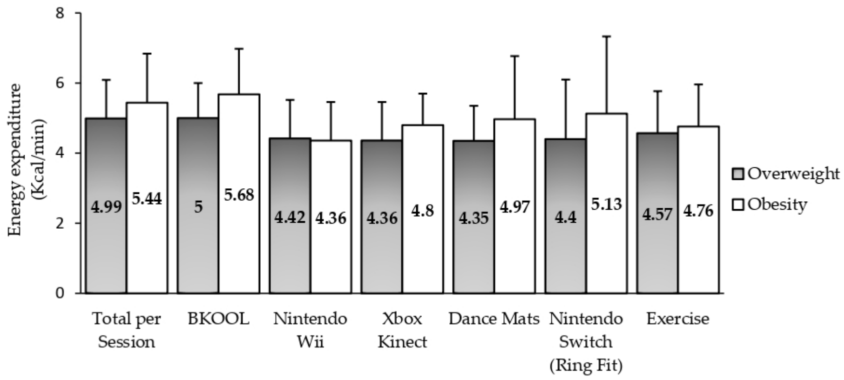


(b)

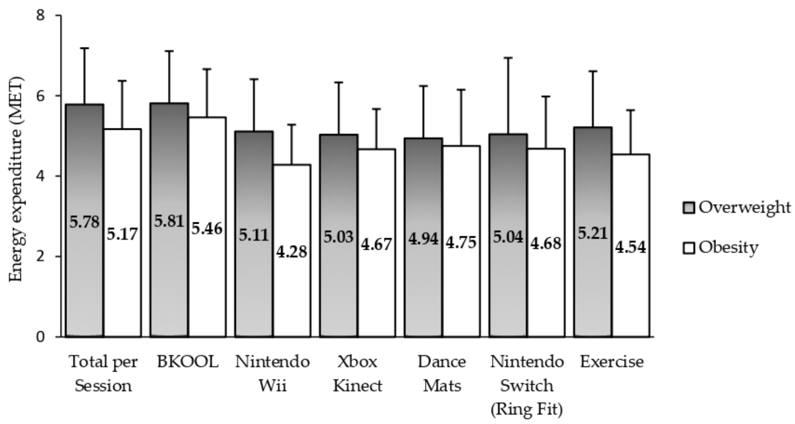
Figure 1. Energy expenditure for the whole session, each AVG, and exercise without AVG categorized by gender. * Indicates a statistically significant difference between boys and girls ($p < 0.05$). (**a**) Energy expenditure measured in kcal/min; (**b**) Energy expenditure measured in MET.

3.3. BMI Status

No significant differences in energy expenditure and average of heart rate were observed between those with overweight and those with obesity, but a tendency was seen towards a higher energy expenditure in those with obesity in kcal/min (Figure 2a), which changed when the energy expenditure was expressed in METs (Figure 2b), indicating again an influence of weight on this energy expenditure.



(**a**)



(**b**)

Figure 2. Energy expenditure for the whole session, each AVG, and exercise without AVG categorized by BMI status. (**a**) Energy expenditure measured in kcal/min; (**b**) Energy expenditure measured in MET.

4. Discussion

The aim of this study was to determine the energy expenditure of AVG sessions combined with exercise, as well as to analyze the energy expenditure of each device used and to investigate the differences between girls and boys. The results showed a mean energy expenditure of 315.1 ± 77.5 kilocalories in a one-hour session using different AVG combined with exercise. It should be noted that the energy expenditure of a complete session includes warming up (8–10 min per session), cooling down (5–8 min), and exercises (mean of 11min) other than the AVG. Regarding gender, some differences in energy expenditure were observed between boys and girls, being partially explained by differences in body weight. In addition, these differences in the energy expenditure expressed in kcal/min disappeared when VO_{2max} and fat-free mas were introduced as covariates, except for Xbox Kinect, in which there may be other factors that can influence energy expenditure, such as enjoyment and motivation, which were not measured in this study.

The energy expenditure in AVG was lower compared with participation in team sports (between 450 and 600 kcal/h), but it should be taken into account that obese children do not feel often ready, willing, or motivated to participate in any sport activity with their counterparts.

Children and adolescents spend much of their free time in sedentary activities, such as playing video games or watching TV (1–1.5 METs) [42]. Through AVG, the participants increased energy expenditure, but the key is to motivate sports participation at the end of the AVG intervention and, above all, to develop a healthier and more active lifestyle.

In accordance with the findings obtained in this study, previous studies that used the Nintendo Wii (Wii Sports or Just Dance), Xbox Kinect (Kinect Sports or Kinect Adventures), and Dance Dance Revolution reported similar results, with a higher energy expenditure in boys than in girls. Most of the previous studies that investigated AVG used an indirect calorimetry by using a portable metabolic analyzer to measure energy expenditure [43–54], but also a SenseWear® armband was used [55–57]. Other studies monitored activity using accelerometers or recorded heart rate and estimated energy expenditure [58–60]. The estimation of energy expenditure through heart rate data, as was used in this study, is a valid, reliable, and practical method which is based on the linear relationship between heart rate and VO_{2max} [38,39]; indeed, this is the most reliable non-calorimetric method measuring energy expenditure at different intensities [40] without the need for a portable metabolic analyzer. One strength of the method is the individualization through the stress tests performed on the participants, which, according to Keytel et al. [38], is especially important.

Research using the Nintendo Wii is wide. The present study showed that the Nintendo Wii was the device that required less kilocalories, with an energy expenditure of 4.38 ± 1.0 kcal/min. These findings are in line with a number of previous studies; Graf et al. [43] showed energy expenditure values of 2.2–2.86 METs and 3.86–3.9 METs in children when playing Wii Sports (bowling and boxing, respectively). Significant differences were found between boys and girls in energy expenditure (METs) for Dance Dance Revolution (level 1) and Nintendo Wii bowling, but not in Dance Dance Revolution (level 2) and Nintendo Wii boxing. Another study performed by Lau et al. [47] reported that Chinese children spent 2.05–5.14 kcal/min when playing Nintendo Wii, and no significant differences were shown between normal weight and overweight or obese children, concluding that AVG could provide an opportunity to increase physical activity, regardless of BMI status. A comparison of the energy cost of playing two games of Nintendo Wii between children with healthy weight and overweight or obesity was performed by O'Donovan [48]. In this study, AVG play resulted in being of light to moderate intensity, which contributes to an increase in daily energy expenditure, but this does not seem to be enough. Again, no differences were seen between normal weight and overweight or obese children, supporting the use of video games specially to treat childhood obesity.

Graves et al. [49] investigated the energy expenditure during three different games of Wii Sports, and showed that boxing produced the highest exergy expenditure (4.05 kcal/min), followed by tennis (3.05 kcal/min) and bowling (2.75 kcal/min), reporting less energy expenditure than the present study. Similar results were found by Lanningham-Foster et al. [44], who showed an increased energy expenditure of 3.15 kcal/min in children by playing Nintendo Wii Boxing, higher than in adults (2.47 kcal/min), and also reporting a lower energy expenditure than the current study. Another study investigated the energy spent by young boys playing several AVG of the Nintendo Wii, establishing Wii Sports boxing (3.05 METs) as the AVG that spent the most energy, followed by Wii Step (2.43 METs), Wii Sports tennis (2.16 METs), Wii Sports bowling (2.03 METs), and Wii Sports ski (1.65 METs) [50].

This study classified the Nintendo Wii as a low-intensity activity and compared this intensity with the intensity of walking at 4.5 km/h. This intensity is lower than the intensity reported in the present study (4.6 ± 1.2 METs). Siegmund et al. [51] reported energy expenditure values of 12.17 mL·kg·min for Wii Sports boxing (1.93 kcal/min), a much lower energy expenditure than the one reported in the current study. As shown, the studies discussed above show a lower energy expenditure compared to the present study. This may be due to an overestimated energy expenditure based on the results of the peak stress test and the heart rate recorded during game time, as the Nintendo Wii mainly requires movement of the upper extremities. Thus, playing the Nintendo Wii will be an activity with less muscle recruitment and therefore less energy expenditure. Another explanation could be that the participants of the present study were constantly supervised and encouraged during the sessions with AVG.

Quan et al. [58] measured 28 AVG sessions with Wii Fit, Just Dance, and Wii Sports to determinate how much time the participants spent at different intensities. The results showed that the participants spent 19.9% in moderate to vigorous physical activity, 32.9% in light physical activity, and 47.2% was sedentary time; no significant differences by gender were observed for moderate to vigorous physical activity, light physical activity, and sedentary behavior. In relation to the physical activity levels, one study compared the children's physical activity levels in physical education, play time, and the Nintendo Wii [59]. The results showed that children had the highest amount of moderate to vigorous and light physical activity, and the lowest sedentary time by playing Nintendo Wii, compared with physical education and play time. The highest sedentary time part was for physical education. Therefore, AVG could increase light and moderate to vigorous physical activity among children.

Several other articles investigated the potential of Wii Sports and Dance Dance Revolution to increase physical activity, concluding that these AVG elicit positive effects on energy balance [43,52]. It is important to note that, in the present study, dance mats were used not only to play Dance Dance Revolution, but were also used to play Mario and Sonic at the Olympic Games, adapted from the Nintendo Wii, which increased the energy expenditure. According to Graf et al. [43], the energy expenditure during Dance Dance Revolution and Wii Sports boxing were comparable to moderate-intensity walking (at 5.7 km/h), but during Wii Sports bowling it was less intense. The energy expenditure reported were lower compared with the present study, possibly due again to the method used to estimate energy expenditure. It is noteworthy that Mario and Sonic at the Olympic Games was adapted from the Nintendo Wii to the dance mats and was used to play at dance mats, recording the energy expenditure along with Dance Dance Revolution, which can increase the energy expenditure of the dance mats. Significant differences were found between girls and boys by Graf et al. [43], with a 19–33% higher energy expenditure (kcal/h per weight (kg)) for boys when playing DDR level 1, DDR level 2, and bowling, and similarly the VO_2 was 20% to 34% higher in boys ($p < 0.05$) during DDR level 1, DDR level 2, and bowling. With these data, it could be checked if, when including the maximum oxygen consumption and the fat-free mass as covariates, these differences still exist or disappear, as in the present study. Similar results were shown by Bailey et al. [52], who displayed an energy cost of 4.2 METs for Wii Sports boxing and 5.5 METs for Dance Dance Revolution, similar to the results shown in this study. It should be noted that the mean age was higher in the study by Bailey et al. [52] compared to the present study (11.5 ± 2.0 vs. 10.1 ± 1.0 years respectively). Bailey et al. [52] found no differences by BMI status for energy expenditure, and children with overweight or obesity had a higher enjoyment. Furthermore, a systematic review that included articles related to energy cost for Nintendo Wii, Eye Toy, and Dance Dance Revolution reported that the physical activity intensity of these AVG is light to moderate but that the energy expenditure was significantly lower for AVG played primarily through upper limb movements compared to those that engaged the lower limbs [61]. Nintendo Wii is primarily played with the upper extremities, which would explain why both the results of the current study and previous scientific evidence report a lower energy expenditure. Furthermore, motivation and enjoyment seem to influence the energy expenditure when playing the Nintendo Wii, as the amount and speed of movement will determine that expenditures. Nonetheless, although the contribution to the energy expenditure of the Nintendo Wii is less than that of other AVG, it is well known that some activity is better than none [48]. The Nintendo Wii could be a good tool to help increase the daily energy expenditure of overweight or obese children who are reluctant to engage in physical activity.

Xbox Kinect is another device often used in AVG interventions. The energy expenditure by Xbox Kinect has been studied, and it seems to elicit a higher intensity than Nintendo Wii, probably because it requires movement of the whole body. The previous scientific evidence agrees with the results obtained in this study. Most studies that evaluated energy expenditure playing Xbox 360 Kinect reported significant differences between girls and boys in kilocalories spent, as this study did. Smallwood et al. [53] showed the energy expenditure of two games of Xbox Kinect (Dance Central and Kinect Sports boxing) in school children between 11 and 15 years old. The energy expenditure was 172 kcal/h. Specifically, for Kinect Sport boxing (one of the AVG used in this study), the energy expenditure was 4.4 METs. Gender differences were found when playing Kinect Sport Boxing for the VO_2 and energy expenditure, with boys showing a significantly higher energy cost than girls (5.1 kcal/min for the boys compared with 3.4 kcal/min for the girls), and this difference remained significant ($p = 0.004$) when the caloric expenditure was normalized for body weight. This supports the results obtained in the present study. Similar results were found by Clevenger et al. [54], who reported an energy cost of 4.6 METs from 335 AVG sessions using the Xbox Kinect, and some AVG such as Kinect Adventures and Wipe Out exceeded 6 METs. Comparisons by groups were performed, showing that males spent significantly more kilocalories per minute than females, which supports the findings of this study; overweight or obese participants had a greater energy expenditure that healthy-weight participants, and teens spent more energy than children, which can be explained by the difference in weight. Two more studies found significant differences in the energy expenditure between males and females [45,60]. Vallabhajosula et al. [60] compared the energy expenditure in Xbox Kinect sessions using "Reflex Ridge" from Kinect Adventures vs. the energy expenditure during regular play time. The results showed higher kilocalories per min and METs in an Xbox Kinect session (1.85 kcal/min and 4.21 METs) in comparison with regular play time (1.59 kcal/min and 3.7 METs), and a higher percentage of very vigorous activity was seen for theXbox Kinect condition. No significant interactions were observed for BMI or gender, but there was a trend toward significance, where the rate of energy expenditure achieved was 34% higher in males. The energy cost in two AVG from Xbox Kinect ("River Rush" and "Reflex Ridge") was measured by McNarry et al. [45], showing that those AVG elicited moderate-intensity physical activity (5.5–5.7 METs), and could be used for meeting physical activity daily recommendations. The results also reported significant differences between males and females in one of the AVG played. As stated above, the energy expenditure playing AVG is similar to the energy spent during a brisk walk. Canabrava et al. [55] agree with this comparison as their results showed the similarity in energy expenditure between walking at 5 km/h and playing Xbox Kinect (Kinect Adventures, Kinect Sports boxing, and a dance videogame), reporting an energy cost of 185 kilocalories per hour and showing that AVG can be an interesting alternative to increase physical activity and to replace traditional sedentary video games. Once again, there were no significant differences in energy cost between children with a normal weight and children with overweight or obesity.

Some articles have shown differences by player mode in Xbox Kinect, comparing single vs. multiplayer mode. Barkman et al. [46] reported significant differences in energy expenditure between the single-player mode, with an energy cost of 15.4 mL·kg·min, and the multiplayer mode, with an energy cost of 16.8 mL·kg·min. METs for several AVG were also reported, with an energy cost of 3.9, 3.8, 3.5, and 3.1 METs for the single-player mode and 4.1, 4.3, 3.7, and 3.2 METs for the multi-player mode of Wipe Out, Kinect Adventures, Kinect Sports, and Just Dance, respectively. In accordance with these results, Verhoeven et al. [56] studied the same conditions, concluding that children consumed more energy in multi-player mode, as reported by Barkam et al. [46]. In addition to the mode of play, another factor that can affect energy expenditure is the narrative of the AVG. According to Sousa et al. [62], the narratives in AVG were associated with moderate to vigorous physical activity and with higher average heart rate, without increasing the rate of perceived exertion.

It might have been interesting to have studied the differences in energy expenditure when comparing the sample of overweight or obese children with a group of normal-weight children. Hwuang et al. [63] studied the differences in energy expenditure among children with normal weight and children with overweight or obesity. The results showed that children in both groups expended similar energy relative to their weight, and AVG were able to elicit moderate to vigorous intensity physical activity for all children, potentially contributing to meet the recommended physical activity levels. However, overweight/obese children spent more time at light intensity, and children with normal weight engaged more in vigorous-intensity activity than those with overweight/obesity.

Some studies go further, such as the study performed by Gao et al. [59], which proposed to integrate AVG within school curricula, with positive results as it contributed to children's daily energy expenditure and moderate to vigorous and light physical activity as much as physical education did, and even with a higher intensity.

AVG interventions need to be structured and supervised to produce positive effects on energy expenditure. No effects were found on physical activity or energy expenditure in home-based and/or unstructured AVG interventions [34,35]. In the present study, not only was a planned and structured intervention carried out, but it was combined with traditional physical exercise with the aim of increasing energy expenditure. This increased the total expenditure of the sessions. In addition, the intervention combined different AVG to achieve motivation based on novelty and variety and to adapt to the preferences of the participants. In this way, the AVG intervention performed in this study goes beyond other AVG interventions. In addition, novel AVG such as BKOOL and Ring Fit Adventures were included in the intervention of the present study, which have hardly been studied.

There is less scientific evidence about AVG interventions using a bicycle simulator or an interactive stationary bike. The BKOOL could be considered a game-based exercise strategy rather than an active video game, used primarily with adults. However, it could be a tool to promote active exercise among children and adolescents because it is an interactive and novel tool. Adamo et al. [64] investigated the effects of an interactive AVG with a stationary bike on overweight or obese adolescents, showing an average energy expenditure of 576.2 kcal/h. Another study performed an AVG intervention with stationary bikes which consisted of cycling to control a virtual tank. The energy expenditure with this AVG was 7.6 kcal/min in young adults [57]. In both articles, the energy spent by AVG on stationary bikes was higher than the expenditure obtained with BKOOL in this study, but the participants of those articles were young adults.

Finally, the Ring Fit Adventures is a recently released AVG, which has not yet been studied to the best of our knowledge. Ring Fit Adventures includes cardiorespiratory fitness and strength exercises, as well as dynamic and static stretches. During the AVG, there are "fitness battles" where strength exercises are used as attacks to defeat virtual enemies. These strength exercises are focused on the legs (such as squats, thigh presses, or knee lifts), arms and chest (such as bow pulls, triceps kickbacks, chest presses, and overhead presses), and core (such as planks, standing twist, and leg raises from the seated or lying positions). There are even yoga positions such as the chair, warrior, and tree poses to train balance and strength. The player has to skip to move through the game, raising their knees further to climb stairs or pass across the water, which is a demanding cardiorespiratory training. Ring Fit, together with BKOOL, are the AVG that required the most energy expenditure in kcal/min in this study, probably because they required full-body movement.

A higher energy expenditure of BKOOL and Ring Fit Adventures and a lower energy expenditure when playing Nintendo Wii can be explained by the muscles involved. Related to these results, a meta-analysis performed by Peng et al. [29] reported that AVG that mainly involved upper-limb movements had significantly smaller effects on energy expenditure than AVG that mainly involved lower-limb or whole-body movements.

Reviews of AVG show positive effects on energy balance and physical activity, helping to decrease sedentary behaviors [29–31]. It is still unclear if the intensity achieved during AVG is enough to help children meet the recommended physical activity levels [32,33], but the results of the present study are in line with those shown by previous scientific evidence, that at least moderate intensity is achieved with AVG. In this study, a wide variety of AVG were measured to find out the energy expenditure of the same group of children with overweight or obesity playing different devices. The results showed that the BKOOL was the device that notably required the most energy, and the Nintendo Wii the one that demanded the least. The energy expenditure when playing AVG was between 4.63 and 5.61 METs. In addition, differences in the kilocalories per minute were reported between boys and girls, which were mostly due to the weight difference. The main novelty was the fact of applying a combined intervention of AVG and exercise to achieve a higher energy expenditure. Another difference with previous research was the inclusion of the Ring Fit from the Nintendo Switch and the BKOOL cycling simulator into the AVG intervention. At the moment, no article has been published including Ring Fit, so this article is the first to report energy expenditure data for this new AVG.

Future research may focus on comparing interventions with AVG and other forms of training and on investigating how to make the most of this promising tool.

5. Conclusions

In view of our results, a structured and supervised AVG intervention combined with multi-component exercise is an effective strategy to produce moderate-intensity physical activity and to increase the energy expenditure in children and adolescents with overweight and obesity. Ring Fit Adventures is a promising tool to increase energy expenditure, exceeding the energy expenditure of the other AVG except BKOOL. The energy expenditure seems to be higher for boys in comparison with girls, but these differences might be partially due to disparities in body weight. In conclusion, AVG are an innovative and interesting tool that can help fight against childhood obesity and its future consequences.

6. Limitations and Strengths

Some limitations should be addressed. The overall energy expenditure for each device was measured, and no measurements were reported for each game used in each AVG. Reporting the kilocalories spent for each game used in each AVG would have been interesting in order to know which of them was the most energy consuming for each device. The energy expenditure was measured with the heart rate data through the maximum stress test data, since a portable metabolic analyzer was not available. In addition, the game mode was not taken into account, and evidence shows that using single-player or multi-player modes affects the energy expenditure, but most of the sessions were performed in pairs. Due to the characteristics of the intervention, it was complicated to record motivation or enjoyment during the AVG, but it would have been interesting to see the relationship between these two variables and energy expenditure.

On the other hand, this study is notable for the wide variety of AVG investigated. In addition, Ring Fit Adventures and BKOOL were included in the sessions with AVG, two novel devices that offer opportunities and possibilities to significantly increase energy expenditure in overweight or obese children. The BKOOL stands out for its interactivity, and the Ring Fit stands out for its playability and its focus on physical exercise and fitness. Despite not having portable metabolic analyzers, the individualized calculation of the energy expenditure through the data of the stress test and the heart rate measured during the sessions was a reliable and effective method [38,40,65], even in children [65]. Thanks to this method, it was possible to measure the energy expenditure of a large number of sessions and participants. Finally, the AVG intervention in this study was combined with multi-component exercise, which allowed us not only to increase the total energy expenditure of the sessions but also to compare the expenditure in the different AVG with the expenditure during exercise.

Author Contributions: All the authors have been actively involved in the planning and enactment of the study. J.A.C. and A.G.-A. were the main researchers in the present study, and C.C.-C. was the first author. G.V.-R., L.V.-H., M.P.-L., G.L.-B., J.M.-P. and Á.M.-L. were co-researchers. C.C.-C., L.V.-H., M.P.-L. and A.G.-A. participated in the performance of the sessions and in obtaining the accelerometry data. J.A.C., A.G.-A., C.C.-C., L.V.-H., Á.M.-L. and

G.L.-B. participated in the pre-intervention measurements. C.C.-C. drafted the document, and L.V.-H. participated in the interpretation of the results. A.G.-A., J.A.C., G.V.-R., G.L.-B., J.M.-P. and Á.M.-L. critically reviewed the document. All authors have read and agreed to the published version of the manuscript.

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References

1. Ng, M.; Fleming, T.; Robinson, M.; Thomson, B.; Graetz, N.; Margono, C.; Mullany, E.C.; Biryukov, S.; Abbafati, C.; Abera, S.F.; et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **2014**, *384*, 766–781. [CrossRef]
2. World Health Organization. Obesity: Preventing and managing the global epidemic. *Tech. Rep. Ser.* **2000**, *894*, 1–268.
3. Chooi, Y.C.; Ding, C.; Magkos, F. The epidemiology of obesity. *Metabolism* **2019**, *92*, 6–10. [CrossRef] [PubMed]
4. Ahluwalia, N.; Dalmasso, P.; Rasmussen, M.; Lipsky, L.; Currie, C.; Haug, E.; Kelly, C.; Damsgaard, M.T.; Due, P.; Tabak, I.; et al. Trends in overweight prevalence among 11-, 13- and 15-year-olds in 25 countries in Europe, Canada and USA from 2002 to 2010. *Eur. J. Public Health* **2015**, *25*, 28–32. [CrossRef]
5. World Health Organization. *Consideration of the Evidence on Childhood Obesity for the Commission on Ending Childhood Obesity: Report of the Ad Hoc Working Group on Science and Evidence for Ending Childhood Obesity*; World Health Organization: Geneva, Switzerland, 2016; ISBN 9789241565332.
6. World Health Organization. World Health Organization Global Health Observatory (GHO) Data. Obesity and Overweight. 2016. Available online: https://www.who.int/gho/ncd/risk_factors/overweight_obesity/obesity_adolescents/en/ (accessed on 9 April 2020).
7. Gurnani, M.; Birken, C.; Hamilton, J. Childhood Obesity: Causes, Consequences, and Management. *Pediatr. Clin. North Am.* **2015**, *62*, 821–840. [CrossRef]
8. McCrindle, B.W. Cardiovascular Consequences of Childhood Obesity. *Can. J. Cardiol.* **2015**, *31*, 124–130. [CrossRef]
9. Ding, D.; Lawson, K.D.; Kolbe-Alexander, T.L.; Finkelstein, E.A.; Katzmarzyk, P.T.; van Mechelen, W.; Pratt, M. The economic burden of physical inactivity: A global analysis of major non-communicable diseases. *Lancet* **2016**, *388*, 1311–1324. [CrossRef]
10. Blüher, M. Obesity: Global epidemiology and pathogenesis. *Nat. Rev. Endocrinol.* **2019**, *15*, 288–298. [CrossRef]
11. World Health Organization. World Health Organization Physical Activity. 2018. Available online: https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed on 6 April 2020).
12. Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [CrossRef]
13. Hallal, P.C.; Andersen, L.B.; Bull, F.C.; Guthold, R.; Haskell, W.; Ekelund, U.; Alkandari, J.R.; Bauman, A.E.; Blair, S.N.; Brownson, R.C.; et al. Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet* **2012**, *380*, 247–257. [CrossRef]
14. Brock, D.W.; Thomas, O.; Cowan, C.D.; Allison, D.B.; Gaesser, G.A.; Hunter, G.R.; Cowan, A. Association Between Insufficiently Physically Active and the Prevalence of Obesity in the United States. *J. Phys. Act. Health* **2009**, *6*, 1–5. [CrossRef] [PubMed]
15. Bar-On, M.E.; Broughton, D.D.; Buttross, S.; Corrigan, S.; Gedissman, A.; De Rivas, M.R.G.; Hogan, M. Children, adolescents, and television. *Pediatrics* **2001**, *107*, 423–426.

16. Santaliestra-Pasías, A.M.; Mouratidou, T.; Verbestel, V.; Bammann, K.; Molnar, D.; Sieri, S.; Siani, A.; Veidebaum, T.; Mårild, S.; Lissner, L.; et al. Physical activity and sedentary behaviour in European children: The IDEFICS study. *Public Health Nutr.* **2013**, *17*, 2295–2306. [CrossRef] [PubMed]
17. Tanaka, C.; Tanaka, M.; Okuda, M.; Inoue, S.; Aoyama, T.; Tanaka, S. Association between objectively evaluated physical activity and sedentary behavior and screen time in primary school children. *BMC Res. Notes* **2017**, *10*, 175. [CrossRef]
18. O'Brien, W.; Issartel, J.; Belton, S. Relationship between Physical Activity, Screen Time and Weight Status among Young Adolescents. *Sports* **2018**, *6*, 57. [CrossRef]
19. Stoner, L.; Rowlands, D.; Morrison, A.; Credeur, D.; Hamlin, M.; Gaffney, K.; Lambrick, D.; Matheson, A. Efficacy of Exercise Intervention for Weight Loss in Overweight and Obese Adolescents: Meta-Analysis and Implications. *Sports Med.* **2016**, *46*, 1737–1751. [CrossRef] [PubMed]
20. Beedie, C.; Mann, S.; Jimenez, A.; Kennedy, L.; Lane, A.M.; Domone, S.; Wilson, S.; Whyte, G. Death by effectiveness: Exercise as medicine caught in the efficacy trap! *Br. J. Sports Med.* **2016**, *50*, 323–324. [CrossRef]
21. Ara, I.; Vicente-Rodríguez, G.; Moreno, L.A.; Gutin, B.; Casajus, J.A. Child obesity can be better reduced through vigorous physical activity rather than through energy intake restriction. *Apunt. Med. De L'esport* **2009**, *44*, 111–118. [CrossRef]
22. Drenowatz, C.; Hand, G.A.; Shook, R.P.; Jakicic, J.M.; Hebert, J.R.; Burgess, S.; Blair, S.N. The association between different types of exercise and energy expenditure in young nonoverweight and overweight adults. *Appl. Physiol. Nutr. Metab.* **2015**, *40*, 211–217. [CrossRef]
23. Tershakovec, A.M.; Kuppler, K.M.; Zemel, B.; Stallings, V.A. Age, sex, ethnicity, body composition, and resting energy expenditure of obese African American and white children and adolescents. *Am. Soc. Clin. Nutr.* **2002**, *75*, 867–871. [CrossRef]
24. Geer, E.B.; Shen, W. Gender differences in insulin resistance, body composition, and energy balance. *Gend. Med.* **2009**, *6*, 60–75. [CrossRef] [PubMed]
25. Klausen, B.; Astrup, A. Age and sex effects on energy expenditure. *Am. J. Clin. Nutr.* **1197**, *65*, 895–907. [CrossRef] [PubMed]
26. Grund, A.; Vollbrecht, H.; Frandsen, W.; Krause, H.; Siewers, M.; Rieckert, H.; Mu, M.J.; Ller, È. No effect of gender on different components of daily energy expenditure in free living prepubertal children. *Int. J. Obes.* **2000**, *24*, 299–305. [CrossRef] [PubMed]
27. Benzing, V.; Schmidt, M. Exergaming for Children and Adolescents: Strengths, Weaknesses, Opportunities and Threats. *J. Clin. Med.* **2018**, *7*, 422. [CrossRef] [PubMed]
28. Robinson, T.N.; Banda, J.A.; Hale, L.; Lu, A.S.; Fleming-Milici, F.; Calvert, S.L.; Wartella, E. Screen media exposure and obesity in children and adolescents. *Pediatrics* **2017**, *140*, S97–S101. [CrossRef]
29. Peng, W.; Lin, J.-H.H.; Crouse, J. Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. *Cyberpsychol. Behav. Soc. Netw.* **2011**, *14*, 681–688. [CrossRef]
30. Gao, Z.; Chen, S.; Pasco, D.; Pope, Z. A meta-analysis of active video games on health outcomes among children and adolescents. *Obes. Rev.* **2015**, *16*, 783–794. [CrossRef]
31. Sween, J.; Wallington, S.F.; Sheppard, V.; Taylor, T.; Llanos, A.A.; Adams-Campbell, L.L. The role of exergaming in improving physical activity: A review. *J. Phys. Act. Health* **2014**, *11*, 864–870. [CrossRef]
32. LeBlanc, A.G.; Chaput, J.P.; McFarlane, A.; Colley, R.C.; Thivel, D.; Biddle, S.J.H.; Maddison, R.; Leatherdale, S.T.; Tremblay, M.S. Active Video Games and Health Indicators in Children and Youth: A Systematic Review. *PLoS ONE* **2013**, *8*, e65351. [CrossRef]
33. Gao, Z.; Chen, S. Are field-based exergames useful in preventing childhood obesity? A systematic review. *Int. Assoc. Study Obes.* **2014**, *15*, 676–691. [CrossRef]
34. Liang, Y.; Lau, P.W.C. Effects of active videogames on physical activity and related outcomes among healthy children: A systematic review. *Games Health J.* **2014**, *3*, 122–144. [CrossRef] [PubMed]
35. De Brito-Gomes, J.L.; Perrier-Melo, R.J.; Melo De Oliveira, S.F.; De Sá Pereira Guimarães, F.J.; Da Cunha Costa, M. Physical effort, energy expenditure, and motivation in structured and unstructured active video games: A randomized controlled trial. *Hum. Mov.* **2016**, *17*, 190–198. [CrossRef]
36. Cole, T.J.; Bellizzi, M.C.; Flegal, K.M.; Dietz, W.H. Establishing a standard definition for child overweight and obesity worldwide: International survey. *Br. Med. J.* **2000**, *320*, 1240. [CrossRef] [PubMed]
37. Romanzini, M.; Petroski, E.L.; Ohara, D.; Dourado, A.C.; Reichert, F.F. Calibration of ActiGraph GT3X, Actical and RT3 accelerometers in adolescents. *Eur. J. Sport Sci.* **2014**, *14*, 91–99. [CrossRef]

38. Keytel, L.R.; Goedecke, J.H.; Noakes, T.D.; Hiiloskorpi, H.; Laukkanen, R.; van der Merwe, L.; Lambert, E.V. Prediction of energy expenditure from heart rate monitoring during submaximal exercise. *J. Sports Sci.* **2005**, *23*, 289–297. [CrossRef]
39. Achten, J.; Jeukendrup, A.E. Heart Rate Monitoring Applications and Limitations. *Sports Med.* **2003**, *33*, 517–538. [CrossRef]
40. Durkalec-Michalski, K.; Woåniewicz, M.; Bajerska, J.; Jeszka, J. Comparison of accuracy of various non-calorimetric methods measuring energy expenditure at different intensities. *Hum. Mov.* **2013**, *14*, 161–167. [CrossRef]
41. Haskell, W.L.; Lee, I.M.; Pate, R.R.; Powell, K.E.; Blair, S.N.; Franklin, B.A.; MacEra, C.A.; Heath, G.W.; Thompson, P.D.; Bauman, A. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med. Sci. Sports Exerc.* **2007**, *39*, 1423–1434. [CrossRef]
42. Harrell, J.S.; Mcmurray, R.G.; Baggett, C.D.; Pennell, M.L.; Pearce, P.F.; Bangdiwala, S.I. Energy costs of physical activities in children and adolescents. *Med. Sci. Sports Exerc.* **2005**, *37*, 329–336. [CrossRef]
43. Graf, D.L.; Pratt, L.V.; Hester, C.N.; Short, K.R. Playing active video games increases energy expenditure in children. *Pediatrics* **2009**, *124*, 534–540. [CrossRef]
44. Lanningham-Foster, L.; Foster, R.C.; McCrady, S.K.; Jensen, T.B.; Mitre, N.; Levine, J.A. Activity-Promoting Video Games and Increased Energy Expenditure. *J. Pediatr.* **2009**, *154*, 819–823. [CrossRef]
45. McNarry, M.A.; Mackintosh, K.A. Investigating the relative exercise intensity of exergames in prepubertal children. *Games Health J.* **2016**, *5*, 135–140. [CrossRef] [PubMed]
46. Barkman, J.; Pfeiffer, K.; Diltz, A.; Peng, W. Examining energy expenditure in youth using XBOX kinect: Differences by player mode. *J. Phys. Act. Health* **2016**, *13*, S41–S43. [CrossRef] [PubMed]
47. Lau, P.W.C.; Liang, Y.; Lau, E.Y.; Choi, C.R.; Kim, C.G.; Shin, M.S. Evaluating physical and perceptual responses to exergames in chinese children. *Int. J. Environ. Res. Public Health* **2015**, *12*, 4018–4030. [CrossRef] [PubMed]
48. O'Donovan, C.; Roche, E.F.; Hussey, J. The energy cost of playing active video games in children with obesity and children of a healthy weight. *Pediatr. Obes.* **2014**, *9*, 310–317. [CrossRef] [PubMed]
49. Graves, L.E.F.; Ridgers, N.D.; Stratton, G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. *Eur. J. Appl. Physiol.* **2008**, *104*, 617–623. [CrossRef] [PubMed]
50. White, K.; Schofield, G.; Kilding, A.E. Energy expended by boys playing active video games. *J. Sci. Med. Sport* **2011**, *14*, 130–134. [CrossRef] [PubMed]
51. Siegmund, L.A.; Naylor, J.B.; Santo, A.S.; Barkley, J.E. The effect of a peer on VO2 and game choice in 6–10 year old children. *Front. Physiol.* **2014**, *5*, 202. [CrossRef]
52. Bailey, B.W.; McInnis, K. Energy cost of exergaming: A comparison of the energy cost of 6 forms of exergaming. *Arch. Pediatr. Adolesc. Med.* **2011**, *165*, 597–602. [CrossRef]
53. Smallwood, S.R.; Morris, M.M.; Fallows, S.J.; Buckley, J.P. Physiologic responses and energy expenditure of kinect active video game play in schoolchildren. *Arch. Pediatr. Adolesc. Med.* **2012**, *166*, 1005–1009. [CrossRef]
54. Clevenger, K.A.; Howe, C.A. Energy Cost and Enjoyment of Active Videogames in Children and Teens: Xbox 360 Kinect. *Games Health J.* **2015**, *4*, 318–324. [CrossRef]
55. Canabrava, K.L.; Faria, F.R.; Lima, J.R.D.; Guedes, D.P.; Amorim, P.R. Energy Expenditure and Intensity of Active Video Games in Children and Adolescents. *Res. Q. Exerc. Sport* **2018**, *89*, 47–56. [CrossRef]
56. Verhoeven, K.; Abeele, V.V.; Gers, B.; Seghers, J. Energy Expenditure During Xbox Kinect Play in Early Adolescents: The Relationship with Player Mode and Game Enjoyment. *Games Health J.* **2015**, *4*, 444–451. [CrossRef] [PubMed]
57. Moholdt, T.; Weie, S.; Chorianopoulos, K.; Wang, A.I.; Hagen, K. Exergaming can be an innovative way of enjoyable high-intensity interval training. *Exerc. Med.* **2017**, *3*, 258. [CrossRef] [PubMed]
58. Quan, M.; Pope, Z.; Gao, Z. Examining Young Children's Physical Activity and Sedentary Behaviors in an Exergaming Program Using Accelerometry. *J. Clin. Med.* **2018**, *7*, 302. [CrossRef] [PubMed]
59. Gao, Z.; Chen, S.; Stodden, D.F. A comparison of children's physical activity levels in physical education, recess, and exergaming. *J. Phys. Act. Health* **2015**, *12*, 349–354. [CrossRef] [PubMed]

60. Vallabhajosula, S.; Holder, J.B.; Bailey, E.K. Effect of Exergaming on Physiological Response and Enjoyment during Recess in Elementary School-Aged Children: A Pilot Study. *Games Health J.* **2016**, *5*, 325–332. [CrossRef]
61. Biddiss, E.; Irwin, J. Active Video Games to Promote Physical Activity in Children and Youth a Systematic Review. *Arch. Pediatr. Adolesc. Med.* **2010**, *164*, 664–672. [CrossRef]
62. Sousa, C.V.; Fernandez, A.; Hwang, J.; Lu, A.S. The effect of narrative on physical activity via immersion during active video game play in children: Mediation analysis. *J. Med. Internet Res.* **2020**, *22*, e17994. [CrossRef]
63. Hwang, J.; Lee, I.-M.; Fernandez, A.M.; Charles, H.H.; Lu, A.S. Exploring energy expenditure and body movement of exergaming in children of different weight status. *Pediatr. Exerc. Sci.* **2019**, *31*, 438–447. [CrossRef]
64. Adamo, K.B.; Rutherford, J.A.; Goldfield, G.S. Effects of interactive video game cycling on overweight and obese adolescent health. *Appl. Physiol. Nutr. Metab.* **2010**, *35*, 805–815. [CrossRef] [PubMed]
65. Iannotti, R.J.; Claytor, R.P.; Horn, T.S.; Chen, R. Heart rate monitoring as a measure of physical activity in children. *Med. Sci. Sports Exerc.* **2004**, *36*, 1964–1971. [CrossRef] [PubMed]

5.4 Artículo IV

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Article

Active Video Games Improve Muscular Fitness and Motor Skills in Children with Overweight or Obesity

Cristina Comeras-Chueca [1,2,3], Lorena Villalba-Heredia [2,3,4], Jose Luis Perez-Lasierra [2,3,4], Jorge Marín-Puyalto [2,3,4], Gabriel Lozano-Berges [1,2,3], Ángel Matute-Llorente [1,2,3], Germán Vicente-Rodríguez [1,2,3], Alex Gonzalez-Aguero [1,2,3] and José A. Casajús [2,3,4,*]

[1] Faculty of Health and Sport Science (FCSD), Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain; ccomeras@unizar.es (C.C.-C.); glozano@unizar.es (G.L.-B.); amatute@unizar.es (Á.M.-L.); gervicen@unizar.es (G.V.-R.); alexgonz@unizar.es (A.G.-A.)
[2] GENUD (Growth, Exercise, NUtrition and Development) Research Group, Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain; lvillalbaheredia@unizar.es (L.V.-H.); jlperez@unizar.es (J.L.P.-L.); jmarinp@unizar.es (J.M.-P.)
[3] EXERNET Red de Investigación en Ejercicio Físico y Salud, 50009 Zaragoza, Spain
[4] Faculty of Health Science, Department of Physiatry and Nursing, Universidad de Zaragoza, 50009 Zaragoza, Spain
* Correspondence: joseant@unizar.es

Abstract: (1) Background: Childhood obesity is an important public health problem. Children with overweight or obesity often tend to show the pediatric inactivity triad components; these involve exercise deficit disorder, pediatric dynapenia, and physical illiteracy. The aim of the study was to examine the influence of an active video games (AVG) intervention combined with multicomponent exercise on muscular fitness, physical activity (PA), and motor skills in children with overweight or obesity. (2) Methods: A total of 29 (13 girls) children (10.07 ± 0.84 years) with overweight or obesity were randomly allocated in the intervention group (AVG group; $n = 21$) or in the control group (CG; $n = 8$). The intervention group performed a 5-month AVG training using the Xbox 360® with the Kinect, the Nintendo Wii®, dance mats, and the BKOOL® interactive cycling simulator, combined with multicomponent exercise, performing three sessions per week. The control group continued their daily activities without modification. Weight, PA using accelerometers, and motor competence using the Test of Gross Motor Development 3rd edition were measured. Muscular fitness was evaluated through the Counter Movement Jump height, maximal isometric strength of knee extension and handgrip strength, and lean mass using Dual-energy X-ray Absorptiometry. Mann–Whitney U and Wilcoxon signed rank tests were performed. The biserial correlation coefficients (r) were calculated. Spearman's correlation coefficients among PA, muscular fitness, and motor competence variables were also calculated. (3) Results: The AVG group significantly increased their knee extension maximal isometric strength (4.22 kg; $p < 0.01$), handgrip strength (1.93 kg; $p < 0.01$), and jump height (1.60 cm; $p < 0.01$), while the control group only increased the knee extension maximal isometric strength (3.15 kg; $p < 0.01$). The AVG group improved motor competence and light physical activity ($p < 0.05$) and decreased sedentary time ($p < 0.05$). Lean mass improved in both AVG group and CG ($p < 0.05$). Lastly, the percentage of improvement of motor skills positively correlated with the percentage of improvement in vigorous PA ($r = 0.673$; $p = 0.003$) and the percentage of improvement in CMJ ($r = 0.466$; $p = 0.039$). (4) Conclusions: A 5-month intervention combining AVG with multicomponent training seems to have positive effects on muscle fitness, motor competence, and PA in children with overweight or obesity.

Keywords: exergaming; muscular fitness; motor competence; exercise; children; obesity

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1. Introduction

Obesity has become a major global health challenge because of its increased prevalence, which has risen significantly over the past three decades [1]. The World Health Organization (WHO) even refers to obesity as "a global pandemic" [2]. Childhood obesity is considered an important public health problem worldwide [3]. The prevalence of overweight and obesity among children and adolescents (aged 5–19) has dramatically risen from 4% in 1975 to just over 18% in 2016 worldwide [4]. The prevalence of obesity in children and adolescents in Spain between the ages of 8 and 16 (the stage of life in which young people are most susceptible to excess body fat) reached 34.9% in 2019 [5]. These results are in line with European results that showed a prevalence of overweight over 30% and a prevalence of obesity over 10% in European children and adolescents in 2016 [6].

Both overweight and obesity are associated with adverse health consequences such as cardiovascular, respiratory, and metabolic diseases; negative psycho-social effects; and are more likely to become overweight or obese adults, resulting in an increased risk of non-communicable diseases [7].

An important factor of childhood obesity is insufficient physical activity (PA). According to the WHO, children and adolescents should participate in an average of 60 min per day of moderate-to-vigorous intensity physical activity (MVPA) across the week, and could expect additional benefits from a greater amount of PA [8]. Nevertheless, a large proportion of children and adolescents do not meet the public health recommendations of PA, with over 80% of the world's adolescent population being insufficiently physically active in 2016 [9].

Physical inactivity is related to the pediatric inactivity triad, a condition observed by Faigenbaum et al. [10] that involves exercise deficit disorder, pediatric dynapenia, and physical illiteracy. The term "exercise deficit disorder" is used to highlight the gravity of this clinical condition with the aim of raising awareness of the importance of meeting the public health recommendations of PA. Children with pediatric dynapenia show low levels of muscle strength and power and, consequently, functional limitations that are not caused by neurological or muscular diseases [10]. The concept of "physical illiteracy" describes the lack of competence, confidence, and motivation to move proficiently [10].

The deficit of PA is closely related to other components since children and adolescents who show lack of muscular fitness and a decreased level of motor skills are less likely to participate in sport activities or just PA, making it impossible to improve muscular fitness or motor skills [10]. PA is a powerful tool to improve youth health [11] and is favorably associated with the management of adiposity, cardio-metabolic biomarkers, health-related physical fitness (including muscular fitness), bone health [12,13], psychological health, motor competence, and quality of life [14].

The importance of muscular fitness lies in its inverse association with total and central adiposity and therefore with cardiovascular diseases and metabolic risk factors, and its positive association with bone health [15] and self-esteem [16]. Children and adolescents with overweight and obesity show higher maximal muscular strength than children and adolescents with normal weight because the excess of weight involves a chronic training stimulus during the activities of daily living [17]. In contrast, when maximal muscular strength is normalized to body mass or lean mass, those with overweight are weaker, probably as a result of reduced mobility, neural adaptations, and changes in muscle morphology [18,19]. Therefore, children and adolescents with a higher weight status had negative effects on the performance of strength tests that involve moving their body weight, showing e.g., a lower jump height [20]. However, children and adolescents with a higher weight status had positive effects on performance of strength tests that do not involve lifting the body such as isometric knee extension strength or handgrip test [20]. Likewise, overweight and obesity are associated with deficient muscular strength and endurance [21,22]. Similarly, children with overweight or obesity showed poorer muscle tissue composition, lower muscle power, and alterations in motor unit recruitment, which led to impaired muscle activation [23]. To this should be added the current declining trend in muscular fitness and the need to target those strength deficits in today's youth [24]. Given the above, children and adolescents with overweight or obesity are more likely to fulfil the pediatric dynapenia condition of the pediatric inactivity triad (PIT) [10].

Lastly, children and adolescents with overweight and obesity are often less skilled than those with healthy weight [25]. Actual and, especially, perceived motor skills are associated with motivation, PA, and sports participation in children and adolescents [26,27], so the improvement of motor skills within this population must be a main goal. In addition to the positive relationship with PA, motor competence has been positively related positively to cardiorespiratory fitness [28] and inversely related to sedentary time, overweight, and obesity [29].

Active video games (AVG) have been proposed as a good alternative for traditional exercise and have become an emerging trend in fitness [30], being investigated to find out its effectiveness against childhood obesity and in promoting PA and health in children and adolescents [31]. AVG are video games that require body movement and therefore an increase in energy expenditure [31,32]. The strategy is to partner with the digital movement in the world to seek to increase PA and achieve health benefits through AVG rather than fighting technology. AVG can be useful tools for improving PA, health-related physical fitness, and motor skills, however, it seems that using AVG exclusively does not provide the benefits needed [33–36]. Therefore, AVG must be used as a complementary activity in the fight against childhood obesity [34,35,37–39]. Evidence supports the use of a structured AVG intervention instead of home-use, with stronger effects of a multicomponent exercise intervention combined with AVG [40].

In addition, AVG seem to have positive effects on motor skills and health-related physical fitness. Some articles have shown improvements in the acquisition and development of motor skills and abilities in a funnier way for the children [41]. Improvements in health-related physical fitness have been shown after an AVG intervention, such as cardiorespiratory and muscular fitness [42] and body composition [43].

However, to the best of our knowledge, no randomized controlled trials (RCT) have been performed to confirm the benefits of AVG in muscular fitness, PA, and motor skills altogether. The effect of an intervention with AVG on the PIT has not yet been investigated, despite being key in the children of today. In addition, an AVG intervention combined with multicomponent exercise could be a novel way of increasing the effects of AVG.

Therefore, the main aim of the study was to examine the influence of an AVG intervention combined with multicomponent exercise on muscular fitness, PA, and motor skills in children with overweight or obesity.

The authors hypothesized that AVG could help to improve the isometric strength of upper and lower limbs and the height jump in a vertical jump, as well as to increase the lean mass, motor skills, and PA without resorting to more traditional sports, which do not seem to be a sufficiently attractive option for overweight or obese children and adolescents.

2. Materials and Methods

This study was performed in accordance with the ethical guidelines for human research outlined by the Declaration of Helsinki (revision of Fortaleza 2013) [44] and the Declaration of Taipei [45], and were reviewed and approved by the Research Ethics Committee of the Government of Aragon (certificate No. 11/2018, CEICA, Zaragoza, Spain). All participants and their parents or legal custodians were informed of the nature and possible risks of the experimental procedures before their written informed consent was obtained.

This RCT is part of a larger cross-over study that is registered in clinicaltrials.gov (identification number NCT04418713). In this RCT, participants were divided into two groups, an intervention group that participated in an AVG exercise program combined with multicomponent exercise (n = 21), and a control group (n = 8) that continued their daily activities without modification.

The recruitment process was carried out through pediatricians from the medical centers. Informative talks about the activity were given in medical centers and it was the pediatricians themselves who proposed the activity to overweight or obese patients who could benefit from the activity. Due to the difficulty of this recruitment process, it was planned to extend the study for one more year in order to obtain a bigger sample. Therefore, a 2:1 randomization was carried out in the first year, prioritizing the AVG intervention. The Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc., Chicago, IL, USA) was used to generate the random allocation sequence, and it was performed by the researcher who carried out the project. In a second moment, randomization was 2:1, favoring the control group. Unfortunately, it was interrupted by the COVID-19 pandemic and groups were, in the end, uneven. The second part of the study with a new recruitment process was interrupted by the pandemic caused by COVID-19.

2.1. Participants

A total of 29 children with overweight or obesity met the inclusion criteria and participated in the RCT. There were a total of 16 boys and 13 girls. The inclusion criteria were as follows: the participants had to be between the ages of 9 and 12 years, in Tanner stage I or II, and not having had menarche, with overweight or obesity established following the cut points of Cole et al. [46]. Tanner's stage was evaluated by a medical doctor by direct observation. Volunteers suffering from pathologies that worsen with physical exercise or having any other contraindications for its practice were excluded from the present study. In addition, the exclusion criteria were the following: participating in regular high-level or high-intensity extracurricular PA, following any special dietary regime, and taking any medication that may interfere with the evaluated variables.

The participants were recruited from medical centers through their pediatricians of Zaragoza (Spain). The involvement of pediatricians in recruitment is especially important because overweight and obesity are health conditions to be treated, so they refer those children to us. Parents and pediatricians were informed about the development of the activity, the results, and the progress of the children.

2.2. Outcomes

2.2.1. Anthropometry

All participants were measured with a stadiometer without shoes and minimum clothing to the nearest 0.1 cm (SECA 225, SECA, Hamburg, Germany) and weighed to the nearest 0.1 kg (SECA 861, SECA, Hamburg, Germany). The body mass index (BMI) was calculated as weight (in kg) divided by height (in m) squared.

2.2.2. Physical Activity

PA and sedentary behaviors were objectively assessed before and after the intervention using the calidated GENEActiv accelerometers (ActivInsights Ltd., Kimbolton, Cambridgeshire, UK) [47]. All participants wore the accelerometer on their left wrist for 7 consecutive days [48]. Devices were set to record at a frequency of 30 Hz.

The instruction was to wear the devices during the whole day for 7 days, including during sleep and water-based activities. Verbal instructions were given to the parents along with a timesheet to register in case the device was removed.

The accelerometer data were downloaded using GENEActiv software 3.2 version and aggregated into 15-s epochs for its posterior analysis using R software. Non-wear periods were detected following the method proposed by van Hees et al. [49] and eliminated from the registers. After that, participants with less than 4 valid days ($\geq$10 h of wear time per day) were excluded from the accelerometry analysis. Time during sedentary behaviors and at different PA intensities (light (LPA), moderate (MPA) or vigorous (VPA)) was determined according to the cut-off points proposed by Schaefer et al. [50], namely 0.190 g, 0.314 g, and 0.998 g for light, moderate, and vigorous intensities, respectively. The sleep time was not included in sedentary time. The total PA was calculated as the sum of minutes in light, moderate, and vigorous intensities.

2.2.3. Pediatric Dynapenia

Pediatric dynapenia was evaluated through three tests: Counter Movement Jump (CMJ) height, maximal isometric strength of knee extension test, and handgrip strength test. Both weight-related and non-weight-related tests were used to assess the muscular strength in upper and lower limbs. In addition, lean mass was assessed as part of pediatric dynapenia.

Counter Movement Jump Height

CMJ was evaluated using a Kistler force plate 9260AA (Kistler Holding AG, Winterthur, Switzerland). Children were in a standing position with both hands on their hips to isolate the lower-limb action. For the performance of the countermovement, children were asked to go down fast and not to stop after going down. Three attempts were permitted, and the best performance was recorded for further analysis. Normalized scores were obtained based on the results of the study performed by Focke et al. [51]. The jump height was calculated from the flight time using the following equation: $h_t = \frac{g(t_v)^2}{8}$ [52].

Maximal Isometric Strength

Maximal isometric strength of knee extension was measured by a signal-frame gauge (Universidad de Zaragoza, Zaragoza, Spain). Children started from a sitting position with their knees flexed 90°. An anchorage was placed on the anterior distal third of the tibia. This anchorage was connected to the strain gauge, registering force data during the time that the participant had to perform the maximum knee extension until the force curve began to decrease. Three attempts were permitted for each leg, with the best performance recorded from each leg. The mean of the best attempt for each leg was obtained to quantify isometric knee extension strength. Normalized scores were obtained based on the reference values of the study performed by Beenakker et al. [53].

Handgrip Strength

Handgrip strength test was measured using a handgrip dynamometer (TKK 5001, grip A; Takei) (range, 0–100 kg; accuracy, 0.1 kg). Children were in a standing position maintaining the arm of the tested side straight down with the shoulder slightly abducted (~10° not touching the rest of the body), the elbow in 0° of flexion, the forearm in neutral position, and the wrist in 0° of flexion. The best value of three attempts with each hand was used. Handgrip strength percentiles by age and sex were calculated based on normative values of children and adolescents aged 9–17 years representing 24 countries proposed by Tomkinson et al. [54].

Lean Mass

Dual energy X-ray absorptiometry scans were performed with the pediatric version of the QDR-Explorer software (Hologic Corp., Software version 12.6.1, Bedford, MA, USA) for the whole body (and its sub-regions). Subtotal (total body less head), legs (calculated as a mean of both legs), and arms (calculated as a mean of both arms) lean mass were obtained from whole body scans. All DXA analyses were performed by the same trained researcher. The coefficient of variation of DXA in the laboratory for lean mass was 1.9% [55]. Furthermore, lean mass index normalized to height was calculated and normalized scores were obtained based on the reference values of the study performed by Weber et al. [56].

2.2.4. Motor Skills

Motor skills were assessed in the AVG group, using the Test for Gross Motor Development—3rd Edition (TGMD-3), which assesses 13 fundamental motor skills, subdivided into locomotor and object control domains [57]. TGMD-3 was tested and coded according to the standardized administration and grading. A detailed explanation of administration and coding can be found in the web page of TGMD-3 [58], with general information, a brief administration guideline, some helpful videos, and four reliability videos. Researchers who evaluated the motor skills with this tool completed the four reliability videos evaluation to check the consistency of administration and coding and the intra- and inter-observer variability. The score of tests, result coding, and percentiles were obtained based on the examiner's manual [59].

2.3. Intervention

The AVG group was engaged in a 5-month intervention with three sessions per week and 60 min per session that included a combination of AVG and multicomponent training. The sessions were composed of 10 min of warm-up, including: joint mobility, dynamic flexibility, muscle activation, core, balance, and coordination exercises. This was followed by the main part, which consisted of 45 min of exercise with a combination of AVG and multicomponent exercises, following a dynamic circuit workout where the participants were continuously rotating from AVG to exercises, and finally a 5 min cool-down performing static flexibility routines. The multicomponent exercise was focused on health-related physical fitness including cardiorespiratory fitness, muscular strength, agility, and coordination.

The AVG and the multi-component training exercises were carried out according to the plan. Two out of the three weekly sessions performed by the participants aimed at improving cardiorespiratory fitness and one at improving muscular fitness. One of the sessions focused on cardiorespiratory fitness included a muscle strength part. The exercises were multi-articular and functional, combining upper and lower body exercises, and aimed to complement the main part using the AVG. Balance, coordination, and agility work was included in the last part of the warm-up to be done without fatigue.

A progression in difficulty of performance and intensity was followed both in the AVG part and in the multi-component training. Each AVG started at the simplest and lowest intensity and ended with the most complex and highest intensity. As for the exercises in multicomponent training, initially low-difficulty and lower-intensity exercises were performed with the aim of inducing learning and self-awareness, and evolving as this learning took place. Thus, an intensity close to 3 MET was planned for the first month, in the following 3 months the intensity was intended to be between 3 and 6 MET, and in the last month it was intended to exceed 6 MET. Taking all sessions into account, the average intensity was 5.4 ± 1.1 MET.

In general, the sessions consisted of four AVG with a total average duration of 24 min, and the multicomponent exercise was performed between the AVG. The multicomponent exercise lasted 13 min on average per session, divided into two or three activities with different aims depending on the planning.

In the main part, the AVG included were the following: The Xbox 360® with the Kinect using "Kinect Adventures" and "Kinect Sport"; the Nintendo Wii® using "Wii Sports", "Just Dance", and "Mario and Sonic at the Olympic Games"; dance mats using "Dance Dance Revolution" and "Mario and Sonic at the Olympic Games" adapted from the Nintendo Wii to the dance mats; and the BKOOL® interactive cycling simulator connected to a tablet HUAWEI MediaPad T5 AGS2-W09.

The intervention was carried out in two locations, the University of Zaragoza and the "San Braulio" public school in Zaragoza. The sessions were different every day, following a progression of difficulty and intensity and fulfilling the objectives previously established in the planning.

2.4. Statistical Analyses

The Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc., Chicago, IL, USA) was used to perform all the statistical analyses. Statistical significance was set at $p < 0.05$ in all tests. Data are presented as mean ± standard deviation (SD). Kolmogorov–Smirnov tests were performed to verify the normal distribution of the variables. As several variables did not show a normal distribution, non-parametric tests were performed.

Differences between AVG and control groups for descriptive characteristics, muscular fitness, physical activity, and motor skills at the pre- and post-intervention were analyses using Mann–Whitney U tests. Wilcoxon signed-rank test was used for within-group comparisons among the pre-intervention and post-intervention measures. Effect size r was calculated for Mann–Whitney U and Wilcoxon signed-rank tests using the formula of Fritz, Morris and Richler [60] for non-parametric contrast/comparisons. The effect size for r can be small (0.1–0.3), medium (0.3–0.5), or large (>0.5) [61]. Spearman's correlation coefficients among the improvement and the percentage of improvement for PA, muscular fitness, and motor competence variables were calculated.

3. Results

Descriptive characteristics of participants by group are summarized in Table 1. No differences between groups at baseline or post-intervention were found (r ranged from 0.082 to 0.335; $p > 0.05$).

Table 1. Subject characteristics of AVG group and control group.

Variable	Time	All (n = 29)	AVG Group (n = 21)			Control Group (n = 8)		
		Mean ± SD	Mean ± SD	Effect Size r	p Value	Mean ± SD	Effect Size r	p Value
Age (years)	1	10.1 ± 0.8	10.2 ± 0.8	0.88	<0.001	9.7 ± 0.8	0.89	0.012
	2	10.7 ± 0.8 *	10.8 ± 0.8 *			10.5 ± 0.8 *		
Weight (kg)	1	53.4 ± 8.9	55.3 ± 8.8	0.74	0.001	48.2 ± 7.2	0.84	0.017
	2	56.3 ± 9.8 *	57.7 ± 9.5 *			52.5 ± 10.3 *		
Height (cm)	1	144.7 ± 7.5	146.0 ± 6.7	0.88	<0.001	141.1 ± 8.8	0.89	0.012
	2	148.9 ± 7.4 *	149.6 ± 7.1 *			147.0 ± 8.3 *		
BMI (kg/m^2)	1	25.4 ± 2.7	25.9 ± 2.9	0.15	0.498	24.1 ± 1.7	<0.00	0.990
	2	25.3 ± 3.0	25.7 ± 3.0			24.1 ± 2.8		
BMI Z-Score	1	1.96 ± 0.33	1.99 ± 0.36	0.71	0.001	1.89 ± 0.18	0.54	0.123
	2	1.84 ± 0.38 *	1.89 ± 0.41			1.72 ± 0.28		
BMI percentile	1	96.8 ± 2.1	96.9 ± 2.35	0.42	0.053	96.6 ± 1.4	0.59	0.093
	2	95.7 ± 4.0 *	95.9 ± 4.5			95.1 ± 2.5		

AVG: active video games, BMI: body mass index, SD: standard deviation. 1: pre-intervention; 2: post-intervention. Effect size r can be small (>0.1), medium (>0.3), or large (>0.5). * Significant differences within groups between pre-intervention and post-intervention ($p < 0.05$). Data presented as mean ± standard deviation.

Muscular fitness in the AVG group and the control group is shown in Table 2. Both the AVG group and the control group significantly increased subtotal lean mass, index, and Z-Score of indexes of subtotal lean mass and lean mass of arms and legs ($p < 0.01$; Table 2). The AVG group significantly increased the knee extension maximal isometric strength ($p < 0.01$; Figure 1A), hand-grip test ($p < 0.01$; Figure 1B), and CMJ together with z-score of CMJ test ($p < 0.01$ and $p < 0.05$ respectively; Figure 1C). Handgrip significantly improved in the AVG group but not in the control group when it was corrected by body weight. The control group increased maximal knee extension isometric strength ($p < 0.01$; Figure 1A). It is worthy to highlight that a significant increase in maximal knee extension isometric strength was found in the AVG group, whereas no changes were found in the control group when the isometric strength of quadriceps was corrected by body weight.

Table 2. Muscular fitness by group.

Variable	Time	AVG Group (n = 21) Mean ± SD	Control Group (n = 8) Mean ± SD	AVG Group Change	AVG Group Effect Size r	AVG Group p Value	Control Group Change	Control Group Effect Size r	Control Group p Value
Knee extension maximal isometric strength (kg)	1	24.8 ± 6.6	24.0 ± 6.7	4.2 ± 5.7 *	0.66	0.003	3.2 ± 3.7 *	0.74	0.036
	2	29.0 ± 8.8	27.2 ± 4.7						
Knee extension maximal isometric strength relative to body weight (kg/body weight in kg)	1	0.46 ± 0.13	0.50 ± 0.12	0.05 ± 0.10 *	0.47	0.030	0.03 ± 0.11	0.15	0.674
	2	0.51 ± 0.15	0.53 ± 0.08						
Knee extension maximal isometric strength Z-Score	1	0.24 ± 1.36	0.46 ± 1.07	0.52 ± 1.38	0.39	0.073	0.14 ± 0.98	0.30	0.401
	2	0.76 ± 2.04	0.59 ± 1.17						
Knee extension maximal isometric strength Z-Score	1	0.24 ± 1.36	0.46 ± 1.07	0.52 ± 1.38	0.39	0.073	0.14 ± 0.98	0.30	0.401
	2	0.76 ± 2.04	0.59 ± 1.17						
Hand-grip strength (kg)	1	16.3 ± 2.6	15.5 ± 3.6	1.93 ± 1.93 *	0.82	<0.001	0.57 ± 1.40	0.35	0.327
	2	18.2 ± 3.4	16.0 ± 4.1						
Hand-grip strength relative to body weight (kg/body weight in kg)	1	0.30 ± 0.05	0.32 ± 0.06	0.02 ± 0.03 *	0.65	0.003	−0.02 ± 0.03	0.45	0.208
	2	0.32 ± 0.53	0.31 ± 0.05						
Percentile of hand-grip strength	1	45.5 ± 24.0	43.8 ± 19.2	3.3 ± 18.8	0.13	0.544	−5.0 ± 16.9	0.23	0.516
	2	48.8 ± 24.7	38.8 ± 23.6						
CMJ (cm)	1	14.9 ± 3.6	16.1 ± 4.6	1.6 ± 1.5 *	0.73	0.001	0.2 ± 2.5	0.10	0.779
	2	16.5 ± 3.6	16.3 ± 4.1						
CMJ Z-Score	1	−1.21 ± 0.80	−0.96 ± 0.92	0.22 ± 0.40 *	0.49	0.025	−0.01 ± 0.58	0.05	0.889
	2	−0.99 ± 0.77	−0.97 ± 0.79						
Total lean mass (kg)	1	30.7 ± 4.6	27.4 ± 5.0	2.0 ± 1.5 *	0.83	<0.001	2.3 ± 2.2 *	0.84	0.017
	2	32.7 ± 5.0	29.7 ± 6.3						
Index of subtotal lean mass	1	9.85 ± 1.99	9.15 ± 1.79	3.82 ± 1.79 *	0.88	<0.001	3.61 ± 2.15 *	0.89	0.012
	2	13.66 ± 1.40	12.76 ± 1.7						
Z-Score of index of subtotal lean mass	1	1.15 ± 0.47	1.05 ± 0.34	−0.72 ± 0.65 *	0.75	0.001	−1.11 ± 0.82 *	0.84	0.017
	2	0.44 ± 0.76	−0.06 ± 0.8						
Legs lean mass (kg)	1	5.5 ± 1.0	4.9 ± 1.0	0.4 ± 0.3 *	0.85	<0.001	0.6 ± 0.6 *	0.79	0.025
	2	5.9 ± 1.0	5.4 ± 1.4						
Arms lean mass (kg)	1	1.4 ± 0.2	1.2 ± 0.2	0.1 ± 0.1 *	0.79	<0.001	0.1 ± 0.2 *	0.79	0.025
	2	1.5 ± 0.3	1.4 ± 0.3						

AVG: active video games; CMJ: counter movement jump; SD: standard deviation, 1: pre-intervention; 2: post-intervention. Effect size r can be small (>0.1), medium (>0.3), or large (>0.5). * Significant differences within groups between pre-intervention and post-intervention ($p < 0.05$).

PA in both AVG and control group is shown in Table 3. Regarding physical inactivity, in the AVG group 93.8% of the participants did not meet the public health recommendations of PA before the intervention, lowering to 75.0% afterwards. In the control group, all the participants were insufficiently active, reducing to 85.7% after the intervention. It should be noted that some data losses occurred due to a failure in one accelerometer register, which prevented the data recorded by the accelerometer from being obtained. It should be noted that some PA data could not be used due to malfunctioning of the device, so data were obtained from 16 children in the AVG group and 7 children in the control group, and only those were analyzed overall. A significant reduction of sedentary time was observed in the AVG group (p = 0.034), whereas no significant changes were observed in the control group. LPA significantly increased in the AVG group (p = 0.02), whereas no significant changes in MPA and VPA were shown in either the AVG group or the control group. An increase in total daily PA was shown in the AVG group while no effects were shown in the control group (Figure 1D). No group by time interactions were found in PA and muscular fitness variables (p > 0.05; Tables 2 and 3).

Table 3. Physical activity by group.

Variable	Time	AVG Group (*n* = 16)	Control Group (*n* = 7)	AVG Group			Control Group		
		Mean ± SD	Mean ± SD	Change	Effects Size r	*p* Value	Change	Effects Size *r*	*p* Value
ST (min/day)	1	841.9 ± 52.7	826.0 ± 51.2	−195.9 ± 311.2 *	0.53	0.034	−12.3 ± 268.2	0.26	0.499
	2	813.9 ± 53.6	824.2 ± 49.3						
LPA (min/day)	1	71.3 ± 20.3	77.9 ± 30.9	89.9 ± 121.4 *	0.58	0.020	−12.8 ± 154.9	0.06	0.866
	2	84.1 ± 19.2	76.1 ± 19.0						
MPA (min/day)	1	44.5 ± 22.9	35.10 ± 16.82	51.3 ± 142.2	0.44	0.079	36.6 ± 119.2	0.38	0.310
	2	51.8 ± 26.7	40.3 ± 16.6						
VPA (min/day)	1	3.9 ± 5.0	1.5 ± 1.1	9.6 ± 20.6	0.45	0.069	−0.3 ± 6.2	0.10	0.799
	2	5.3 ± 5.9	1.5 ± 1.2						
MVPA (min/day)	1	48.4 ± 27.4	36.6 ± 17.8	60.9 ± 161.2	0.47	0.063	36.3 ± 124.3	0.32	0.398
	2	57.1 ± 32.3	41.83 ± 17.7						
PA (min/day)	1	119.7 ± 43.9	122.7 ± 40.5	150.8 ± 258.5 *	0.53	0.034	23.5 ± 275.6	0.26	0.499
	2	141.2 ± 46.4	109.3 ± 33.5						

AVG: active video games; LPA: light physical activity; MPA: moderate physical activity; MVPA: moderate-to-vigorous physical activity, PA: physical activity; SD: standard deviation, ST: sedentary time; VPA: vigorous physical activity. 1: pre-intervention; 2: post-intervention. Effect size r can be small (>0.1), medium (>0.3), or large (>0.5). * Significant differences within groups between pre-intervention and post-intervention ($p < 0.05$).

As can be seen in Table 4, the AVG group improved motor skills in both the locomotive skills and the object skills (all $p < 0.001$; Figure 2). According to the scores obtained in TGMD-3, the AVG group was in the 5th percentile before the intervention, and had an improvement after it, up to the 22nd percentile.

Table 4. Motor skills in AVG group before and after the intervention.

Variable	Pre-Intervention (*n* = 21) Mean ± SD	Post-Intervention (*n* = 21) Mean ± SD	Effects Size *r*	*p* Value
Total motor skills score (points)	64.7 ± 9.7	78.3 ± 8.1 *	0.88	<0.001
Locomotor skills (points)	30.3 ± 6.5	38.7 ± 5.0 *	0.88	<0.001
Object control skills (points)	34.6 ± 5.6	39.6 ± 4.3 *	0.81	<0.001

AVG: active video games; SD: standard deviation. Effect size r can be small (>0.1), medium (>0.3), or large (>0.5).
* Significant differences within groups between pre-intervention and post-intervention ($p < 0.05$).

All participants assigned to the intervention group attended a minimum of 80% of the sessions, indicating high adherence to the program and at the end of the program, 100% of the participants were willing to continue with the program.

Lastly, correlations were observed between the percentage of improvement of motor skills and the percentage of increment in CMJ (r = 0.466; p = 0.039) and between the percentage of improvement of motor skills and the percentage of increment in VPA (r = 0.663; p = 0.004). Also, some relations between improvement of muscle fitness and the improvement of PA were found. Specifically, the results showed that the percentage of improvement of Z-Score of lean mass index was correlated with the percentage of improvement of VPA (r = 0.434; p = 0.039). The improvement and the percentage of improvement of handgrip strength test was positively correlated with the increase of arm lean mass (r = 0.492; p = 0.007; and r = 0.459; p = 0.012) and with the increase of total lean (r = 0.463; p = 0.012), subtotal lean (r = 0.421; p = 0.023), and Z-Score of index of lean mass (r = 0.463; p = 0.012).

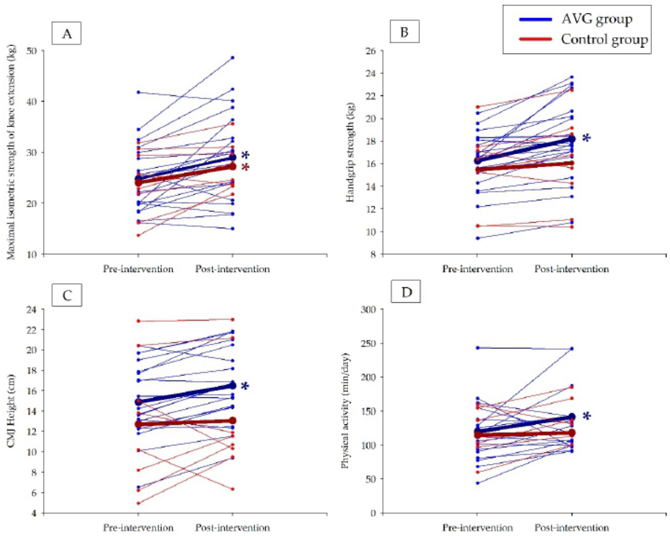

Figure 1. Individual changes for muscular fitness and physical activity variables in AVG and control groups. AVG: active video games; CMJ: counter movement jump. The thickest line represents the mean. * Significant changes between pre-intervention and post-intervention in AVG group were set at $p < 0.05$. (**A**) Maximal isometric strength of knee extension interactions in the AVG group and the control group. (**B**) Handgrip strength interactions in the AVG group and the control group. (**C**) CMJ height interactions in the AVG group and the control group. (**D**) Physical activity per day interactions in the AVG group and the control group.

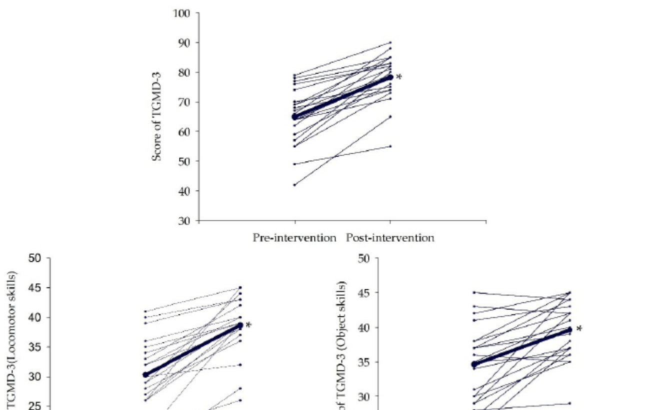

Figure 2. Individual changes for the score of motor competence of the AVG group. TGMD-3: Test of gross motor development 3rd edition. The thickest line represents the mean. The unit of measurement is points. * Significant interactions were set at $p < 0.05$.

4. Discussion

The main finding of this study is that this AVG intervention has the potential for improving muscular fitness in overweight and obese children, and can have some impact on motor skills related variables. Results showed that whereas both groups increased lean mass as they are growing populations, only AVG group experienced a significant increase in CMJ test and handgrip strength tests. In addition, both groups increased isometric knee extension strength, possibly due to the development of lean mass as a consequence of maturational development. However, significant improvements in isometric knee extension strength were only found in the AVG group when the results were corrected by body weight, which means that the gain of the isometric knee extension strength was not entirely due to the increase in body weight, unlike the control group whose significant increases disappeared when dividing by body weight. Therefore, as the authors hypothesized, AVG seem to be an effective tool to improve the muscular fitness and to increase PA and motor skills in children with overweight or obesity, according to the results of this article. The high attendance of the participants assigned to the AVG group and the willingness and desire to continue with the exercise program through active video games showed a high motivation to participate.

Up to now, only three non-controlled trials [62–64] have investigated the effects of an AVG intervention on muscular fitness of children and adolescents with overweight and obesity. Calcaterra et al. [62] showed an increase in muscular strength of 22 obese children, improving from 29.6 ± 9.3 to 32.3 ± 9.8 kg ($p = 0.003$) in handgrip test. Duman et al. [63] investigated the effects of an AVG intervention combined with traditional exercise on several physical performance tests that require muscle strength and endurance, such as time to ascend and descend 20 stairs, number of squats they can perform in 120 s, time to run 50 m, and number of rope jumps in 30 s. The results showed enhancements in all test performances. Lastly, Huang et al. [64] investigated the effect of AVG on muscular strength. No changes in muscular strength of the quadriceps or muscular endurance were found. Low frequency and program duration may explain the lack of significant changes.

Participants in this study showed a high maximal muscular strength of knee extension (Z-Score) and a high performance in the hand-grip test (percentile), probably due to the chronic stimulus produced by their weight excess, while they showed lower values of jump height in both the initial and the final measurements, with results according to the reference values [51]. Therefore children with overweight or obesity are more likely to fulfil the pediatric dynapenia condition of the pediatric inactivity triad [10], so it seems necessary to bet for strength training also in the interventions with overweight and obese children. AVG could be an interesting and promising strategy to improve muscular fitness and fight against the pediatric dynapenia of overweight and obese children.

Both the AVG and control groups significantly increased subtotal lean mass and lean mass of arms and legs. Since there are no significant differences between the AVG group and the control group, it seems that these increases can be the result of growth and development rather than the intervention. Furthermore, in both groups, the index of subtotal lean mass increased, with a higher increase in the AVG group, and the Z-Score of the index of subtotal lean mass decreased, with a higher decrease in the control group, even showing a negative Z-Score value. The AVG intervention does not appear to influence this variable. Despite this, there seems to be a positive trend in the lean mass index and lean mass index Z-Score variables favoring the AVG group. However, issues such as the lack of dietary control or the progression of intensity during the intervention that resulted in not reaching as high intensities as necessary makes it difficult to detect significant changes. Another explanation for the lack of differences in lean mass after AVG intervention may be that there is insufficient muscle stimulation. On the other hand, other interesting AVG devices such as the Nintendo Switch Ring Fit Adventures, which incorporates a muscle resistance implement, might provide higher muscle stimulation. It would be interesting to study the effect of the Ring Fit Adventures, especially considering the restrictions on physical exercise due to COVID-19, with home exercise predominating.

To the best of our knowledge, there are four controlled trials that informed about or reported the effects of AVG on lean mass [65–68]. Maddison et al. [65] did not find changes between groups for lean mass. Similar results were reported by Adamo et al. [66], with no differences between groups. Staiano et al. [67,68] informed about no effects on lean mass after an AVG intervention. Evidence on the effect of AVG on lean mass is limited and no effects were shown. All the articles investigating the effects of AVG on lean mass [65–68] lasted less than 6 months. This could explain why no positive effects compared to control groups were observed. Thus, interventions lasting 6 months or more may be needed to observe clear benefits compared to a control group, also taking into account growth and muscle development in the pre-pubertal stages. In addition, the previously mentioned articles were mainly focused on the decrease of body fat and not so much on the increase of lean mass. However, in the present study, multicomponent training focused on the improvement of muscular strength, which was included as one of the objectives.

Total PA and LPA significantly increased in the AVG group ($p < 0.01$). No significant changes in MPA and VPA were shown in either the AVG group or the control group. However, the AVG group showed an increasing trend in MPA and VPA. The importance of this significant increase in LPA lies in the opportunity to replace sedentary time with LPA [69], and in this way, to fight against the opposite trend of replacing LPA with more sedentary time that occurs in pre-adolescence and adolescence [70]. In addition, LPA has a strong influence on cardio-metabolic health [69]. In addition, the AVG group showed significant reductions in sedentary time which, together with the LPA results, implies a very positive effect of the AVG intervention.

A very up-to-date systematic review performed by Gao et al. [36] concluded that AVG appears to be a promising and attractive strategy to promote PA in children with overweight or obesity. Other meta-analyses reported that AVG could be a good alternative for sedentary behavior and could be complementary to traditional exercise [34,71]. Mack et al. [35] agree with the use of the AVG as a complementary tool to increase PA, claiming that the exclusive use of AVG does not achieve satisfactory results. AVG could promote light-to-moderate intensity PA and replace sedentary screen-time [72], but the long-term benefits in PA are limited [73]. AVG could even be an exercising strategy to help meet PA recommendations [74]. In short, AVG could help achieve a more active and healthy lifestyle among children with overweight and obesity [33], provided that the AVG interventions were supervised and structured [40]. On the other hand, several systematic reviews do not support the effectiveness of AVG to increase PA levels sufficiently [38,39,75]. This ineffectiveness may be due to the wrong approach to AVG interventions in the studies included in these reviews, carried out without supervision, with an insufficient length or with insufficient participants. On the other hand, several systematic reviews [34,35,37,71] stress that AVG can be a complementary tool to increase PA and health, so multicomponent training has been included in the intervention of this study in a novel way.

A noteworthy improvement in the motor competence of the AVG group was observed. The lack of data on the motor competence of the control group due to time, material, and available evaluator is a major limitation, which made a comparison with a control group impossible. Nevertheless, the improvement in the motor competence of the AVG group is quite considerable, so it hardly seems to be explained by children's growth and development alone. In accordance with the results of the present study, Van Biljon et al. [76] showed improvements in the AVG group in motor ability compared to two control groups, a control group with access to traditional sedentary video games and another control group that did not receive any intervention. Motor competence was evaluated in 30 overweight and obese children using the short form of the Bruininks-Oseretsky test for motor proficiency, and the AVG group performed a 6-week AVG intervention of 3 days per week for 30 min per session using Wii. The AVG group showed improvements in motor competence compared with both control groups; specifically, in agility and speed, coordination, and reaction time. Another recent article [77] also evaluated the improvement of motor skills in primary school students with overweight or obesity, with the same limitation as the present study since the results could not be compared with a control group. To evaluate the motor competence, three movements (catch, vertical jump, and kick) were analyzed and a significant improvement in the score of vertical jump movement was observed, in addition to the improvement in jumping height. A systematic review concluded that AVG, used as a complementary tool and not as the only tool, can be a good strategy to improve motor competence in children [41]. This conclusion supports the intervention performed in the present study, which combines AVG with multicomponent exercise and justifies the improvements found.

Actual and perceived motor competence are positively associated with motivation for exercising, PA, and sports participation in children and adolescents, and inversely associated with sedentary time, overweight, and obesity [26,27], which is especially important in children with a high weight status [29]. According to the interrelationship of the components of the pediatric inactivity triad [10] (exercise deficit disorder, pediatric dynapenia, and physical illiteracy), an increase of motor competence could lead to an increase of PA, which in turn could lead to an improvement in muscle fitness and motor competence. This interrelationship can also happen in a reverse way, so that a worsening of the motor skill can lead to a deficit of PA that produces a worsening of the muscular fitness and of the motor skill. This process is the same in children who do not develop their motor skills in a normal way and show a worse motor competence, which usually happens in children who are overweight or obese [25]. In addition, this physical illiteracy that usually appears in children with a high weight status increases over time, with all the difficulties that it entails in terms of adherence to exercise and improvement of the health-related physical fitness, including muscular fitness.

The pediatric inactivity triad is a novel conceptual approach that reflects a public health crisis in today's children and adolescents. Despite the forcefulness of this concept, which expresses the tendency of children to be weaker, less agile, slower, less active, and more overweight, there are currently no articles focused on proposing solutions or strategies to this reality. Furthermore, although this concept is defined, no cut-off points or normative data have been identified to determine whether the pediatric inactivity triad, namely pediatric dynapenia and physical illiteracy, is met. A great contribution to future research would be the possibility of detecting this pediatric triad of inactivity in the pediatrician's office through simple tests that could be carried out in the office itself.

Lastly, the present study found correlations between the percentage of improvement of motor skills and the percentage of improvement in VPA. This relationship suggests that children with better motor skills can reach higher intensities. The pediatric inactivity triad supports this interrelationship between these two variables that together with muscular fitness make it up. The key to this condition lies in the influence of its components, explaining that a deficit of PA will lead to a worsening of motor skills in children and to muscular weakness, which in turn will lead to a lower motivation to perform PA and a decrease in it. The correlation between motor competence and VPA is supported by Barnett et al. [78], showing a positive association between PA and motor competence and coordination, but also showing an inverse relationship between sedentary time and motor competence. There are more articles supporting this association between motor competence and PA [79,80], stating that motor competence may be a key determinant of PA behaviors across time and primary school years are the optimal time to develop motor competence [80]. A positive association between motor competence and muscular fitness was expected since the development of motor competence in childhood may improve health-related physical fitness, according to Cattuzzo et al. [81]. Stricker et al. [82] highlighted the importance of strength in children and adolescents and its relationship to motor competence. A very current study shows potential positive effects for the integrated combination of fundamental movement skill and strength training when delivered in a primary school setting with the aim of improving motor competence [83]. On the other hand, as expected, a correlation was found between the percentage of improvement of motor skills and the percentage of improvement in CMJ. This can be explained by the motor skill component found in a countermovement jump, even without using the arms [84]. This result indicates that caution should be exercised when using the CMJ as a test for measuring lower body strength, given that it has a significant motor skill component that challenges leg strength. This is even more noticeable in children who are overweight or obese as they have to move their own body weight [20]. However, no association between motor competence and isometric strength was found in the results of the current study. It could be due to their higher absolute strength in the maximal isometric strength of lower and upper limbs.

There was another correlation between the percentage of improvement of Z-Score of lean mass index and the percentage of improvement of VPA, thus corroborating the importance of VPA for muscular development.

Finally, and as expected, the results showed that the improvement and the percentage of improvement of handgrip strength test was positively correlated with the increase of arm lean mass and with the increase of total lean, subtotal lean, and Z-Score of index of lean mass. This relationship between strength test performance and lean mass was expected as the tests measured upper body isometric strength, excluding the motor skill factor. However, in the lower body isometric strength tests, no relationship with lean mass was found, which may be due to the low number of participants. A systematic review supported that PA was favorably associated with muscular fitness, as well as cardio-metabolic biomarkers, cardiorespiratory fitness, motor competence, bone health, and quality of life [14].

AVG seem to have some positive effects on the components of the pediatric triad of inactivity. However, our main objective of using AVG was to catch the attention of children who are reluctant to engage in traditional PA, so that they do so voluntarily. These AVG seek to make this PA fun and enjoyable, through a virtual environment that is more comfortable for children with this profile (i.e., obesity, low motor skills). The aim was to change the relationships of these children with PA to move from rejection to habit, and in this way achieve a more active lifestyle. This goes beyond the aims of the study, but the improvement of the components of the pediatric inactivity triad through the AVG will make these overweight or obese children feel stronger, more agile, and more skilled, so they will have more desire to move and more interest in practicing other sports.

Future research may focus on the effects of interventions with AVG combined with multicomponent training on the component of the pediatric inactivity triad due to the inverse relationship between pediatric inactivity triad and obesity, and the positive relationship between pediatric inactivity triad and health and quality of life. Despite the strength of this concept, as mentioned above, there is currently a limited amount of articles focused on proposing solutions or strategies to this reality.

5. Limitations and Strengths

Some limitations must be considered in this study. The number of participants was low, especially in the control group. This could make it more difficult to find effects of the intervention itself, given that in some variables trends are observed that are not statistically significant, probably due to insufficient statistical power. On the other hand, another important limitation is the absence of the control group for motor competence. Although such a considerable improvement in motor skills hardly seems to be explained by children's growth and development alone, it is necessary to consider the absence of data for the control group for this variable.

Finally, the intervention was supervised and structured, with a frequency (three sessions per week and 60 min per session) similar or higher to other interventions that reported benefits and with a duration close to what is needed to achieve positive results (5 months). Another aspect to highlight was the combination of AVG and multicomponent training focused on cardiorespiratory fitness, muscular strength, agility, and coordination. In addition, the wide variety of AVG used should be highlighted. All these devices offer opportunities and possibilities to significantly increase energy expenditure in overweight or obese children [32].

6. Conclusions

A 5-month intervention of AVG combined with multicomponent training seems to have positive effects on muscle fitness and motor competence. Furthermore, this intervention seems to be a potential strategy to increase LPA and decrease sedentary time, but its ability to increase MVPA is unclear. In short, AVG combined with multicomponent exercise carried out in structured and supervised sessions could be a useful tool in improving some components of the pediatric inactivity triad in overweight or obese children.

Author Contributions: All the authors were actively involved in the planning and enactment of the study. J.A.C. and A.G.-A. were the main researchers in the present study, and C.C.-C. was the first author. G.V.-R., J.L.P.-L., J.M.-P., G.L.-B., L.V.-H. and Á.M.-L. were co-researchers. C.C.-C., J.L.P.-L., J.M.-P., L.V.-H. and A.G.-A. participated in the performance of the sessions of the AVG intervention. J.A.C., A.G.-A., C.C.-C., L.V.-H., Á.M.-L. and G.L.-B. participated in the pre-intervention and post-intervention measurements. C.C.-C. drafted the document, and J.M.-P. and G.L.-B. participated in the interpretation of the results. A.G.-A., J.A.C., G.V.-R., G.L.-B., J.M.-P., Á.M.-L., J.L.P.-L. and L.V.-H. critically reviewed the document. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Committee of the Government of Aragon (certificate No. 11/2018, CEICA, Spain).

Informed Consent Statement: Written informed consent has been obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

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References

1. Ng, M.; Fleming, T.; Robinson, M.; Thomson, B.; Graetz, N.; Margono, C.; Mullany, E.C.; Biryukov, S.; Abbafati, C.; Abera, S.F.; et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **2014**, *384*, 766–781. [CrossRef]
2. World Health Organization. *Obesity: Preventing and Managing the Global Epidemic*; World Health Organization: Geneva, Switzerland, 2000; pp. 1–268.
3. Ahluwalia, N.; Dalmasso, P.; Rasmussen, M.; Lipsky, L.; Currie, C.; Haug, E.; Kelly, C.; Damsgaard, M.T.; Due, P.; Tabak, I.; et al. Trends in overweight prevalence among 11-, 13- and 15-year-olds in 25 countries in Europe, Canada and USA from 2002 to 2010. *Eur. J. Public Health* **2015**, *25*, 28–32. [CrossRef] [PubMed]
4. World Health Organization Global Health Observatory (GHO) Data. Obesity and Overweight. Available online: https://www.who.int/gho/ncd/risk_factors/overweight_obesity/obesity_adolescents/en (accessed on 9 April 2020).
5. Gasol Foundation. *Estudio Pasos 2019. Physical Activity, Sedentarism and Obesity of Spanish Youth*; Gasol Foundation: Geneva, Switzerland, 2019.
6. Nittari, G.; Scuri, S.; Petrelli, F.; Pirillo, I.; Di Luca, N.M.; Grappasonni, I. Fighting obesity in children from European world health organization member states. Epidemiological data, medical-social aspects, and prevention programs. *Clin. Ter.* **2019**, *170*, E223–E230. [CrossRef] [PubMed]
7. World Health Organization. *Consideration of the Evidence on Childhood Obesity for the Commission on Ending Childhood Obesity Report of the Ad Hoc Working Group on Science and Evidence for Ending Childhood Obesity*; World Health Organization: Geneva, Switzerland, 2016.
8. Bull, F.C.; Al-Ansari, S.S.; Biddle, S.; Borodulin, K.; Buman, M.P.; Cardon, G.; Carty, C.; Chaput, J.-P.; Chastin, S.; Chou, R.; et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* **2020**, *54*, 1451–1462. [CrossRef]

9. Guthold, R.; Stevens, G.A.; Riley, L.M.; Bull, F.C. Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc. Health* **2020**, *4*, 23–35. [CrossRef]
10. Faigenbaum, A.D.; Rial Rebullido, T.; MacDonald, J.P. Pediatric Inactivity Triad: A Risky PIT. *Curr. Sports Med. Rep.* **2018**, *17*, 45–47. [CrossRef] [PubMed]
11. Micheli, L.; Mountjoy, M.; Engebretsen, L.; Hardman, K.; Kahlmeier, S.; Lambert, E.; Ljungqvist, A.; Matsudo, V.; McKay, H.; Sundberg, C.J. Fitness and health of children through sport: The context for action. *Br. J. Sports Med.* **2011**, *45*, 931–936. [CrossRef] [PubMed]
12. Marin-Puyalto, J.; Mäestu, J.; Gómez-Cabello, A.; Lätt, E.; Remmel, L.; Purge, P.; Vicente-Rodríguez, G.; Jürimäe, J. Frequency and duration of vigorous physical activity bouts are associated with adolescent boys' bone mineral status: A cross-sectional study. *Bone* **2019**, *120*, 141–147. [CrossRef] [PubMed]
13. Marin-Puyalto, J.; Mäestu, J.; Gomez-Cabello, A.; Lätt, E.; Remmel, L.; Purge, P.; Casajús, J.A.; Vicente-Rodríguez, G.; Jürimäe, J. Vigorous physical activity patterns affect bone growth during early puberty in boys. *Osteoporos. Int.* **2018**, *29*, 2693–2701. [CrossRef]
14. Poitras, V.J.; Gray, C.E.; Borghese, M.M.; Carson, V.; Chaput, J.P.; Janssen, I.; Katzmarzyk, P.T.; Pate, R.R.; Connor Gorber, S.; Kho, M.E.; et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, S197–S239. [CrossRef]
15. Gomez-Bruton, A.; Gonzalez-Aguero, A.; Matute-Llorente, A.; Lozano-Berges, G.; Gomez-Cabello, A.; Moreno, L.A.; Casajus, J.A.; Vicente-Rodríguez, G. The muscle-bone unit in adolescent swimmers. *Osteoporos. Int.* **2019**, *30*, 1079–1088. [CrossRef] [PubMed]
16. Smith, J.J.; Eather, N.; Morgan, P.J.; Plotnikoff, R.C.; Faigenbaum, A.D.; Lubans, D.R. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sport. Med.* **2014**, *44*, 1209–1223. [CrossRef] [PubMed]
17. Garcia-Vicencio, S.; Coudeyre, E.; Kluka, V.; Cardenoux, C.; Jegu, A.G.; Fourot, A.V.; Ratel, S.; Martin, V. The bigger, the stronger? Insights from muscle architecture and nervous characteristics in obese adolescent girls. *Int. J. Obes.* **2016**, *40*, 245–251. [CrossRef] [PubMed]
18. Tomlinson, D.J.; Erskine, R.M.; Morse, C.I.; Winwood, K.; Onambélé-Pearson, G. The impact of obesity on skeletal muscle strength and structure through adolescence to old age. *Biogerontology* **2016**, *17*, 467–483. [CrossRef] [PubMed]
19. Tsiros, M.D.; Coates, A.M.; Howe, P.R.C.; Grimshaw, P.N.; Buckley, J.D. Obesity: The new childhood disability? *Obes. Rev.* **2011**, *12*, 26–36. [CrossRef]
20. Ervin, R.B.; Fryar, C.D.; Wang, C.Y.; Miller, I.M.; Ogden, C.L. Strength and body weight in US children and adolescents. *Pediatrics* **2014**, *134*, e782–e789. [CrossRef]
21. Moliner-Urdiales, D.; Ruiz, J.R.; Vicente-Rodriguez, G.; Ortega, F.B.; Rey-Lopez, J.P.; España-Romero, V.; Casajús, J.A.; Molnar, D.; Widhalm, K.; Dallongeville, J.; et al. Associations of muscular and cardiorespiratory fitness with total and central body fat in adolescents: The HELENA study. *Br. J. Sports Med.* **2011**, *45*, 101–108. [CrossRef]
22. Garcia-Pastor, T.; Salinero, J.J.; Sanz-Frias, D.; Pertusa, G.; Del Coso, J. Body fat percentage is more associated with low physical fitness than with sedentarism and diet in male and female adolescents. *Physiol. Behav.* **2016**, *165*, 166–172. [CrossRef]
23. Herda, T.J.; Ryan, E.D.; Kohlmeier, M.; Trevino, M.A.; Gerstner, G.R.; Roelofs, E.J. Examination of muscle morphology and neuromuscular function in normal weight and overfat children aged 7–10 years. *Scand. J. Med. Sci. Sports* **2018**, *28*, 2310–2321. [CrossRef]
24. Moliner-Urdiales, D.; Ruiz, J.R.; Ortega, F.B.; Jiménez-Pavón, D.; Vicente-Rodriguez, G.; Rey-López, J.P.; Martínez-Gómez, D.; Casajús, J.A.; Mesana, M.I.; Marcos, A.; et al. Secular trends in health-related physical fitness in Spanish adolescents: The AVENA and HELENA Studies. *J. Sci. Med. Sport* **2010**, *13*, 584–588. [CrossRef] [PubMed]
25. Han, A.; Fu, A.; Cobley, S.; Sanders, R.H. Effectiveness of exercise intervention on improving fundamental movement skills and motor coordination in overweight/obese children and adolescents: A systematic review. *J. Sci. Med. Sport* **2018**, *21*, 89–102. [CrossRef] [PubMed]
26. Bardid, F.; De Meester, A.; Tallir, I.; Cardon, G.; Lenoir, M.; Haerens, L. Configurations of actual and perceived motor competence among children: Associations with motivation for sports and global self-worth. *Hum. Mov. Sci.* **2016**, *50*, 1–9. [CrossRef]
27. De Meester, A.; Maes, J.; Stodden, D.; Cardon, G.; Goodway, J.; Lenoir, M.; Haerens, L. Identifying profiles of actual and perceived motor competence among adolescents: Associations with motivation, physical activity, and sports participation. *J. Sports Sci.* **2016**, *34*, 2027–2037. [CrossRef] [PubMed]
28. Lubans, D.R.; Morgan, P.J.; Cliff, D.P.; Barnett, L.M. Fundamental Movement Skills in Children and Adolescents. *Sport Med.* **2010**, *40*, 1019–1035. [CrossRef]
29. Engel, A.C.; Broderick, C.R.; van Doorn, N.; Hardy, L.L.; Parmenter, B.J. Exploring the Relationship Between Fundamental Motor Skill Interventions and Physical Activity Levels in Children: A Systematic Review and Meta-analysis. *Sport Med.* **2018**, *48*, 1845–1857. [CrossRef] [PubMed]
30. Thompson, W.R. Worldwide Survey of Fitness Trends for 2021. *ACSM's Health Fit. J.* **2020**, *25*, 10–19. [CrossRef]
31. Benzing, V.; Schmidt, M. Exergaming for Children and Adolescents: Strengths, Weaknesses, Opportunities and Threats. *J. Clin. Med.* **2018**, *7*, 422. [CrossRef] [PubMed]
32. Comeras-Chueca, C.; Villalba-Heredia, L.; Pérez-Llera, M.; Lozano-Berges, G.; Marín-Puyalto, J.; Vicente-Rodríguez, G.; Matute-Llorente, Á.; Casajús, J.A.J.A.J.A.; González-Agüero, A. Assessment of active video games' energy expenditure in children with overweight and obesity and differences by gender. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6714. [CrossRef]

33. Lamboglia, C.M.G.F.; da Silva, V.T.B.L.; de Vasconcelos Filho, J.E.; Pinheiro, M.H.N.P.; da Munguba, M.C.S.; Silva Júnior, F.V.I.; de Paula, F.A.R.; da Silva, C.A.B. Exergaming as a Strategic Tool in the Fight against Childhood Obesity: A Systematic Review. *J. Obes.* **2013**, *2013*, 438364. [CrossRef]
34. Gao, Z.; Chen, S.; Pasco, D.; Pope, Z. A meta-analysis of active video games on health outcomes among children and adolescents. *Obes. Rev.* **2015**, *16*, 783–794. [CrossRef]
35. Mack, I.; Bayer, C.; Schäffeler, N.; Reiband, N.; Brölz, E.; Zurstiege, G.; Fernandez-Aranda, F.; Gawrilow, C.; Zipfel, S. Chances and Limitations of Video Games in the Fight against Childhood Obesity—A Systematic Review. *Eur. Eat. Disord. Rev.* **2017**, *25*, 237–267. [CrossRef] [PubMed]
36. Gao, Z.; Zeng, N.; McDonough, D.J.; Su, X. A Systematic Review of Active Video Games on Youth's Body Composition and Physical Activity. *Int. J. Sports Med.* **2020**, *41*, 561–573. [CrossRef]
37. Gao, Z.; Chen, S. Are field-based exergames useful in preventing childhood obesity? A systematic review. *Int. Assoc. Study Obes.* **2014**, *15*, 676–691. [CrossRef] [PubMed]
38. Kari, T. Promoting Physical Activity and Fitness with Exergames. In *Transforming Gaming and Computer Simulation Technologies across Industries*; IGI Global: Jyvaskyla, Finland, 2016.
39. Kari, T. Can exergaming promote physical fitness and physical activity? *Int. J. Gaming Comput. Simul.* **2014**, *6*, 59–77. [CrossRef]
40. Liang, Y.; Lau, P.W.C. Effects of active videogames on physical activity and related outcomes among healthy children: A systematic review. *Games Health J.* **2014**, *3*, 122–144. [CrossRef]
41. De Medeirosa, P.; Capistranoa, R.; Almeida, M.; Aparecida, S.; Silva, T.; Cardoso, F. Exergames as a tool for the acquisition and development of motor skills and abilities: A systematic review. *Rev. Paul. Pediatr.* **2017**, *35*, 464–471.
42. Chen, H.; Sun, H. Effects of Active Videogame and Sports, Play, and Active Recreation for Kids Physical Education on Children's Health-Related Fitness and Enjoyment. *Games Health J.* **2017**, *6*, 312–318. [CrossRef] [PubMed]
43. Foley, L.; Jiang, Y.; Ni Mhurchu, C.; Jull, A.; Prapavessis, H.; Rodgers, A.; Maddison, R.; Mhurchu, C.N.; Jull, A.; Prapavessis, H.; et al. The effect of active video games by ethnicity, sex and fitness: Subgroup analysis from a randomised controlled trial. *Int. J. Behav. Nutr. Phys. Act.* **2014**, *11*, S66–S67. [CrossRef]
44. World Medical Association. World Medical Association Declaration of Helsinki, Ethical Principles for Scientific Requirements and Research Protocols. *Bull. World Health Organ.* **2013**, *79*, 373.
45. Assembly, W.M.A.G.; Assembly, W.M.A.G.; Declaration, T.; Declaration, T.; Databases, H.; Declaration, T.; Database, H. Annexe 2. WMA Declaration of Taipei on ethical considerations regarding health databases and biobanks. *J. Int. Bioéthique D'éthique Des. Sci.* **2017**, *28*, 113. [CrossRef]
46. Cole, T.J.; Bellizzi, M.C.; Flegal, K.M.; Dietz, W.H. Establishing a standard definition for child overweight and obesity worldwide: International survey. *Br. Med. J.* **2000**, *320*, 1240. [CrossRef] [PubMed]
47. Esliger, D.W.; Rowlands, A.V.; Hurst, T.L.; Catt, M.; Murray, P.; Eston, R.G. Validation of the GENEA Accelerometer. *Accelerometer. Med. Sei. Sport. Exerc.* **2011**, *43*, 1085–1093. [CrossRef] [PubMed]
48. Trost, S.G.; Pate, R.R.; Freedson, P.S.; Sallis, J.F.; Taylor, W.C. Using objective physical activity measures with youth: How many days of monitoring are needed? *Med. Sci. Sports Exerc.* **2000**, *32*, 426–431. [CrossRef] [PubMed]
49. Van Hees, V.T.; Renström, F.; Wright, A.; Gradmark, A.; Catt, M.; Chen, K.Y.; Löf, M.; Bluck, L.; Pomeroy, J.; Wareham, N.J.; et al. Estimation of daily energy expenditure in pregnant and Non-Pregnant women using a Wrist-Worn Tri-Axial accelerometer. *PLoS ONE* **2011**, *6*, e22922. [CrossRef] [PubMed]
50. Schaefer, C.A.; Nigg, C.R.; Hill, J.O.; Brink, L.A.; Browning, R.C. Establishing and evaluating wrist cutpoints for the GENEActiv accelerometer in youth. *Med. Sci. Sports Exerc.* **2014**, *46*, 826–833. [CrossRef] [PubMed]
51. Focke, A.; Strutzenberger, G.; Jekauc, D.; Worth, A.; Woll, A.; Schwameder, H. Effects of age, sex and activity level on counter-movement jump performance in children and adolescents. *Eur. J. Sport Sci.* **2013**, *13*, 518–526. [CrossRef]
52. Asmussen, E.; Bonde-Petersen, F. Storage of Elastic Energy in Skeletal Muscles in Man. *Acta Physiol. Scand.* **1974**, *91*, 385–392. [CrossRef] [PubMed]
53. Beenakker, E.A.C.; Van Der Hoeven, J.H.; Fock, J.M.; Maurits, N.M. Reference values of maximum isometric muscle force obtained in 270 children aged 4–16 years by hand-held dynamometry. *Neuromuscul. Disord.* **2001**, *11*, 441–446. [CrossRef]
54. Tomkinson, G.R.; Carver, K.D.; Atkinson, F.; Daniell, N.D.; Lewis, L.K.; Fitzgerald, J.S.; Lang, J.J.; Ortega, F.B. European normative values for physical fitness in children and adolescents aged 9–17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *Br. J. Sports Med.* **2018**, *52*, 1445–1456. [CrossRef]
55. Gracia-Marco, L.; Ortega, F.B.; Jiménez-Pavón, D.; Rodríguez, G.; Castillo, M.J.; Vicente-Rodríguez, G.; Moreno, L.A. Adiposity and bone health in Spanish adolescents. The HELENA study. *Osteoporos. Int.* **2012**, *23*, 937–947. [CrossRef]
56. Weber, D.R.; Moore, R.H.; Leonard, M.B.; Zemel, B.S. Fat and lean BMI reference curves in children and adolescents and their utility in identifying excess adiposity compared with BMI and percentage body fat. *Am. J. Clin. Nutr.* **2013**, *98*, 49–56. [CrossRef]
57. Webster, E.K.; Ulrich, D.A. Evaluation of the psychometric properties of the Test of Gross Motor Development-third edition. *J. Mot. Learn. Dev.* **2017**, *5*, 45–58. [CrossRef]
58. Ultrich, D.; Webster, K. Test of Gross Motor Development—3rd edition (TGMD-3). Available online: https://sites.google.com/a/umich.edu/tgmd-3/home (accessed on 1 June 2020).
59. Ulrich, D.A. *Test of Gross Motor Development: Examiner's Manual*, 3rd ed.; Pro-ED: Austin, TX, USA, 2019.

60. Fritz, C.O.; Morris, P.E.; Richler, J.J. Effect size estimates: Current use, calculations, and interpretation. *J. Exp. Psychol. Gen.* **2012**, *141*, 2–18. [CrossRef] [PubMed]
61. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Academic Press: Cambridge, MA, USA, 2013.
62. Calcaterra, V.; Larizza, D.; Codrons, E.; De Silvestri, A.; Brambilla, P.; Abela, S.; Arpesella, M.; Vandoni, M. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. *J. Pediatr. Endocrinol. Metab.* **2013**, *26*, 271–276. [CrossRef]
63. Duman, F.; Kokaçya, M.H.; Doğru, E.; Katayıfcı, N.; Canbay, Ö.; Aman, F. The role of active video-accompanied exercises in improvement of the obese state in children: A prospective study from Turkey. *JCRPE J. Clin. Res. Pediatr. Endocrinol.* **2016**, *8*, 334–340. [CrossRef]
64. Huang, H.-H.; Cook, L.; Harrison, J.; O'keefe, N.; Schultz, K.; Curtis, D.A. Exercise by playing active video gaming in overweight and obese children. *J. Phys. Ther. Sport Med.* **2017**, *1*, 3. [CrossRef]
65. Maddison, R.; Foley, L.; Ni Mhurchu, C.; Jiang, Y.; Jull, A.; Prapavessis, H.; Hohepa, M.; Rodgers, A. Effects of active video games on body composition: A randomized controlled trial. *Am. J. Clin. Nutr.* **2011**, *94*, 156–163. [CrossRef] [PubMed]
66. Adamo, K.B.; Rutherford, J.A.; Goldfield, G.S. Effects of interactive video game cycling on overweight and obese adolescent health. *Appl. Physiol. Nutr. Metab.* **2010**, *35*, 805–815. [CrossRef]
67. Staiano, A.E.; Marker, A.M.; Beyl, R.A.; Hsia, D.S.; Katzmarzyk, P.T.; Newton, R.L. A randomized controlled trial of dance exergaming for exercise training in overweight and obese adolescent girls. *Pediatr. Obes.* **2017**, *12*, 120–128. [CrossRef]
68. Staiano, A.E.; Beyl, R.A.; Guan, W.; Hendrick, C.A.; Hsia, D.S.; Newton, R.L. Home-based exergaming among children with overweight and obesity: A randomized clinical trial. *Pediatr. Obes.* **2018**, *13*, 724–733. [CrossRef]
69. Kuzik, N.; Carson, V.; Andersen, L.B.; Sardinha, L.B.; Grøntved, A.; Hansen, B.H.; Ekelund, U. Physical Activity and Sedentary Time Associations with Metabolic Health Across Weight Statuses in Children and Adolescents. *Obesity* **2017**, *25*, 1762–1769. [CrossRef] [PubMed]
70. Santos, A.; Silva-Santos, S.; Duncan, M.; Lagoa, M.J.; Vale, S.; Mota, J. Relationship among changes in sedentary time, physical activity, and body mass index in young schoolchildren: A 3-year longitudinal study. *Pediatr. Exerc. Sci.* **2018**, *30*, 426–432. [CrossRef] [PubMed]
71. LeBlanc, A.G.; Chaput, J.P.; McFarlane, A.; Colley, R.C.; Thivel, D.; Biddle, S.J.H.; Maddison, R.; Leatherdale, S.T.; Tremblay, M.S. Active Video Games and Health Indicators in Children and Youth: A Systematic Review. *PLoS ONE* **2013**, *8*, e65351. [CrossRef]
72. Peng, W.; Lin, J.-H.H.; Crouse, J. Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. *Cyberpsychol. Behav. Soc. Netw.* **2011**, *14*, 681–688. [CrossRef]
73. Biddiss, E.; Irwin, J. Active Video Games to Promote Physical Activity in Children and Youth A Systematic Review. *Arch Pediatr Adolesc. Med.* **2010**, *164*, 664–672. [CrossRef]
74. Sween, J.; Wallington, S.F.; Sheppard, V.; Taylor, T.; Llanos, A.A.; Adams-Campbell, L.L. The role of exergaming in improving physical activity: A review. *J. Phys. Act. Health* **2014**, *11*, 864–870. [CrossRef]
75. Oliveira, C.B.; Pinto, R.Z.; Saraiva, B.T.C.C.; Tebar, W.R.; Delfino, L.D.; Franco, M.R.; Silva, C.C.M.M.; Christofaro, D.G.D.D. Effects of active video games on children and adolescents: A systematic review with meta-analysis. *Scand. J. Med. Sci. Sports* **2020**, *30*, 4–12. [CrossRef]
76. Van Biljon, A.; Longhurst, G.K. The influence of exergaming on the functional fitness in overweight and obese children. *Recreat. Danc.* **2012**, *18*, 984–991.
77. Argarini, R.; Herawati, L.; Irwadi, I.; Arum Cahyaning Putri, E.; Meinar Sari, G. Fundamental Movement Skill Approach to Combat Childhood Obesity in Surabaya, Indonesia: Potential Effects of Video Games Based Exercises (Exergaming). *Talent Dev. Excell.* **2020**, *12*, 3026–3034.
78. Barnett, L.M.; Lai, S.K.; Veldman, S.L.C.; Hardy, L.L.; Cliff, D.P.; Morgan, P.J.; Zask, A.; Lubans, D.R.; Shultz, S.P.; Ridgers, N.D.; et al. Correlates of Gross Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sport Med.* **2016**, *46*, 1663–1688. [CrossRef]
79. Jaakkola, T.; Yli-Piipari, S.; Huotari, P.; Watt, A.; Liukkonen, J. Fundamental movement skills and physical fitness as predictors of physical activity: A 6-year follow-up study. *Scand. J. Med. Sci. Sport* **2016**, *26*, 74–81. [CrossRef]
80. Lai, S.K.; Costigan, S.A.; Morgan, P.J.; Lubans, D.R.; Stodden, D.F.; Salmon, J.; Barnett, L.M. Do school-based interventions focusing on physical activity, fitness, or fundamental movement skill competency produce a sustained impact in these outcomes in children and adolescents? A systematic review of follow-up studies. *Sport Med.* **2014**, *44*, 67–79. [CrossRef]
81. Cattuzzo, M.T.; dos Santos Henrique, R.; Ré, A.H.N.; de Oliveira, I.S.; Melo, B.M.; de Sousa Moura, M.; de Araújo, R.C.; Stodden, D. Motor competence and health related physical fitness in youth: A systematic review. *J. Sci. Med. Sport* **2016**, *19*, 123–129. [CrossRef]
82. Stricker, P.R.; Faigenbaum, A.D.; McCambridge, T.M. Resistance training for children and adolescents. *Pediatrics* **2020**, *145*, e20201011. [CrossRef]
83. Grainger, F.; Innerd, A.; Graham, M.; Wright, M. Integrated Strength and Fundamental Movement Skill Training in Children: A Pilot Study. *Children* **2020**, *7*, 161. [CrossRef]
84. Behan, S.; Belton, S.; Peers, C.; O'Connor, N.E.; Issartel, J. Exploring the relationships between fundamental movement skills and health related fitness components in children. *Eur. J. Sport Sci.* **2020**, *17*, 1–11. [CrossRef]

5.5 Artículo V

Original Paper

Effect of an Active Video Game Intervention Combined With Multicomponent Exercise for Cardiorespiratory Fitness in Children With Overweight and Obesity: Randomized Controlled Trial

Cristina Comeras-Chueca[1,2,3], MSc; Lorena Villalba-Heredia[1,2,3], MSc; Jose Luis Perez-Lasierra[1,2,3], MSc; Gabriel Lozano-Berges[2,3,4,5,6], PhD; Angel Matute-Llorente[2,3,4,5,6], PhD; German Vicente-Rodriguez[2,3,4,5,6], PhD; Jose Antonio Casajus[1,2,3,5,6], Prof Dr; Alex Gonzalez-Aguero[2,3,4,5,6], PhD

[1]Department of Physiatry and Nursing, Faculty of Health Science, University of Zaragoza, Zaragoza, Spain

[2]GENUD (Growth, Exercise, Nutrition and Development) Research Group, Zaragoza, Spain

[3]EXERNET Red de Investigación en Ejercicio Físico y Salud para Poblaciones Especiales, Zaragoza, Spain

[4]Department of Physiatry and Nursing, Faculty of Health and Sport Science, Universidad de Zaragoza, Zaragoza, Spain

[5]Instituto Agroalimentario de Aragón-IA2, Centro de Investigación y Tecnología Agroalimentaria de Aragón, Universidad de Zaragoza, Zaragoza, Spain

[6]Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición, Madrid, Spain

Corresponding Author:
Alex Gonzalez-Aguero, PhD
Department of Physiatry and Nursing
Faculty of Health and Sport Science
Universidad de Zaragoza
San Juan Bosco St., nº 13; 2th Ft.
Zaragoza, 50009
Spain
Phone: 34 876 55 37 56
Email: alexgonz@unizar.es

Abstract

Background: Childhood overweight and obesity have become major global health problems and are negatively related with the cardiorespiratory fitness (CRF) level in school children and adolescents. Exercise, specifically multicomponent training, is effective for CRF improvement, but the main challenge is to ensure adherence to exercise in children with overweight and obesity. Therefore, new ways of exercising that are more attractive and motivational for this population are needed and playing or training with active video games (AVGs) has been proposed as an effective alternative because they require full-body movement and therefore increase energy expenditure.

Objective: The main aim of this study was to investigate the effects of an AVG intervention combined with multicomponent training on CRF at maximal and submaximal intensities in children with overweight or obesity.

Methods: We recruited 28 children (13 girls and 15 boys) aged 9 to 11 years with overweight or obesity from medical centers and divided them into 2 groups, an intervention group (n=20) that participated in a 5-month supervised AVG exercise program combined with multicomponent exercise, and a control group (n=8) that continued daily activities without modification. A maximal stress test to measure CRF using a walking-graded protocol with respiratory gas exchange was performed by the participants.

Results: The AVG group showed a significant decrease in heart rate and oxygen uptake for the same intensities in the submaximal stages of the maximal treadmill test, as well as a lower oxygen uptake percentage according to the individual maximal oxygen uptake, whereas the control group did not show overall changes. No change in the peak oxygen uptake (VO_{2peak}) was found.

Conclusions: A 5-month AVG intervention combined with multicomponent exercise had positive effects on CRF at submaximal intensity, showing a lower heart rate and oxygen uptake at the same intensities and displaying a lower oxygen uptake percentage according to the individual (VO_{2peak}). Greater benefits were found in children with the highest fat percentage.

Trial Registration: ClinicalTrials.gov NCT04418713; https://clinicaltrials.gov/show/NCT04418713

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KEYWORDS
active videogames; VO2peak; obesity; prepuberty; cardiorespiratory; fitness; gaming; childhood; intervention

Introduction

Background

Childhood overweight and obesity have become major global health problems [1,2]. The World Health Organization even refers to obesity as a "global pandemic" [3]. The worldwide prevalence of childhood overweight and obesity remains high, but the rising trends have plateaued in many high-income countries [4]. Nevertheless, the prevalence of overweight was over 30% and that of obesity was over 10% in European children and adolescents in 2016 [5]. This high prevalence is still worrisome because childhood obesity has important health implications such as the increased risk of developing cardiovascular and cardiometabolic diseases (eg, type 2 diabetes, hypertension, or metabolic syndrome), psychosocial problems (eg, low self-esteem, low self-confidence, low self-efficacy, low motivation for physical activity, bullying, or difficulties in establishing relationships) [6,7], and an increased risk of becoming overweight or obese adults [3].

Overweight and obesity have been shown to be negatively related with cardiorespiratory fitness (CRF) levels in school children and adolescents [8,9]. The relationship between both factors has also been found in preschoolers [10] and becomes more pronounced as children grow older [11], suggesting that high CRF levels should be promoted as early as possible as a preventive measure because poor CRF is even associated with the development of cardiometabolic risk factors [12,13] and metabolic syndrome [14]. Preschool BMI is also inversely associated with fitness in adolescence [15]. It is noteworthy that a higher proportion of girls than boys have reduced aerobic capacity [16]. Among all physical fitness variables, the peak oxygen uptake (VO_{2peak}) shows the strongest inverse relationship with BMI and fat mass or body fat percentage [17]. Based on the inverse relationship between CRF and body fat [18,19], it seems that the cutoff point for the negative effects of fatness depending on CRF starts above 16%-20% relative body fat content [18].

On the other hand, an inverse reciprocal relationship was observed between motor competence, and VO_{2peak} and body fatness during childhood [20,21]; therefore, improving motor competence will go hand in hand with improving CRF in the objectives of an exercise intervention.

Exercise, specifically multicomponent training, is effective for improving CRF [22,23]. However, the main challenge is to ensure adherence to exercise in children with overweight and obesity [24]. Therefore, new ways of exercising that are more attractive and motivational for this population are needed.

Playing or training with active video games (AVGs) has been proposed as an effective alternative to exercise and can be as effective as moderate exercising; AVGs are being investigated to determine their effectiveness against childhood obesity. AVGs generally require full-body movement and therefore increase energy expenditure [25,26]; nevertheless, the effects of AVG interventions on CRF are unclear due to the lack of evidence. In fact, the few studies investigating the effects of AVGs on CRF use indirect methods to assess CRF such as the shuttle run test, step test, or The Progressive Aerobic Cardiovascular Endurance Run test. This is a limitation in detecting positive effects at submaximal intensities. In addition, it should be noted that AVG interventions need to be supervised and structured to ensure their effectiveness in improving physical fitness or increasing physical activity [27,28].

Objective

The main aim of this study was to investigate the effects of an AVG intervention combined with multicomponent training on CRF at maximal and submaximal intensities in children with overweight or obesity.

Methods

Ethics Approval

The ethical guidelines of the 1964 Declaration of Helsinki (revised in Fortaleza, 2013) [29] and the Declaration of Taipei [30] were followed in the conduct of this study. The protocol was reviewed and approved by the Research Ethics Committee of the Government of Aragón (certificate number 11/2018, CEICA, Spain). Written informed consent was obtained from all participants and their parents or guardians, after being informed of the nature and possible risks of the experimental procedures in the study.

Study Overview

This randomized controlled trial (RCT) is part of a larger cross-over study (trial registration number: NCT04418713). In this RCT, participants were divided into 2 groups, an intervention group that participated in the AVG exercise program combined with multicomponent exercise, and a control group that continued daily activities without modification.

The recruitment process was carried out through pediatricians from the medical centers. Informative talks about the activity were given in medical centers, and it was the pediatricians themselves who proposed the activity to patients with overweight or obesity who could benefit from the activity. Due to the difficulty of this recruitment process, it was planned to extend the study for another year to obtain a bigger sample. Therefore, a 2:1 randomization was carried out in the first year, prioritizing the AVG intervention. SPSS (version 22.0; SPSS Inc) was used to generate the random allocation sequence and it was performed by the researchers who carried out the project. In the second moment, randomization was going to be 2:1, favoring the control group; unfortunately, it was interrupted by the COVID-19 pandemic and the final groups were not uniform. The second part of the study with a new recruitment process was also interrupted by the COVID-19 pandemic.

Participants

The sample consisted of 28 children (13 girls and 15 boys) with overweight or obesity recruited from medical centers through their pediatricians or from the schools of Zaragoza (Spain). Participants met the following inclusion criteria: aged between 9 and 12 years, Tanner I or II (assessed through direct observation by a physician) and not having had menarche, overweight or obesity calculated by BMI and following the cutoff points of Cole and Lobstein [31], without contraindications for the practice of physical exercise, and without pathologies that worsen with physical exercise. In addition, the following were the exclusion criteria: participating in regular high-level or high-intensity extracurricular physical activities, following any special diet regime, and taking any medication that may interfere with the variables evaluated. The parents and pediatricians were informed about the development of the activity, results, and progress of the children through briefings.

Intervention

The participants were requested to attend 3 sessions per week, lasting approximately 60 minutes each, and the intervention lasted 5 months. The sessions were composed of a regime with a 10-minute warm up, including joint mobility; dynamic flexibility; muscle activation; and core, balance, and coordination exercises. This was followed by the main part, which consisted of 45 minutes of exercise with a combination of AVG and multicomponent exercise, followed by a circuit training dynamic where the participants continuously rotated from AVG to exercises, and finally a 5-minute cooldown part to lower the heart rate (HR) and end the session with static flexibility routines. In general, the sessions consisted of 4 AVGs with an average duration of 8 minutes, and the multicomponent exercise was performed between the AVG sessions. The multicomponent exercise lasted 13 minutes on average per session, divided into 2 or 3 activities with different objectives depending on the planning. Several physical activity and sport professionals supervised the sessions.

In the main part, the AVGs included were the following: the Xbox 360 with Kinect using "Kinect Adventures" and "Kinect Sports;" the Nintendo Wii using "Wii Sports;" "Just Dance" and "Mario and Sonic at the Olympic Games;" dance mats using "Dance Revolution" and "Mario and Sonic at the Olympic Games" adapted from the Nintendo Wii to the dance mats; and the BKOOL interactive cycling simulator connected to a HUAWEI MediaPad T5 AGS2-W09 tablet. The intervention was carried out in 2 locations, the University of Zaragoza and the San Braulio public school in Zaragoza. All the AVGs were provided through funding, and each site was equipped with the AVGs necessary to develop the intervention. The sessions were different every day, following a progression in difficulty and intensity and fulfilling the objectives previously established during planning. The participants did not play all the AVGs in each session, so the number of sessions recorded for each AVG was different. The order in which the activities were carried out was different among the participants, as each participant started in an AVG and changed it after playing.

The AVGs were combined with multicomponent exercises focused on enhancing health-related physical fitness, such as CRF, muscular endurance, and muscular strength, along with coordination and balance. This intervention design combining AVGs with traditional exercise was selected due to a potentially greater energy expenditure [32]. The multicomponent exercise performed had a playful background to enhance motivation and enjoyment.

Outcomes

Anthropometry

All the participants underwent anthropometric examination wearing minimal clothing. Height was measured to the nearest 1 mm with a stadiometer (SECA 225, SECA) and weight to the nearest 0.1 kg with an electronic scale (SECA 861, SECA). BMI was calculated as the weight (kg) divided by the square of the height (m^2).

CRF Measurements

A walking-graded protocol was employed to assess cardiovascular fitness. The test was performed on a treadmill (Quasar Med 4.0, h/p/cosmos) with a face mask fitted. The tests were carried out in the laboratory of the GENUD (Growth, Exercise, Nutrition and Development) research group. The test was explained to the participants, who were fitted with electrodes and had their resting HR measured before starting. After fitting the safety harness, the test started at a comfortable walking pace (3.2 km/h), and the speed was increased by 0.8 km/h every 2 minutes until the participants walked quickly (5.6 km/h), which was the maximum speed reached during the test. Then the slope was increased by 4% every minute until exhaustion or up to a maximal slope of 24%. A sports medicine physician supervised the entire test and performed a preclinical examination to determine if the participant was suitable for performing the stress test. The respiratory gas exchange data were measured breath by breath using open-circuit spirometry (Oxycon Pro, Jaeger/Viasys Healthcare).

Peak values of the VO_2 and HR were defined as the highest average values obtained for any continuous 15-second period. The metabolic cart was calibrated daily with a known gas and volume as recommended by the manufacturer.

The HR was continuously recorded using 12-lead electrocardiography (H12+, Mortara Instrument) from the beginning to the end of the stress test. The maximal HR value was the highest HR value recorded during the last stage of exercise. The blood pressure was also measured with a digital monitor (M3, HEM-72OO-E, Omron Healthcare Europe), for health and safety reasons, before the maximal effort test with the participant lying in a tilt, and during the recovery period in the standing position, both on the right arm. The cuffs were adjusted to the circumference of the tested arm, and the measurement was taken twice. The participants had to be at rest 5 min before the pretest measurement.

Statistical Analyses

SPSS (version 22.0, SPSS Inc) was used to perform all the statistical analyses. Statistical significance was set at $P<.05$ in all tests. Data are presented as means and SDs.

Kolmogorov-Smirnov tests were performed to verify the normal distribution of the variables; several variables did not show a normal distribution, and therefore nonparametric tests were performed.

The Mann-Whitney *U* test was conducted to examine differences between the AVG group and control group for descriptive characteristics and CRF parameters before and after intervention, whereas the Wilcoxon test was performed for within-group comparisons among the preintervention and postintervention measures. The biserial correlation coefficient (r) was calculated using the formula of Fritz et al [33] for nonparametric contrasts/comparisons and the following thresholds were considered: small effect (>0.1), medium effect (>0.3), and large effect (>0.5) [34].

In addition, 2 groups were created based on the baseline body fat percentage using the 50th percentage of the sample to investigate the effect of body fat on the participants' response after the AVG intervention and multicomponent exercise. Low and high CRF categories were established using the 50th percentile based on sex published by Johansson et al [35] for children with overweight and obesity. The reference 50th percentile values for the relative maximal oxygen uptake in boys and girls were 30.8 and 30.6 mL/kg/min, respectively.

The percentage of the VO_{2peak} achieved by all the participants at each stage was calculated through the objective data of their VO_{2peak} obtained in the maximal exercise test. The percentage of change from the pretest measurement to the posttest measurement was calculated for the HR, VO_{2peak}, and percentage of the VO_{2peak}.

Results

Participant Characteristics

The descriptive variables of the participants included in this study are shown in Table 1. No differences between the groups at baseline were found.

No differences between groups were observed in preintervention measurements. Age, weight, height, and lean mass significantly increased in the AVG and control groups from the pretest to the posttest (P<.05). The AVG group showed a decreased body fat percentage and BMI z-score (P<.05). For the control group, the VO_{2peak} (L/min) increased (P<.05).

All the participants completed at least 75% of the sessions, showing good adherence to this AVG intervention combined with multicomponent exercise.

Table 1. Characteristics of the subjects in active video game and control groups.

Variable	Total (N=28)	AVG[a] group (n=20)	Control group (n=8)
Age (years), mean (SD)			
Preintervention	10 (0.8)	10.2 (0.8)	9.7 (0.8)
Postintervention	10.7 (0.8)	10.7 (0.8) *	10.5 (0.8)*
Weight (kg) , mean (SD)			
Preintervention	53.3 (9)	55.3 (9)	48.2 (7.2)
Postintervention	56.2 (10)	57.7 (9.7)*	52.5 (10.3)*
Height (cm) , mean (SD)			
Preintervention	144.6 (7.7)	146 (6.9)	141.1 (8.8)
Postintervention	148.9 (7.5)	149.6 (7.3)*	147 (8.3)*
BMI (kg/m^2)>, mean (SD)			
Preintervention	25.3 (2.8)	25.8 (3)	24.1 (1.7)
Postintervention	25.2 (3)	25.7 (3.1)	24.1 (2.8)
BMI z-score , mean (SD)			
Preintervention	1.95 (0.3)	1.98 (0.4)	1.89 (0.2)
Postintervention	1.84 (0.4)	1.88 (0.42)*	1.72 (0.3)
BMI percentile , mean (SD)			
Preintervention	96.8 (2.2)	96.8 (2.6)	96.8 (1.2)
Postintervention	95.6 (4.1)	95.8 (4.6)	95.1 (2.5)
Body fat percentage, mean (SD)			
Preintervention	40.9 (4)	41.3 (3.7)	39.8 (4.7)
Postintervention	40.1 (4.4)	40.1 (4.5)*	39.9 (4.4)
Lean mass (kg), mean (SD)			
Preintervention	29.7 (4.9)	30.6 (4.7)	27.4 (5)
Postintervention	31.8 (5.5)	32.6 (5.1)*	29.7 (6.3)*
VO_{2peak}[b] (mL/kg/min), mean (SD)			
Preintervention	32.85 (5.9)	32.75 (5.9)	33.1 (6.2)
Postintervention	33.3 (5.3)	32.8 (5.5)	34.7 (4.6)
VO_{2peak} (L/min), mean (SD)			
Preintervention	1.72 (0.29)	1.77 (0.21)	1.6 (0.42)
Postintervention	1.85 (0.29)	1.86 (0.27)	1.81 (0.37)*

[a]AVG: active video games.

[b]VO_{2peak}: peak oxygen uptake.

*Significant differences within groups between preintervention and postintervention ($P<.05$).

Effects of the AVG Intervention Combined With Multicomponent Exercise on HR at Submaximal and Maximal Effort

The effects of the intervention using AVGs combined with multicomponent exercise on the HR for maximal and submaximal efforts are detailed in Table 2. No differences between groups were found neither before nor after the intervention for any HR variable ($P>.05$). Nevertheless, the results showed a significant decrease in the maximal HR of the AVG group (r=0.535) and at every submaximal stage: 3.2 km/h (r=0.505), 4 km/h (r=0.577), 4.8 km/h (r=0.689), 5.6 km/h (r=0.765), and 5.6 km/h with a slope of 4% (r=0.480). Lower HR values were observed for the same intensities, whereas the control group did not show any changes.

Table 2. Heart rates in the different submaximal stages of the maximal stress test by group (N=28).

Heart rate at various levels (bpm[a]), mean (SD)	AVG[b] group (n=20)	Control group (n=8)
Speed: 3.2 km/h; slope: 1%		
Preintervention	118.2 (12.44)	120.38 (10.31)
Postintervention	113.7 (10.6)*	116.38 (9.49)
% change	–3.45 (7.19)	–3.08 (7.21)
Speed: 4 km/h; slope: 1%		
Preintervention	127.6 (13.86)	124 (11.51)
Postintervention	121.75 (11.48)*	122.75 (10.22)
% change	–4.27 (6.34)	–0.75 (6.71)
Speed: 4.8 km/h; slope: 1%		
Preintervention	137.75 (15.42)	133.13 (13.04)
Postintervention	129.9 (10.97)*	130.13 (9.6)
% change	–5.28 (6.22)	–1.91 (6.34)
Speed: 5.6 km/h; slope: 1%		
Preintervention	152.3 (17.42)	146 (14.78)
Postintervention	143.40 (14.43)*	142.63 (12.98)
% change	–5.59 (5.4)	–2.03 (7.03)
Speed: 5.6 km/h; slope: 4%		
Preintervention	157.2 (37.76)	155.5 (16.57)
Postintervention	153.95 (15.74)*	152 (12.88)
% change	–5.48 (44.53)	–1.92 (6.05)
Maximum HR[c] (bpm)		
Preintervention	197.1 (12.24)	191.63 (10.51)
Postintervention	187.2 (22.42)*	191.75 (6.94)
% change	–4.86 (11.1)	0.2 (3.75)

[a]bpm: beats per minute.

[b]AVG: active video game.

[c]HR: heart rate.

*Significant differences within the group between preintervention and postintervention ($P<.05$).

Effects of the AVG Intervention Combined With Multicomponent Exercise on Submaximal and Maximal Effort Oxygen Uptake and Length of the Maximal Treadmill Test

The effects of the intervention using AVGs combined with multicomponent exercise on VO_2 for the maximal and submaximal efforts are detailed in Table 3. No pretest differences were found between groups ($P>.05$). After the AVG intervention combined with multicomponent exercise, a decrease in the submaximal VO_2 was found, but no effects were reported for the VO_{2peak}. As shown in Figure 1, lower VO_2 values occur for the same intensities after the intervention at every submaximal stage of the test: at 3.2 km/h (r=0.518), 4 km/h (r=0.434), 4.8 km/h (r=0.593), 5.6 km/h (r=0.535), and 5.6 km/h with a slope of 4% (r=0.551). The control group did not show any change in the VO_2 parameters. In addition, significant differences between groups were found in the submaximal VO_2 after the AVG intervention, with significantly lower VO_2 in the AVG group at 3.2 km/h and 5.6 km/h. The duration in minutes of the maximal treadmill test significantly increased in the AVG and control groups, with no differences observed.

Table 3. Oxygen uptake in the different submaximal stages of the maximal stress test by group (N=28).

Variable, mean (SD)	AVG[a] group (n=20)	Control group (n=8)
VO_2[b] (mL/kg/min); speed: 3.2 km/h; slope: 1%		
Preintervention	13.47 (2.81)	14.59 (1.96)
Postintervention	11.76 (2.26)*	14.86 (2.46)**
% change	–8.73 (27.85)	2.8 (17.3)
VO_2 (mL/kg/min); speed: 4 km/h; slope: 1%		
Preintervention	14.95 (3.05)	15.55 (1.43)
Postintervention	13.15 (2.22)	15.34 (2.58)
% change	–8.73 (23.65)	–1.13 (15.43)
VO_2 (mL/kg/min);speed: 4.8 km/h; slope: 1%		
Preintervention	17.02 (2.9)	17.48 (2.25)
Postintervention	14.92 (2.39)*	17.03 (2.73)
% change	–10.41 (17.92)	–2.06 (13.55)
VO_2 (mL/kg/min); speed: 5.6 km/h; slope: 1%		
Preintervention	19.97 (3.09)	21.50 (2.72)
Postintervention	18.16 (2.88)*	21.13 (2.56)**
% change	–7.49 (18.56)	–0.47 (16.13)
VO_2 (mL/kg/min); speed: 5.6 km/h; slope: 4%		
Preintervention	22.05 (3.18)	23.30 (2.78)
Postintervention	20.59 (2.93)*	23.18 (3.03)
% change	–4.54 (21.04)	–0.04 (11.43)
VO_{2peak} (mL/kg/min)		
Preintervention	32.75 (5.9)	33.11 (6.18)
Postintervention	32.82 (5.54)	34.68 (4.65)
% change	1.23 (13.08)	6.6 (15.36)
Length of the maximal treadmill test (min)		
Preintervention	11.38 (0.94)	11.16 (0.95)
Postintervention	12.37 (1.20)*	12.42 (0.58)*
% change	8.76 (5.58)	11.72 (7.13)
Length of the effort phase of the maximal treadmill test (min)		
Preintervention	3.39 (0.92)	3.25 (0.98)
Postintervention	4.38 (1.16)*	4.42 (0.58)*
% change	36.34 (44.57)	44.4 (38.15)

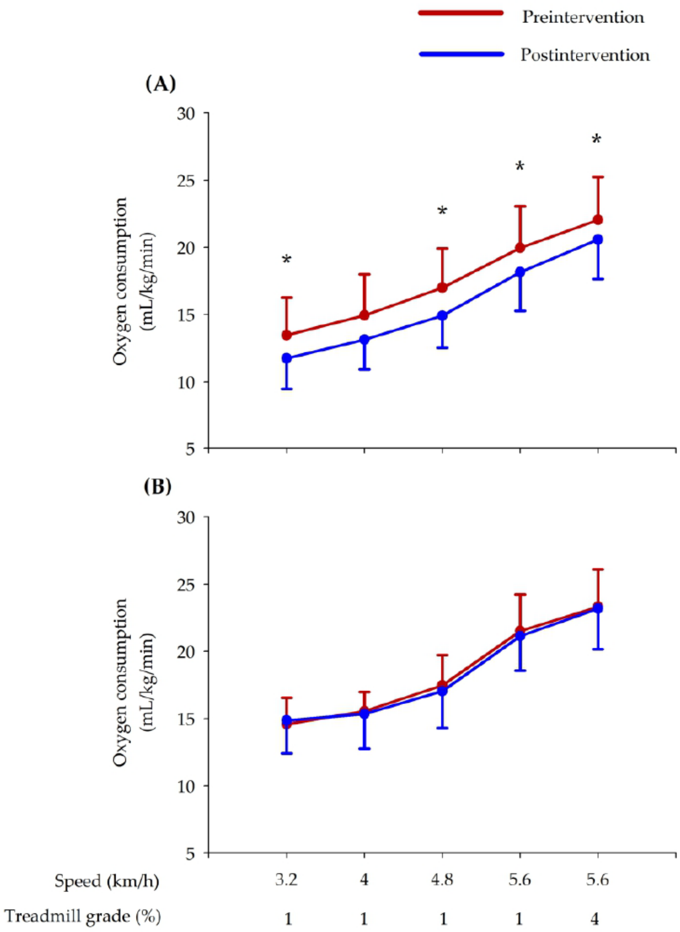
[a]AVG: active video game.

[b]VO_2: oxygen uptake.

* Significant differences within groups between preintervention and postintervention (*P*<.05).

**Significant differences between AVG and control groups (*P*<.05).

Figure 1. Changes in VO_2 during the different stages of the maximal stress test observed for the (A) active video game group and (B) control group.



In addition, the VO_2 percentage was calculated for each participant according to the VO_2 peak obtained from the maximal treadmill test. Results reported no differences between groups before the AVG intervention. Based on the VO_2 values in mL/kg/min, the AVG group showed significant decreases in the VO_2 percentage at all submaximal stages of the maximal treadmill test: 3.2 km/h (r=0.609), 4 km/h (r=0.551), 4.8 km/h (r=0.693), 5.6 km/h (r=0.576), and 5.6 km/h with a slope of 4% (r=0.476). On the other hand, the control group showed decreases in the VO_2 at only 4.8 km/h (r=0.792). Significant differences in the VO_2 were found between the AVG and control groups after the AVG intervention at 3.2 km/h.

Effects of the AVG Intervention Combined With Multicomponent Exercise on Submaximal and Maximal Effort Oxygen Uptake Percentage by Groups According to Body Fat Percentage Baseline in the AVG Group

As explained before, the sample was divided into 2 groups according to the 50th percentile of the body fat percentage for the AVG group. The results showed that the participants with a higher body fat percentage showed a significantly decreased HR and VO_2 at the same intensities after the intervention. Specifically, lower HR values were found for the participants in the AVG group with higher body fat percentages at 3.2 km/h (r=0.737), 4 km/h (r=0.662), 4.8 km/h (r=0.751), 5.6 km/h (r=0.886), and 5.6 km/h with a slope of 4% (r=0.864); furthermore, lower HR values were found for the AVG group participants with lower body fat percentages at only 4.8 km/h (r=0.454). On the other hand, lower VO_2 values were found for the AVG group participants with higher body fat percentages in the submaximal stages of the maximal treadmill test at 4 km/h

(r=0.617), 4.8 km/h (r=0.697), and 5.6 km/h (r=0.885); in contrast, the AVG group participants with lower body fat percentages did not show any changes. However, the influence of the body fat percentage on the VO_2 percentage determined from the individual VO_{2peak} of the maximal treadmill test was low, showing that the AVG group participants with higher body fat percentages displayed significant decreases in the VO_2 percentage during the submaximal stage at 4.8 km/h (r=0.590) and 5.6 km/h (r=0.751). However, the AVG group participants with lower body fat percentages displayed significant decreases in the VO_2 percentage during the submaximal stages at 3.2 km/h (r=0.691) and 4.8 km/h (r=0.810). No significant differences between the AVG group participants with higher and lower body fat percentages were found in the baseline and posttest.

Discussion

Principal Findings

The aim of this study was to investigate the effects of an AVG intervention combined with multicomponent training on CRF at maximal and submaximal effort levels in children with overweight and obesity. The main finding of this study was the significant decrease in the HR and VO_2 shown by the AVG group for the same intensities at the submaximal stages of the maximal treadmill test, along with a lower VO_2 percentage according to the individual maximal oxygen uptake. As a reference, the control group did not show overall changes in the HR, VO_2, or VO_2 percentage in the submaximal stages of the maximal treadmill test, except for a significant decrease in the VO_2 percentage at 4.8 km/h. However, no changes in the relative or absolute VO_{2peak} values (in mL/kg/min and L/min) were found for the AVG group, although an increment in the absolute VO_{2peak} value was observed for the control group. This might be due to the weight gain in the control group, mainly fat accumulation. Although we did not expect improvements in the VO_{2peak}, the adequate intensity level required for achieving the desired improvements at the maximum intensities was not reached. This may be explained by the nature of the intervention limiting the intensity to that produced by the AVGs and the inability of the participants to reach such demanding intensities due to excess body fat. However, one of the objectives of the intervention was to improve quality of life by enabling these children to better cope with daily activities, which are often submaximal efforts.

Regarding the CRF endurance level of the participants, mean VO_{2peak} values of 32.75 (SD 5.90) mL/kg/min for the AVG group and 33.11 (SD 6.18) mL/kg/min for the control group were obtained. The children with overweight and obesity who participated in this study showed low CRF levels with an increased risk of health problems due to this low level of CRF in 75% of the participants, according to the cutoff points proposed by Ruiz et al [36]. Moreover, 67.9% of the participants are above the 50th percentile according to Johansson et al [35], which means that the participants in this study had a higher CRF compared to the mean of the normative data of children with overweight or obesity.

In relation to maximal exercise testing, it is difficult for children, especially those with overweight or obesity, to meet all the maximal criteria and demonstrate a plateau in their maximal oxygen uptake [37]. To determine if the exercise test was maximal and the VO_{2peak} data were valid, the percentage of the theoretical maximal HR reached at the end of the test and the respiratory exchange ratio≥1.15 [38] were used. Only 4 of the 28 participants in the preintervention maximal exercise test and 3 of the 28 participants in the postintervention maximal exercise test did not reach 90% of their theoretical maximum HR at the end of the maximal stress test, but they achieved a respiratory exchange ratio very close to (1.13 and 1.14), equal to, or higher than 1.15. Therefore, it can be strongly believed that the tests were maximal.

Thus far, only 7 studies have investigated the effects of AVG interventions on the CRF of children with overweight or obesity, and the results are unclear. The first study that reported the effects of AVGs on the CRF of adolescents with overweight and obesity was that by Adamo et al [39] and the results showed a significant training effect over time with two different interventions: AVG cycling and stationary cycling with music interventions, with sessions of 60 minutes twice per week for 10 weeks. Both interventions produced significant improvements in the peak HR, peak workload, or the time to exhaustion, along with significant reductions in the body fat percentage; however, no significant differences were found between the exercise groups. With this same intervention, Goldfield et al [40] observed that the psychological benefits of these aerobic exercises were related to improved aerobic fitness. These positive effects are in line with our results. Although they show that the positive effects of AVG cycling on CRF are comparable to those of the stationary cycling with music intervention, adherence to this stationary cycling with music intervention was greater. Maddison et al [41] found decreases in body fat percentage with no significant increases in the CRF for the AVG group, measured by the 20-m shuttle test. However, this positive effect of AVGs on body composition in children with overweight or obesity is most likely mediated through improved aerobic fitness [42]. This relationship between body fat percentage and CRF supports the results of this study in which participants with higher body fat percentage had greater improvements in CRF. The interpretation of this result could be that participants with higher body fat percentage have a greater facility for decreasing body fat, which is associated with an increase in CRF. Maloney et al [43] observed no improvements in CRF of the AVG and control groups, assessed by a 3-minute step test after playing Dance Dance Revolution for 12 weeks. This discrepancy may be due to the method used to measure CRF; the participants did not reach adequate intensities and the study did not report the number of sessions per week and the duration of these sessions, which could also explain the lack of positive effects. Christison et al [44] showed that the number of shuttle runs did not change after a 6-month AVG intervention, with 2 sessions per week using several devices. This study has several limitations that could explain the lack of positive effects of the AVG intervention such as the small sample, the difference in the number of participants between the intervention and control groups, the short length of the intervention whose duration was 10 weeks, and the method for measuring the CRF for which the 20-m shuttle run test was used. The most recent study was conducted by Bonney et al [45], who investigated the effect of Wii Fit, in comparison with a task-oriented functional training, on the performance in the shuttle run test and positive effects on CRF in both groups. However, no differences between the AVG and control groups performing the task-oriented functional training were found after a 14-week intervention conducted once a week with each session lasting for 45 minutes. Furthermore, 2 noncontrolled trials studied the effects of AVG on CRF in children with overweight and obesity [46,47]; the limitation of these trials was the lack of a control group, which means that the results should be interpreted with caution. Calcaterra et al [47] observed an improvement in CRF (3.8 mL/kg/min, $P<.001$) measured by a walking test on a treadmill reaching 85% of the maximal HR after a 12-week intervention using interactive video games. Huang et al [46] showed no effects of AVGs using Nintendo Wii and Xbox Kinect on CRF after 16 sessions, probably due to the inclusion of only 14 participants and the short length of the intervention. A systematic review performed by Zeng and Gao [48] included only 1 RCT [41], which reported positive effects of an AVG intervention in comparison with an exercise group, but these results were unclear due to the inclusion of only 1 study. Given the lack of studies on the usefulness of AVGs to improve CRF, more quality research investigating AVGs as tools to improve CRF is needed. In addition, systematic reviews on AVGs that include CRF are needed, given that CRF is one of the key components of health-related physical fitness and is closely related to quality of life and health.

On the other hand, when the AVG group was divided in 2 groups according to body fat percentage, the results showed that the participants with higher body fat percentage showed significantly decreased HR and VO_2 values at the same intensities after the intervention, which translates into improved efficiency during submaximal efforts. As stated above, participants with higher body fat percentages had a greater range of improvement, and therefore, it is easier for them to achieve improvements, showing significant decreases in the HR and VO_2 at the same submaximal intensities after the AVG intervention combined with multicomponent exercise. However, smaller improvements were observed in participants with lower body fat percentages. These results are supported by previous studies considering the effect of AVGs on CRF, although there are none that determine CRF with breath-by-breath measurements, indirect calorimetry, and the maximal stress test along with gas exchange measurements. As previously stated, there are several studies that support the use of AVGs to improve CRF in children with overweight or obesity. None of these studies compare the outcomes in children based on body fat, and they do not differentiate between overweight and obesity. However, the studies investigating the use of AVGs to improve CRF in children with a healthy weight indicate low effectiveness; among the 6 controlled trials, 3 studies [49-51] report positive effects and the other 3 studies [52-54] report no effects, contrary to the studies involving children with overweight or obesity, most of which found significant improvements in CRF.

Strengths and Limitations

Some limitations must be considered in this study. The number of participants was low, especially in the control group. This could make it more difficult to identify the effects of the AVG intervention and achieve enough statistical power. Another important limitation is the unequal number of participants in the AVG and control groups because the control group could not be completely formed owing the COVID-19 pandemic, which interrupted research activities worldwide.

However, some strengths can be highlighted. The intervention was supervised and structured, with a duration (5 months) and frequency (3 sessions per week and 60 minutes per session) similar to or higher than that of any other previous AVG intervention reporting benefits for this population. Another important aspect is the combination of AVG and multicomponent training focused on CRF, muscular strength, agility, and coordination. In addition, the wide variety of AVGs used should be highlighted. All these devices offer opportunities and possibilities to significantly increase energy expenditure in children with overweight or obesity [26]. Finally, the main strength was the maximal stress test conducted to measure CRF using a walking-graded protocol with respiratory gas exchange measurements that allowed HR and VO_2 values to be recorded at submaximal intensities.

Conclusions

A 5-month intervention of AVGs combined with multicomponent exercise had positive effects on CRF at submaximal intensity, showing lower HR and VO_2 values at the same intensities and lower VO_2 percentages according to the individual VO_{2peak} values. The body fat percentage and the BMI z-score were also reduced after the AVG intervention. In addition, greater improvements were found in children with the highest fat percentage.

Future research could focus on the design and implementation of AVG interventions with higher intensities than those used in this study to produce improvements in CRF at submaximal and maximal effort levels, as this type of intervention appears effective for children with overweight or obesity.

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Authors' Contributions

All the authors have been actively involved in the planning and execution of the study. JAC and AG-A were the main researchers, and CC-C was the first author. All authors have read and approved the published version of the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

CONSORT-EHEALTH checklist (V 1.6.1).
[PDF File (Adobe PDF File), 1112 KB-Multimedia Appendix 1]

References

1. Katzmarzyk PT, Chaput J, Fogelholm M, Hu G, Maher C, Maia J, et al. International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): contributions to understanding the global obesity epidemic. Nutrients 2019 Apr;11(4):1-24 [FREE Full text] [doi: 10.3390/nu11040848] [Medline: 30991687]
2. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2014 Aug;384(9945):766-781. [doi: 10.1016/S0140-6736(14)60460-8] [Medline: 24880830]
3. World Health Organization. Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity: report of the ad hoc working group on science and evidence for ending childhood obesity. World Health Organization. Geneva, Switzerland: World Health Organization; 2016. URL: https://apps.who.int/iris/handle/10665/206549 [accessed 2019-05-03] [WebCite Cache ID 209655]
4. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet 2017 Dec;390(10113):2627-2642 [FREE Full text] [doi: 10.1016/S0140-6736(17)32129-3] [Medline: 29029897]
5. Nittari G, Scuri S, Petrelli F, Pirillo I, di Luca NM, Grappasonni I. Fighting obesity in children from European World Health Organization member states. Epidemiological data, medical–social aspects, and prevention programs. Clin Ter 2019 May;170(3):e223-e230 [FREE Full text] [doi: 10.7417/CT.2019.2137] [Medline: 31173054]
6. Gurnani M, Birken C, Hamilton J. Childhood obesity: causes, consequences, and management. Pediatr Clin North Am 2015 Aug;62(4):821-840. [doi: 10.1016/j.pcl.2015.04.001] [Medline: 26210619]
7. McCrindle BW. Cardiovascular consequences of childhood obesity. Can J Cardiol 2015 Feb;31(2):124-130. [doi: 10.1016/j.cjca.2014.08.017]
8. Ceschia A, Giacomini S, Santarossa S, Rugo M, Salvadego D, Da Ponte A, et al. Deleterious effects of obesity on physical fitness in pre-pubertal children. Eur J Sport Sci 2016;16(2):271-278. [doi: 10.1080/17461391.2015.1030454] [Medline: 25866877]
9. Tsiros MD, Coates AM, Howe PRC, Walkley J, Hills AP, Wood RE, et al. Adiposity is related to decrements in cardiorespiratory fitness in obese and normal-weight children. Pediatr Obes 2016 Apr;11(2):144-150. [doi: 10.1111/ijpo.12037] [Medline: 25950151]
10. Tuan SH, Li CH, Sun SF, Li MH, Liou IH, Weng TP, et al. Comparison of cardiorespiratory fitness between preschool children with normal and excess body adipose ~ an observational study. PLoS One 2019 Oct;14(10):e0223907 [FREE Full text] [doi: 10.1371/journal.pone.0223907] [Medline: 31603948]
11. Brunet M, Chaput JP, Tremblay A. The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: the 'Québec en Forme' Project. Int J Obes (Lond) 2007 Apr;31(4):637-643. [doi: 10.1038/sj.ijo.0803448] [Medline: 17006443]
12. Schmidt MD, Magnussen CG, Rees E, Dwyer T, Venn AJ. Childhood fitness reduces the long-term cardiometabolic risks associated with childhood obesity. Int J Obes (Lond) 2016 Jul;40(7):1134-1140. [doi: 10.1038/ijo.2016.61] [Medline: 27102049]
13. Zaqout M, Michels N, Bammann K, Ahrens W, Sprengeler O, Molnar D, et al. Influence of physical fitness on cardio-metabolic risk factors in European children. The IDEFICS study. Int J Obes (Lond) 2016 Jul;40(7):1119-1125. [doi: 10.1038/ijo.2016.22] [Medline: 26857382]
14. Eisenmann JC. Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatr 2007 Dec;96(12):1723-1729. [doi: 10.1111/j.1651-2227.2007.00534.x] [Medline: 17971189]
15. Pahkala K, Hernelahti M, Heinonen OJ, Raittinen P, Hakanen M, Lagström H, et al. Body mass index, fitness and physical activity from childhood through adolescence. Br J Sports Med 2012 Jul 18;47(2):71-77. [doi: 10.1136/bjsports-2011-090704] [Medline: 22809525]

16. Racette SB, Uhrich ML, White ML, Yu L, Clark BR. Sex differences in FITNESSGRAM® health risk based on aerobic capacity and body composition among urban public elementary school children. Prev Med 2017 Oct;103:56-59. [doi: 10.1016/j.ypmed.2017.07.032] [Medline: 28782561]
17. Ara I, Moreno LA, Leiva MT, Gutin B, Casajús JA. Adiposity, physical activity, and physical fitness among children from Aragón, Spain. Obesity (Silver Spring) 2007 Aug;15(8):1918-1924 [FREE Full text] [doi: 10.1038/oby.2007.228] [Medline: 17712107]
18. Szmodis M, Szmodis I, Farkas A, Mészáros Z, Mészáros J, Kemper HCG. The relationship between body fat percentage and some anthropometric and physical fitness characteristics in pre- and peripubertal boys. Int J Environ Res Public Health 2019 Apr;16(7):1170 [FREE Full text] [doi: 10.3390/ijerph16071170] [Medline: 30939794]
19. García-Hermoso A, Izquierdo M, Alonso-Martínez AM, Faigenbaum A, Olloquequi J, Ramírez-Vélez R. Association between exercise-induced changes in cardiorespiratory fitness and adiposity among overweight and obese youth: a meta-analysis and meta-regression analysis. Children (Basel) 2020 Sep;7(9):147 [FREE Full text] [doi: 10.3390/children7090147] [Medline: 32967205]
20. Lima RA, Pfeiffer KA, Bugge A, Møller NC, Andersen LB, Stodden DF. Motor competence and cardiorespiratory fitness have greater influence on body fatness than physical activity across time. Scand J Med Sci Sports 2017 Dec;27(12):1638-1647. [doi: 10.1111/sms.12850] [Medline: 28164374]
21. Lima RA, Bugge A, Ersbøll AK, Stodden DF, Andersen LB. The longitudinal relationship between motor competence and measures of fatness and fitness from childhood into adolescence. J Pediatr (Rio J) 2019 Jul;95(4):482-488 [FREE Full text] [doi: 10.1016/j.jped.2018.02.010] [Medline: 29782811]
22. García-Hermoso A, Ramírez-Vélez R, Saavedra JM. Exercise, health outcomes, and pædiatric obesity: a systematic review of meta-analyses. J Sci Med Sport 2019 Jan;22(1):76-84. [doi: 10.1016/j.jsams.2018.07.006] [Medline: 30054135]
23. Alves ASR, Venâncio TL, Honório SAA, Martins JMC. Multicomponent training with different frequencies on body composition and physical fitness in obese children. An Acad Bras Cienc 2019 Nov;91(4):e20181264 [FREE Full text] [doi: 10.1590/0001-3765201920181264] [Medline: 31778458]
24. Beedie C, Mann S, Jimenez A, Kennedy L, Lane AM, Domone S, et al. Death by effectiveness: exercise as medicine caught in the efficacy trap!. Br J Sports Med 2015 Feb;50(6):323-324. [doi: 10.1136/bjsports-2014-094389] [Medline: 25807166]
25. Oh Y, Yang S. Meaningful Play 2010 Conference Proceedings. 2010 Oct Presented at: Meaningful Play; October 21-23, 2010; East Lansing, MI, United States URL: https://meaningfulplay.msu.edu/proceedings2010/mp2010_paper_63.pdf
26. Comeras-Chueca C, Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, et al. Assessment of active video games' energy expenditure in children with overweight and obesity and differences by gender. Int J Environ Res Public Health 2020 Sep;17(18):6714 [FREE Full text] [doi: 10.3390/ijerph17186714] [Medline: 32942663]
27. Liang Y, Lau PWC. Effects of active videogames on physical activity and related outcomes among healthy children: a systematic review. Games Health J 2014 Jun;3(3):122-144. [doi: 10.1089/g4h.2013.0070] [Medline: 26196172]
28. De Brito-Gomes JL, Perrier-Melo R, Fernandes Melo de Oliveira S, De Sá Pereira Guimarães FJ, da Cunha Costa M. Physical effort, energy expenditure, and motivation in structured and unstructured active video games: a randomized controlled trial. Human Movement 2016;17(3):190-198. [doi: 10.1515/humo-2016-0021]
29. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA 2013 Nov;310(20):2191-2194. [doi: 10.1001/jama.2013.281053] [Medline: 24141714]
30. World Medical Association. Declaration of Taipei- research on health databases, big data and biobanks. World Medical Association. 2016. URL: https://www.wma.net/what-we-do/medical-ethics/declaration-of-taipei/ [accessed 2020-01-23]
31. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 2012 Aug;7(4):284-294. [doi: 10.1111/j.2047-6310.2012.00064.x] [Medline: 22715120]
32. Gao Z, Chen S, Pasco D, Pope Z. A meta-analysis of active video games on health outcomes among children and adolescents. Obes Rev 2015 May;16(9):783-794. [doi: 10.1111/obr.12287] [Medline: 25943852]
33. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. J Exp Psychol Gen 2012 Feb;141(1):2-18. [doi: 10.1037/a0024338] [Medline: 21823805]
34. Cohen J. Statistical Power Analysis for the Behavioral Sciences. New York: Routledge; 1988:567.
35. Johansson L, Brissman M, Morinder G, Westerståhl M, Marcus C. Reference values and secular trends for cardiorespiratory fitness in children and adolescents with obesity. Acta Paediatr 2020 Aug;109(8):1665-1671. [doi: 10.1111/apa.15163] [Medline: 31917879]
36. Ruiz JR, Cavero-Redondo I, Ortega FB, Welk GJ, Andersen LB, Martinez-Vizcaino V. Cardiorespiratory fitness cut points to avoid cardiovascular disease risk in children and adolescents; what level of fitness should raise a red flag? a systematic review and meta-analysis. Br J Sports Med 2016 Dec;50(23):1451-1458. [doi: 10.1136/bjsports-2015-095903] [Medline: 27670254]
37. Armstrong N, Welsman J, Winsley R. Is peak VO2 a maximal index of children's aerobic fitness? Int J Sports Med 1996 Jul;17(5):356-359. [doi: 10.1055/s-2007-972860] [Medline: 8858407]
38. Howley ET, Basseti DR, Welch HG. Criteria for maximal oxygen uptake: review and commentary. Med Sci Sports Exerc 1995 Sep;27(9):1292-1301. [Medline: 8531628]

39. Adamo KB, Rutherford JA, Goldfield GS. Effects of interactive video game cycling on overweight and obese adolescent health. Appl Physiol Nutr Metab 2010 Dec;35(6):805-815. [doi: 10.1139/h10-078] [Medline: 21164552]
40. Goldfield GS, Adamo KB, Rutherford J, Murray M. The effects of aerobic exercise on psychosocial functioning of adolescents who are overweight or obese. J Pediatr Psychol 2012 Nov;37(10):1136-1147. [doi: 10.1093/jpepsy/jss084] [Medline: 23027721]
41. Maddison R, Foley L, Ni MC, Jiang Y, Jull A, Prapavessis H, et al. Effects of active video games on body composition: a randomized controlled trial. Am J Clin Nutr 2011 Jul;94(1):153-163. [doi: 10.3945/ajcn.110.009142] [Medline: 21562081]
42. Maddison R, Mhurchu CN, Jull A, Prapavessis H, Foley LS, Jiang Y. Active video games: the mediating effect of aerobic fitness on body composition. Int J Behav Nutr Phys Act 2012 May;9(1):54. [doi: 10.1186/1479-5868-9-54]
43. Maloney AE, Threlkeld KA, Cook WL. Comparative effectiveness of a 12-week physical activity intervention for overweight and obese youth: exergaming with "Dance Dance Revolution". Games Health J 2012 Apr;1(2):96-103. [doi: 10.1089/g4h.2011.0009] [Medline: 6193183]
44. Christison AL, Evans TA, Bleess BB, Wang H, Aldag JC, Binns HJ. Exergaming for health: a randomized study of community-based exergaming curriculum in pediatric weight management. Games Health J 2016 Dec;5(6):413-421. [doi: 10.1089/g4h.2015.0097] [Medline: 27911621]
45. Bonney E, Ferguson G, Burgess T, Smits-Engelsman B. Benefits of activity-based interventions among female Adolescents Who are overweight and obese. Pediatr Phys Ther 2019 Oct;31(4):338-345. [doi: 10.1097/PEP.0000000000000636] [Medline: 31568378]
46. Huang HH, Cook L, Harrison J, O'Keefe N, Schultz K, Curtis DA. Exercise by playing active video gaming in overweight and obese children. J Phys Ther Sports Med 2017;01(01):25-31. [doi: 10.35841/physical-therapy.1.1.25-31]
47. Calcaterra V, Larizza D, Codrons E, De Silvestri A, Brambilla P, Abela S, et al. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. J Pediatr Endocrinol Metab 2013;26(3-4):271-276. [doi: 10.1515/jpem-2012-0157] [Medline: 23327787]
48. Zeng N, Gao Z. Exergaming and obesity in youth: current perspectives. Int J Gen Med 2016 Aug;9:275-284 [FREE Full text] [doi: 10.2147/IJGM.S99025] [Medline: 27536158]
49. Ye S, Lee JE, Stodden DF, Gao Z. Impact of exergaming on children's motor skill competence and health-related fitness: a quasi-experimental study. J Clin Med 2018 Sep;7(9):1-11. [doi: 10.3390/jcm7090261] [Medline: 30205483]
50. Fu Y, Burns RD. Effect of an active video gaming classroom curriculum on health-related fitness, school day step counts, and motivation in sixth graders. J Phys Act Health 2018 Sep;15(9):644-650. [doi: 10.1123/jpah.2017-0481] [Medline: 29741441]
51. Lau PWC, Wang JJ, Maddison R. A randomized-controlled trial of school-based active videogame intervention on Chinese children's aerobic fitness, physical activity level, and psychological correlates. Games Health J 2016 Dec;5(6):405-412. [doi: 10.1089/g4h.2016.0057] [Medline: 27855265]
52. Gao Z, Lee JE, Zeng N, Pope ZC, Zhang Y, Li X. Home-based exergaming on preschoolers' energy expenditure, cardiovascular fitness, body mass index and cognitive flexibility: a randomized controlled trial. J Clin Med 2019 Oct;8(10):1745 [FREE Full text] [doi: 10.3390/jcm8101745] [Medline: 31640158]
53. Ye S, Pope Z, Lee J, Gao Z. Effects of school-based exergaming on urban children's physical activity and cardiorespiratory fitness: a quasi-experimental study. Int J Environ Res Public Health 2019 Oct;16(21):4080. [doi: 10.3390/ijerph16214080] [Medline: 31652857]
54. Azevedo LB, Burges Watson D, Haighton C, Adams J. The effect of dance mat exergaming systems on physical activity and health-related outcomes in secondary schools: results from a natural experiment. BMC Public Health 2014 Sep;14:951 [FREE Full text] [doi: 10.1186/1471-2458-14-951] [Medline: 25217144]

Abbreviations

AVG: active video game
CRF: cardiorespiratory fitness
HR: heart rate
RCT: randomized controlled trial

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6. Discusión global

La evidencia científica resumida en las revisiones sistemáticas con meta-análisis realizadas muestra efectos positivos de intervenciones con VJA en la composición corporal, especialmente en niños/as y adolescentes con sobrepeso u obesidad. La gran mayoría de estudios coinciden en encontrar que las intervenciones con VJA disminuyen el peso, IMC y la grasa corporal (126–129,134–144), aunque hay algún estudio que no reporta efectos (111,130–132,145–147) o incluso reporta incrementos en el IMC (133). El análisis cuantitativo que se resume en la Tabla 2 muestra el efecto positivo de los VJA en el IMC, Z-Score de IMC, el porcentaje de grasa corporal y la masa grasa de la población infantil con sobrepeso u obesidad mientras que no se reportaron efectos en el IMC en infantes con peso saludable. Estos resultados van en la misma línea que las reducciones tanto de IMC como de grasa corporal conseguidas con la intervención de VJA del presente proyecto.

Tabla 2. Tamaños de los efectos y heterogeneidad de los resultados de los estudios que comparan una intervención con VJA con el grupo de control.

Niños/as y adolescentes con peso saludable					
	N	Hedges´g effect size	95 % CI	*p* value	I^2
IMC	7	-0.291	-0.631; 0.049	0.000	78.47%
Condición cardiorrespiratoria	4	0.438	0.022; 0.855	0.001	82.9%
Niños/as y adolescentes con sobrepeso u obesidad					
	N	Hedges´g effect size	95 % CI	*p* value	I^2
IMC	4	-0.209	-0.388; -0.031	0.699	0%
Z-Score de IMC	6	-0.066	-0.124; -0.007	<0.0001	97.55%
Porcentaje de grasa corporal	3	-0.462	-0.819; -0.105	0,059	64.59%
Masa grasa	2	-0.879	-1.138; -0.620	0.756	0%

Masa libre de grasa	3	0.106	-0.594; 0.806	0,522	0%
Circunferencia de cintura	3	-0.426	-1.295; 0.444	0.271	23.5%

Como se puede ver en la Tabla 2, los resultados son menos claros y hay más controversia en cuanto al efecto de los VJA en la condición cardiorrespiratoria, con estudios mostrando efectos positivos (127,133,134,150) frente a otros estudios que no reportan efectos significativos (111,126,130,147,149,151). Mientras que el análisis cuantitativo del efecto de los VJA en la condición cardiorrespiratoria de niños/as con peso saludable mostraba mejoras significativas (Tabla 2), este análisis no se pudo realizar en población infantil con sobrepeso u obesidad. Esta poca claridad en los efectos se podría achacar al diseño de las intervenciones, tanto a la duración como a la intensidad, por lo que se decidió combinar una intervención de VJA con ejercicio multicomponente para potenciar el efecto en la condición cardiorrespiratoria. La evidencia científica tampoco esclarece los efectos de los VJA en la fuerza muscular con artículos que han reportado mejoras en la fuerza muscular después de una intervención con VJA (127,143,144,149,152) y con artículos que no reportan efectos (153–155), y con la misma justificación que para la condición cardiorrespiratoria, se diseñó una combinación de los VJA con ejercicio multicomponente, incluyendo el entrenamiento de fuerza para la intervención. No se pudo realizar ningún análisis cuantitativo del efecto de los VJA en la condición muscular. Además, los VJA podrían ser una estrategia efectiva para mejorar la habilidad motriz en niños y niñas (157–163), con pocos artículos que no mostraron efectos positivos (127,164,165). Por lo tanto, los VJA parecen tener el potencial para mejorar la competencia motriz a través de los VJA (166,167), aunque no se pudieron realizar análisis cuantitativos en las revisiones sistemáticas.

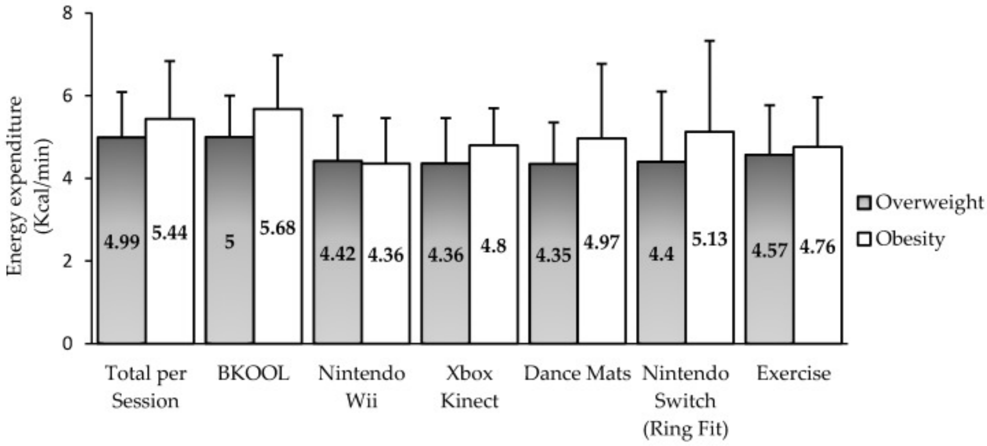
Así mismo, los VJA podrían ser una estrategia efectiva para mejorar la habilidad motriz en niños y niñas (157–163), con pocos artículos que no mostraron efectos positivos (127,164,165). Por lo tanto, los VJA parecen tener el potencial para mejorar la competencia motriz a través de los VJA (166,167), aunque no se pudieron realizar análisis cuantitativos en las revisiones sistemáticas.

La idea clave de las revisiones sistemáticas con meta-análisis que se realizaron es que se necesitan más ensayos controlados aleatorizados para investigar los efectos de las intervenciones con VJA, sobre todo en componentes de la CF como la condición cardiorrespiratoria y la fuerza muscular, además de en la habilidad motriz en niños/as y adolescentes con sobrepeso u obesidad, para conocer las posibilidades y el potencial de las intervenciones con VJA para detener el círculo vicioso de la tríada de la inactividad pediátrica y luchar contra la obesidad infantil.

Los resultados del proyecto "Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva" muestran que una intervención de ejercicio físico con VJA combinados con ejercicio multicomponente es efectiva para incrementar el gasto energético y mejorar la CF y habilidad motriz en niños/as prepuberales con sobrepeso u obesidad.

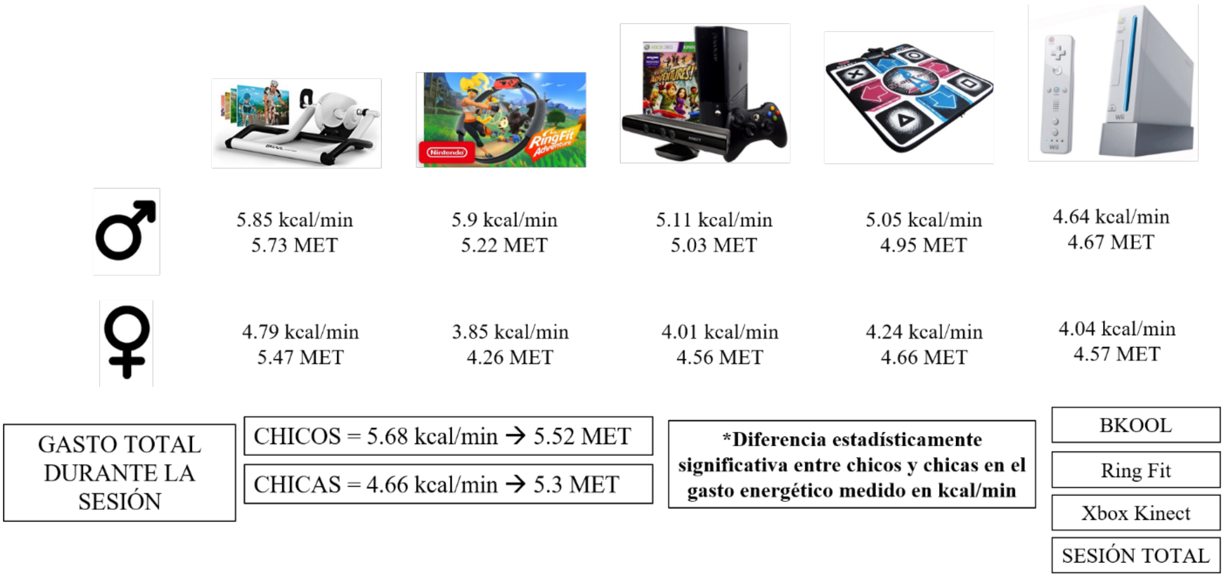
Los VJA parecen una estrategia prometedora para población infantil con obesidad debido al gasto calórico que provocan que oscila entre 4,35 y 5,68 kcal/min como se muestra en la Figura 24, con gastos energéticos cercanos a la intensidad vigorosa (>6 METs), independientemente del sexo (Figura 25) o del grado de sobrepeso u obesidad (Figura 26) (204). Este gasto es menor que el reportado en deportes de equipo más populares como el fútbol o el baloncesto (8-9 METs) (205), pero se debe tener en cuenta que los niños/as con sobrepeso u obesidad no practican estos deportes, y si lo hacen, no alcanzan esas intensidades. Además, el gasto energético de los VJA es bastante más elevado que el de jugar a videojuegos convencionales o ver la televisión (1-1,5 METs) (205), dos de las actividades lúdicas más populares entre los jóvenes. De este modo, la literatura científica evidencia el potencial de los VJA para sustituir esos comportamientos lúdicos sedentarios (114,115) y provocar un gasto energético que promueva la lucha contra la obesidad infantil (204).

Figura 24. Gasto energético durante una sesión de videojuegos activos combinados con ejercicio multicomponente, mostrando cada dispositivo y el ejercicio sin videojuegos activos, categorizado por sobrepeso u obesidad.



Fuente: La figura pertenece a un artículo propio «Assessment of Active Video Games' Energy Expenditure in Children with Overweight and Obesity and Differences by Gender». (204)

Figura 25. Gasto energético de toda la sesión y de cada VJA categorizado por género.



Fuente: Elaboración propia.

Figura 26. Gasto energético de toda la sesión y de cada VJA categorizado por estatus de peso

Fuente: Elaboración propia.

La mayoría de los estudios anteriores al de la presente tesis que investigaron el gasto energético de los VJA utilizaron una calorimetría indirecta mediante un analizador metabólico portátil para medir el gasto energético (118,120,206–215), o un brazalete SenseWear® (216–218). El gasto energético obtenido para la Nintendo Wii® fue de 2,05 a 5,14 kcal/ min, dependiendo del juego (209,211,213,215), resultados bastante acordes con los resultados del presente proyecto. El juego más usado para la Nintendo Wii® fue Wii Sports®, con gastos energéticos de entre 2,03 a 2,86 METs para el juego de los bolos y de entre 3,05 a 4,2 METs para el juego del boxeo, que fue el que más gasto reportó (118,208,214), lo cual estuvo bastante en consonancia con los resultados del proyecto, ya que el juego del boxeo fue el que más se utilizó en la Nintendo Wii®. La Nintendo Wii® fue capaz de conseguir una AF ligera-moderada (208,212), aunque en el presente proyecto fue de los VJA que reportó menor gasto energético, debido probablemente al uso de tren superior principalmente, con menor masa y reclutamiento muscular (116,204). Además, en la Nintendo Wii® se observó mayor gasto en chicos que en chicas (208) y mayor grado de disfrute en jóvenes con sobrepeso u obesidad (118). Otro VJA bastante usado en intervenciones de ejercicio con VJA es la Xbox Kinect®, que ha producido gastos de entre 1,85 y 3,1 kilocalorías por hora de sesión (206,216,219). La evidencia científica actual evidenció gastos de la Xbox Kinect® que variaban de 4,24 a 5,7 METs (120,206,207,219), pudiendo llegar incluso a superar los 6 METs (207), y reportando mayores gastos en chicos que en chicas (207,219), como ocurría con la Nintendo Wii®. También se reportó mayor gasto en las modalidades multijugador (210,220) y en los juegos en los que había narrativas (221). De este modo parece que la Xbox Kinect® produce una AFMV (120,222). Las esterillas de baile también han sido estudiadas, mostrando un gasto de 5,5 METs (118), algo mayor que las reportadas por el presente proyecto. Los ciclosimuladores como la BKOOL® también tienen potencial, e incluso mayor que el de los VJA convencionales, con consumos calóricos bastante más elevados, llegando incluso a 576,2 kcal por hora (134). En el proyecto VIDEOACTIVO fue el VJA que mayor gasto energético produjo, aunque no alcanzó los 6 METs que clasifican una actividad como vigorosa. Por último, este proyecto incluyó en el segundo año de intervención un VJA muy novedoso: el Ring Fit Adventures®. A día de hoy hay tan solo 5 artículos publicados, siendo el artículo en el que reportamos el gasto energético en niños/as con sobrepeso u obesidad el primero que se publicó. Ninguno de los artículos restantes publicados investigó los efectos de este VJA en niños/as o adolescentes, no obstante, puede ser un dispositivo a tener en cuenta dado que fue de los que más gasto energético provocó, junto con el ciclosimulador BKOOL®. Cabe destacar que es el único VJA que incluye un trabajo de fuerza, ya que incluye tanto ejercicios para la mejora de la condición cardiorrespiratoria como ejercicios de fuerza, además de estiramientos dinámicos y estáticos y equilibrio. Durante el juego, se suceden una serie de batallas en las que los ataques son diferentes ejercicios y se usan para derrotar a diferentes enemigos virtuales. Los ejercicios que se usan en estas batallas pueden ser aeróbicos como jumping jacks, skipping, escalador…; ejercicios de fuerza que pueden estar enfocados a las piernas con sentadillas, flexiones de muslo o elevaciones de rodilla, a los brazos y el pecho con tirones de arco, retrocesos de tríceps o flexiones de pecho, los músculos estabilizadores con planchas, torsiones, escalador o inclinaciones de tronco y elevaciones de piernas desde la posición de sentado o tumbado, e incluso hay posiciones de yoga como la silla, el guerrero y las posturas del árbol para entrenar el equilibrio y la fuerza. El jugador tiene que realizar un skipping para avanzar en el juego, elevando más las rodillas para subir escaleras o atravesar zonas de agua. Una característica muy distintiva y única de este VJA es el aro como mando de control, con el que fortalecer los brazos, realizando presiones para disparar o saltar, y tracciones para absorber diferentes objetos de utilidad como monedas o vidas, requiriendo el movimiento de todo el cuerpo y combinando ejercicio aeróbico y de fuerza. En definitiva, el mayor gasto energético de BKOOL® y Ring Fit Adventures® y el menor gasto energético al jugar a la Nintendo Wii® pueden explicarse por los músculos implicados. En relación con estos resultados, un meta-análisis realizado por Peng y col. (112) informó de que los VJA que implicaban principalmente movimientos de las extremidades superiores tenían efectos significativamente menores en el gasto energético que los VJA que implicaban principalmente movimientos de las extremidades inferiores o de todo el cuerpo. El gasto energético de los VJA fue de entre 4,63 y 5,61 METs, acercándose a la intensidad vigorosa. También se registraron diferencias en las kilocalorías por minuto entre chicos y chicas, que se debieron principalmente a la diferencia de peso.

En cuanto a los resultados de la intervención con VJA combinados con ejercicio multicomponente, los resultados fueron prometedores. Concretamente, la intervención de ejercicio físico con VJA combinados con ejercicio multicomponente mejoró la composición corporal de los niños/as prepuberales con sobrepeso u obesidad que realizaron la intervención con VJA, mostrando una disminución del porcentaje de grasa corporal y del Z-Score del IMC ($p < 0,05$). Estos resultados van en consonancia con la evidencia científica en la que la gran mayoría de estudios coinciden en encontrar que las intervenciones con VJA disminuyen el peso, el IMC o la grasa corporal tanto en niños/as con peso saludable (126–129) como sobre todo el población infantil con sobrepeso u obesidad (134–144), con pocos estudios que no reportan efectos (111,130–132,145–147). En cuanto a la masa magra, tanto el grupo de intervención con VJA como el grupo control aumentaron significativamente la masa magra subtotal y la masa magra de brazos y piernas y puesto que no se encontraron diferencias significativas entre grupos, parece que estos aumentos pueden ser el resultado del crecimiento y el desarrollo y no de la intervención. Hubo también un aumento del índice de masa magra subtotal en ambos grupos, con un mayor incremento en el grupo VJA, y una disminución del Z-Score del índice de masa magra subtotal, con un mayor descenso en el grupo de control, mostrando incluso un valor Z-Score negativo. A pesar de que esta intervención de VJA no parece haber tenido un efecto en la masa magra, existe una tendencia positiva en las variables índice de masa magra y de Z-Score de índice de masa magra que favorece al grupo de intervención con VJA. Sin embargo, cuestiones como la falta de control de la dieta o la progresión de la intensidad durante la intervención, que hicieron que no se alcanzaran intensidades tan altas como para producir cambios significativos. Otra explicación de que esta intervención con VJA no produjera efectos en la masa magra puede ser que el diseño de los propios VJA y los ejercicios o movimientos que se realizan durante la intervención no están tan enfocados hacia la ganancia muscular y no producen una estimulación muscular suficiente. Sin embargo, actualmente están surgiendo otros dispositivos de VJA muy interesantes como el Ring Fit Adventures para Nintendo Switch, que incorpora un implemento de resistencia muscular a través de un aro de pilates interactivo, lo que podría proporcionar una mayor estimulación muscular. Este dispositivo se adquirió para el proyecto y se intentó investigar su potencial en la intervención del segundo año, la cual se suspendió en mitad del periodo de intervención debido a la COVID-19, como se ha explicado anteriormente. Revisando bibliografía previa, solamente 4 artículos (134,138,139,145) examinaron los efectos de una intervención de VJA en la masa magra, y en la misma línea que los resultados del proyecto VIDEOACTIVO, ningún artículo reportó efectos positivos de una intervención con VJA en la masa magra, aunque es necesario mencionar que las intervenciones de estos artículos duraron menos de 6 meses y se centraron en la pérdida de grasa más que en el mantenimiento o incremento de la masa magra.

En cuanto a los efectos en la condición cardiorrespiratoria, la intervención de VJA con entrenamiento multicomponente produjo una disminución significativa en la FC y el VO_2 en las mismas intensidades durante las etapas submáximas del test máximo en cinta ergométrica. También se reportaron porcentajes de VO_2 más bajos de acuerdo con el consumo máximo de oxígeno individual en etapas submaximas de la prueba de esfuerzo tras la realización de la intervención con VJA. Como referencia, el grupo control no mostró cambios globales en la FC, VO_2 o en el porcentaje de VO_2 en las etapas submáximas de la prueba máxima, excepto por una disminución significativa en el porcentaje de VO_2 a 4,8 km/h. Por otro lado, no se encontraron cambios en los valores relativos o absolutos de VO_2 pico (en mL/kg/min y L/min) para el grupo que realizó la intervención con VJA. También se observó un incremento en el valor absoluto de VO_{2pico} para el grupo control, lo que podría deberse al desarrollo y crecimiento. Aunque no esperábamos mejoras en el VO_{2pico}, no se alcanzó el nivel de intensidad adecuado requerido durante las sesiones de entrenamiento para lograr las mejoras deseadas a las intensidades máximas. Esto puede ser debido a la naturaleza de la intervención que limita la intensidad a la producida por los VJA, junto con la incapacidad de los participantes para alcanzar intensidades tan exigentes debido al exceso de grasa corporal. Sin embargo, uno de los objetivos de la intervención era mejorar la calidad de vida al permitir que estos niños hicieran mejor frente a las actividades diarias, que en su mayoría son esfuerzos submáximos. Para saber si la intervención con VJA tiene diferente potencial o efectividad en niños/as en función de la grasa corporal, se estudió la influencia del porcentaje de grasa en los efectos producidos por la intervención con VJA. Los resultados obtenidos mostraron que los participantes con mayor porcentaje de grasa corporal alcanzaron valores menores de FC y VO_2 a las mismas intensidades después de la intervención, lo que se traduce en una mayor eficiencia durante los esfuerzos submáximos. Esto se traduce en que los participantes con porcentajes de grasa corporal más altos tuvieron un mayor rango de mejora y, por lo tanto, es más fácil para ellos lograr mejoras, mostrando disminuciones significativas en la FC y el VO_2 a las mismas intensidades submáximas después de la intervención con VJA combinada con ejercicio multicomponente. Estos resultados están respaldados por estudios previos que consideran el efecto de los VJA en la condición cardiorrespiratoria, aunque no hay ninguno que determine la capacidad aeróbica con mediciones de respiración a respiración, calorimetría indirecta y la prueba de esfuerzo máximo junto con mediciones de intercambio de gases. Existen varios estudios que respaldan el uso de VJA para mejorar la condición cardiorrespiratoria en niños con sobrepeso u obesidad. No hay evidencia científica que compare los resultados en niños en función de la grasa corporal y tampoco diferencian entre sobrepeso y obesidad, pero un indicativo de que el porcentaje de grasa podría influir en las mejoras es que los estudios que investigan el uso de VJA para mejorar la condición cardiorrespiratoria en niños con un peso saludable indican una baja efectividad, con algunos que reportan efectos positivos (127,133,150) pero otros que no reportan efectos (126,130,151). A la hora de revisar la concordancia de los resultados con la evidencia científica actual, hasta el momento, solo 7 estudios han investigado los efectos de las intervenciones de los VJA en la condición cardiorrespiratoria de niños/as y adolescentes con sobrepeso u obesidad, y los resultados no están claros. Varios estudios han evidenciado un efecto o una mejora de la condición cardiorrespiratoria equivalente al ejercicio convencional (134,149,223). Otros, sin embargo, han reportado que una intervención con VJA no ha tenido efectos en la capacidad aeróbica de los participantes (111,138,147,155), lo que probablemente puede ser explicado por la baja intensidad del ejercicio y una insuficiente duración de la intervención y/o frecuencia de entrenamiento, además de que el método para valorar la condición cardiorrespiratoria en todos los artículos fue un método indirecto, y no una prueba de esfuerzo con medición de intercambio gaseoso como se realizó en el presente proyecto. Cabe destacar que parece que algunos efectos de las intervenciones con VJA en la composición corporal, en concreto la disminución de la grasa corporal, pueden estar mediados por la mejora de la capacidad aeróbica (224). Por último, un estudio sin grupo control evidenció mejoras significativas en la condición cardiorrespiratoria en niños/as obesos (143).

Así mismo, los VJA tienen el potencial para mejorar la condición muscular en niños/as prepuberales con sobrepeso u obesidad ya que, mientras que tanto el grupo de intervención con VJA y el grupo control mostraron un aumento de masa magra al tratarse de poblaciones en crecimiento y en desarrollo sexual, el grupo de intervención con VJA mostró una mejora significativa en los test de fuerza, con un aumento significativo de la altura de salto en el CMJ y de los kilos de fuerza en la dinamometría manual. Además, tanto el grupo control como el grupo de intervención con VJA mejoró la fuerza isométrica de extensión de la rodilla, posiblemente debido al desarrollo de la masa magra como consecuencia del desarrollo madurativo. Sin embargo, cuando los resultados se corrigieron por el peso corporal, sólo se encontraron mejoras significativas en la fuerza isométrica de extensión de la rodilla en el grupo de intervención con VJA, lo que significa que la ganancia de la fuerza isométrica de extensión de la rodilla no se debió íntegramente al aumento del peso corporal, a diferencia del grupo de control cuyos aumentos significativos desaparecieron al dividir los resultados de fuerza isométrica de cuádriceps por el peso corporal. Estos resultados parece que van en consonancia con la escasa evidencia científica. Hasta la fecha, hay tan solo tres estudios sin grupos control que investigaron el efecto de intervenciones con VJA en la condición muscular, de los cuales dos a mostraron efectos positivos (143,144) y uno reportó ausencia de efectos tras la intervención con VJA (155), probablemente por una insuficiente frecuencia de entrenamiento o duración de la intervención. No obstante, la mejora en la competencia motriz del grupo VJA es bastante considerable, por lo que difícilmente puede explicarse por el crecimiento y desarrollo de los participantes.

La tríada de la inactividad pediátrica es un enfoque conceptual novedoso que refleja una crisis de salud pública en los niños y adolescentes actuales y la condición muscular (36). A pesar de la contundencia de este concepto, que expresa la tendencia de los niños a ser más débiles, menos ágiles, más lentos, menos activos y con más sobrepeso, actualmente no existen artículos enfocados a proponer soluciones o estrategias a esta realidad.

Siguiendo con los componentes de esa triada de la inactividad pediátrica, la intervención con VJA pretendió ser una propuesta disruptiva, como el título del proyecto indica, que rompiera con ese déficit de AF que en la mayoría de los casos se da en los niños/as y adolescentes con sobrepeso u obesidad. Concretamente, con esta intervención con VJA se pretendía romper con esa dinámica de hábitos poco saludables que componían el círculo vicioso en el que están inmersos los niños/as con sobrepeso u obesidad, en el que desarrollan dificultades para incrementar su AF debido a su CF y habilidad motriz empeoradas, optando por comportamientos sedentarios durante su tiempo libre que suele estar asociado a una mayor ingesta energética, favoreciendo un mayor desequilibrio energético y un mayor desarrollo de la obesidad. Es por eso que a través de esta intervención con VJA se busca incrementar la AF del niño/a, con el objetivo principal de incrementar el gasto energético y desarrollar mayores preferencias o motivación en la participación deportiva a través de una mejora de la CF y de la habilidad motriz. Los resultados mostraron que la AF total y la AFL aumentaron significativamente en el grupo de intervención con VJA, pero no se observaron cambios en la AFM o en la AFV, aunque se detectó una tendencia de aumento de la AFM y AFV en el grupo de intervención con VJA. La importancia de este aumento significativo de la AFL radica en la oportunidad de sustituir el tiempo sedentario por la AFL (225) para luchar contra la tendencia opuesta (226), teniendo en cuenta la fuerte influencia que tiene la AFL en la salud cardiometabólica (225). Es importante destacar que el grupo de intervención con VJA mostró reducciones significativas del tiempo de sedentarismo que, junto con los resultados del incremento de AFL, implica un efecto muy positivo de la intervención con VJA. Atendiendo a la evidencia científica existente y a su concordancia con los resultados del presente proyecto, una revisión sistemática muy actual realizada por Gao y col. (227) concluyó que los VJA parecen ser una estrategia prometedora y atractiva para promover la AF en jóvenes con sobrepeso u obesidad. Otros meta-análisis informaron de que los VJA podrían ser una buena alternativa para sustituir comportamientos sedentarios tales como el tiempo de pantalla y podría ser una herramienta complementaria al ejercicio tradicional (114,115), además del potencial que parece que tienen para ayudar a cumplir con las recomendaciones de AF diaria (113). Mack y col. (228) apoyan el uso de los VJA como una herramienta complementaria para incrementar la AF, afirmando también que el uso exclusivo de los VJA no consigue resultados satisfactorios, afirmación que fue apoyada por otras revisiones

(114,115,124), por lo que en este proyecto de investigación de los VJA se decidió combinar la intervención de VJA con ejercicio multicomponente para potenciar los beneficios. En definitiva, los VJA podrían ayudar a promover un estilo de vida más activo y por tanto más saludable entre niños/as con sobrepeso u obesidad (123), siempre que las sesiones con VJA sean supervisadas y estructuradas (125). Bien es cierto que varias revisiones sistemáticas no apoyan esta eficacia de los VJA para incrementar los niveles de AF lo suficiente (229–231), aunque esta ineficacia podría ser debida a un mal enfoque de las intervenciones con VJA en los estudios incluidos en estas revisiones, realizadas sin supervisión, con una duración o frecuencia insuficientes o con una muestra pequeña.

Abordando el último componente de la triada pediátrica de la inactividad, se observó una notable mejoría en la habilidad motriz del grupo de intervención con VJA, pasando del percentil 5 al percentil 22 tras la intervención con VJA. Es necesario señalar la gran limitación que supone no tener datos de habilidad motriz del grupo control, debido a la poca disponibilidad de tiempo, material y evaluador. En consonancia con los resultados del presente proyecto, la literatura científica ha evidenciado la efectividad de los VJA para mejorar las habilidades motrices (141,232), e incluso una revisión sistemática concluyó que los VJA, utilizados como herramienta complementaria y no como única, puede ser una buena estrategia para mejorar la competencia motriz en jóvenes (166). Es por esta razón que la intervención con VJA que se planificó para el proyecto incluyo ejercicio multicomponente para intentar sacar el máximo partido. A parte de la competencia motriz real, medida a través de baterías validadas, existe también la competencia motriz percibida, que es el nivel de habilidad motriz que un sujeto percibe de sí mismo. Tanto la competencia motriz real como la percibida se asocian positivamente con la motivación para practicar ejercicio físico, con la realización de AF y con la participación deportiva durante la infancia y adolescencia, y se asocian inversamente con el tiempo de sedentarismo, el sobrepeso y la obesidad (233,234), lo que es especialmente importante en los niños y niñas con una grasa corporal elevada (235). Basándonos en la interrelación de los componentes de la tríada de la inactividad pediátrica (36) (trastorno por déficit de ejercicio, dinapenia pediátrica y baja habilidad motriz), un aumento de la competencia motriz podría conducir a un aumento de la AF, que a su vez podría conducir a una mejora de la condición muscular y de la competencia motriz. Esta interrelación también puede darse de forma inversa, de manera que un empeoramiento de la competencia motriz puede llevar a un déficit de AF que produzca un empeoramiento de la condición muscular y de la competencia motriz. Este proceso negativo ocurre en niños/as que no desarrollan sus habilidades motrices de forma normal y muestran una peor habilidad motriz, como en los niños y niñas con sobrepeso u obesidad (106). Esta habilidad motriz empeorada que suele detectarse en los niños y niñas con sobrepeso u obesidad se va progresivamente haciendo más notable con el paso del tiempo, alejándose cada vez más de la habilidad motriz óptima, con todas las dificultades que conlleva en cuanto a la adherencia al ejercicio y la mejora de la CF relacionada con la salud.

Los participantes en este proyecto, niños/as y adolescentes con sobrepeso u obesidad, exhibieron un peor rendimiento tanto en la prueba de esfuerzo con la que se valoró la condición cardiorrespiratoria como en los test de fuerza, lo que va en consonancia con lo que muestra la evidencia científica sobre una CF empeorada en niños/as y adolescentes con sobrepeso u obesidad (57–59,71). También se reportó un déficit de AF, que promueve ese desequilibrio energético tan relacionado con la obesidad. También cabía esperar unos peores resultados en habilidad motriz, ya que se correlaciona negativamente con un mayor IMC, circunferencia de la cintura o de porcentaje de grasa corporal (101,102) y positivamente con la condición cardiorrespiratoria y la condición muscular (102–104), además de con la AF (103,105), por lo que si los participantes mostraron peores resultados en todo lo anterior, es lógico pensar que mostrarán también una habilidad motriz empeorada, en consonancia con lo que se ha estudiado previamente (106).

Con respecto al nivel de condición cardiorrespiratoria de los participantes, se obtuvieron valores medios de VO_{2pico} de 32,75 (DE ± 5,90) mL/kg/min para el grupo VJA y de 33,11 (DE ± 6,18) mL/kg/min para el grupo control. Los niños con sobrepeso y obesidad que participaron en este estudio mostraron niveles bajos de FRC con un mayor riesgo de problemas de salud debido a este bajo nivel de FRC en el 75% de los participantes, según los puntos de corte propuestos por Ruiz y col. (236). Además, el 67,9% de los participantes se encuentran por encima del percentil 50 según los puntos de corte en niños/as y adolescentes con obesidad de Johansson y col. (237), lo que significa que los participantes de este estudio tenían una condición cardiorrespiratoria superior a la media de los datos normativos de niños con sobrepeso u obesidad.

En cuanto a los niveles de condición muscular, los participantes en este estudio mostraron una elevada fuerza muscular máxima de extensión de rodilla (Z-Score) (185) y un alto rendimiento en el test de agarre de manos (percentil) (79), probablemente debido al estímulo crónico producido por su exceso de peso, mientras que mostraron valores más bajos de altura de salto tanto en la medición inicial como en la final, con resultados acordes a los valores de referencia (238). Por tanto, los niños con sobrepeso u obesidad pueden cumplir la condición de dinapenia pediátrica, uno de los componentes de la tríada de inactividad pediátrica (36), sobre todo si se tiene en cuenta la fuerza que requiera el movimiento o desplazamiento del propio peso corporal, por lo que parece necesario apostar por el entrenamiento de fuerza también en las intervenciones con niños con sobrepeso y obesidad. Los VJA podrían ser una estrategia interesante y prometedora para mejorar la aptitud muscular y luchar contra la dinapenia pediátrica de los niños con sobrepeso y obesidad.

Los niveles de AF de los participantes fueron deficientes, ya que los resultados mostraron que el 88,9% de los participantes no cumplieron con las recomendaciones de AF diaria.

Por último, la puntuación en el test para evaluar la habilidad motriz fue muy baja, y los participantes se clasificaron en el percentil 5, lo que refuerza la idea de que los niños/as y adolescentes con sobrepeso u obesidad tienen una habilidad motriz peor en comparación con aquellos con peso saludable (106). Además, en ciertos test de fuerza, sobre todo los que requieren el desplazamiento del propio peso corporal, la baja habilidad motriz condiciona el rendimiento, como en los test de salto, por lo que hay que tenerlo en cuenta a la hora de evaluar la fuerza en niños/as con sobrepeso u obesidad.

Afortunadamente, la intervención con VJA combinados con ejercicio multicomponente produjo efectos positivos en la CF y la habilidad motriz de los participantes, incrementando además su AF. Otro aspecto clave de la intervención con VJA de este proyecto fue la asistencia y adherencia al programa. Todos los participantes asignados al grupo de intervención con VJA completaron al menos el 80% de las sesiones, mostrando una buena adherencia a esta intervención VJA combinada con ejercicio multicomponente. La alta asistencia de los participantes asignados al grupo de VJA y la voluntad y el deseo de continuar con el programa de ejercicio a través de VJA mostraron una alta motivación para participar, puesto que el 100% de los participantes estaban dispuestos a continuar con el programa.

6.1 Limitaciones y fortalezas

A continuación, se van a exponer las diferentes limitaciones encontradas y asumidas, así como las principales fortalezas de esta Tesis Doctoral.

6.1.1 Limitaciones y fortalezas de las revisiones sistemáticas

Se ha incluido una gran variedad de intervenciones de VJA, con diferentes dispositivos e intervenciones de entrenamiento (duración, frecuencia, entorno o dinámica de entrenamiento y tipo de VJA), lo que dificulta el análisis de todos los artículos en conjunto y la obtención de resultados generalizados. Además, el riesgo potencial de sesgo de algunos estudios no se tuvo en cuenta al interpretar los resultados. Por último, no se realizaron algunos análisis de subgrupos debido al reducido número de ensayos controlados. La influencia del género, la demografía o la raza no se abordó en profundidad porque los estudios no mostraron los resultados divididos por estas covariables.

Una fortaleza de estos meta-análisis es que son los primeros meta-análisis que resumen la investigación actual sobre los efectos de la VJA en la aptitud física relacionada con la salud y la competencia motora en niños y adolescentes de peso saludable, incluyendo no sólo los efectos de la VJA sobre el IMC, sino también sobre la composición corporal, la condición cardiorrespiratoria, la condición muscular y la habilidad motriz. Además, el hecho de que se haya hecho una revisión sistemática con meta-análisis para niños/as y adolescentes con sobrepeso u obesidad y otra para niños/as y adolescentes con peso saludable, lo que permite diferenciar los resultados en función del estatus del peso, ya que el exceso de grasa corporal puede afectar tanto a la intensidad alcanzada durante las intervenciones, lo que producirá respuestas diferentes en variables como la condición cardiorrespiratoria, como al efecto de las mismas en variables más susceptibles al cambio debido al exceso de tejido graso como puede ser el IMC o la grasa corporal.

6.1.2 Limitaciones y fortalezas del estudio VIDEOACTIVO

La principal limitación fue el bajo número de participantes, especialmente en el grupo control. Esto podría dificultar la búsqueda de efectos de la propia intervención, ya que en algunas variables se observan tendencias que no son estadísticamente significativas, probablemente por una potencia estadística insuficiente. Otra limitación importante es el número desigual de participantes en los grupos de VJA y de control. Esto se debió a la dificultad en el proceso de reclutamiento, que hizo que se priorizara el grupo intervención en el primer año de reclutamiento con el objetivo de completar el grupo control en el reclutamiento del segundo año, por lo que se prorrogó a tres años el proyecto debido a su diseño cruzado y se hizo una aleatorización 2:1 en el primer año de proyecto, como se ha explicado anteriormente. No obstante, ante la paralización del proyecto durante el segundo año debido a la COVID-19, el número de participantes asignados al grupo de intervención y al grupo control quedó desequilibrado al tener 21 niños que realizaron la intervención con VJA el primer año frente a 8 niños/as que compusieron el grupo control, tras dos perdidas en el grupo control. A esto se suma otra limitación importante como es la ausencia del grupo control para la competencia motriz. Aunque una mejora tan considerable en la competencia motriz difícilmente puede explicarse sólo por el crecimiento y desarrollo de los niños, es necesario considerar la ausencia de datos del grupo de control para esta variable. También podría haber sido interesante valorar la autopercepción de habilidad motriz o competencia motriz percibida.

En cuanto al cálculo del gasto de energía, se midió el gasto energético global de cada dispositivo, pero no se informó de las mediciones de cada juego utilizado en cada VJA. Informar de las kilocalorías gastadas por cada juego utilizado en cada VJA habría sido interesante para saber cuál de ellos era el que más energía consumía para cada dispositivo. A esto se le añade que el gasto energético se midió con los datos de la FC a través de los datos de la prueba de esfuerzo máximo, ya que no se disponía de un analizador metabólico portátil. A pesar de no disponer de analizadores metabólicos portátiles, el cálculo individualizado del gasto energético a través de los datos de la prueba de esfuerzo y de la FC medida durante las sesiones fue un método fiable y efectivo (191,193), incluso en niños (239). De esta manera, fue posible medir el gasto energético de un gran número de sesiones y participantes.

En cuanto a las fortalezas del estudio, una gran fortaleza fue la gran variedad de VJA investigados. Además, en las sesiones con VJA se incluyeron el Ring Fit Adventures y el BKOOL, dos dispositivos novedosos que ofrecen oportunidades y posibilidades de aumentar significativamente el gasto energético en niños con sobrepeso u obesidad. El BKOOL destaca por su interactividad, el control de la carga y su carga aeróbica; y el Ring Fit destaca por su jugabilidad y su enfoque hacia el ejercicio físico y el fitness, con ejercicios específicos, entrenando con autocargas o cargas externas y con ejercicios determinados incluyendo una explicación gráfica.

Es importante destacar que la intervención de VJA en este estudio se combinó con ejercicio multicomponente, lo que nos permitió no sólo aumentar el gasto energético total de las sesiones, sino también comparar el gasto en las diferentes VJA con el gasto durante el ejercicio. Cierto es que la combinación con ejercicio multicomponente tiene la limitación intrínseca de la dificultad de diferenciar el estímulo que produce el efecto positivo, imposibilitando saber si ha sido por los VJA o por el entrenamiento multicomponente, aunque es verdad que pasaban mucho más tiempo en los VJA que en las transiciones activas con ejercicio.

Otra fortaleza metodológica es la realización de una prueba de esfuerzo máxima con analizador de gases, siendo el primer estudio en evaluar el efecto de los VJA en la condición cardiorrespiratoria de una forma tan precisa y directa.

Por último, la principal fortaleza de esta intervención con VJA fue que la intervención fue supervisada y estructurada, con una frecuencia (tres sesiones semanales y 60 minutos por sesión) similar o superior a la de otras intervenciones que reportaron beneficios y con una duración cercana a la necesaria para lograr resultados positivos (5 meses), lo cual facilitó que se observaran efectos positivos. Es reseñable que esta intervención fue diseñada y supervisada por profesionales de la AF y graduados en educación física, con la capacidad suficiente para dinamizar las sesiones.

7. Conclusiones

- **Artículo I**. Los videojuegos activos parecen ser una herramienta eficaz para mejorar la aptitud física relacionada con la salud y son una herramienta prometedora para mejorar la competencia motora en niños y adolescentes con sobrepeso u obesidad, por lo que parecen ser una buena estrategia para luchar contra la obesidad infantil, con efectos positivos sobre el índice de masa corporal y el porcentaje de grasa corporal, mejoras en la condición cardiorrespiratoria e incluso posibles mejoras en la habilidad motriz, aunque se necesitan más investigaciones para confirmar esta última idea. Los efectos de los programas de videojuegos activos sobre la aptitud muscular o la masa libre de grasa aún no están claros.
- **Artículo II.** Los videojuegos activos parecen ser una buena estrategia para mejorar algunos componentes de la aptitud física relacionada con la salud, controlando el índice de masa corporal y el porcentaje de grasa corporal, y mejorando la condición cardiorrespiratoria siempre que las intervenciones de videojuegos activos estén supervisadas y estructuradas, y duren al menos 18 semanas; y parecen ser una herramienta prometedora también para mejorar la habilidad motriz y la aptitud muscular en niños y adolescentes con peso saludable, lo que podría ser importante para combatir la tríada de la inactividad pediátrica, aunque se necesita más investigación.
- **Artículo III.** Una intervención de videojuegos activos estructurada y supervisada, combinada con ejercicio multicomponente, es una estrategia eficaz para producir actividad física de intensidad moderada y aumentar el gasto energético en niños y adolescentes con sobrepeso y obesidad. Ring Fit Adventures es una herramienta prometedora para aumentar el gasto energético, superando el gasto energético de los otros videojuegos activos exceptuando el BKOOL. El gasto energético parece ser mayor en niños que en niñas, pero

estas diferencias podrían deberse en parte a las disparidades en el peso corporal. En definitiva, los videojuegos activos son una herramienta innovadora e interesante que puede incrementar en gasto energético y por tanto ayudar a luchar contra la obesidad infantil y sus futuras consecuencias, actuando sobre el balance energético.

- **Artículo IV.** Una intervención de 5 meses usando videojuegos activos combinada con un entrenamiento multicomponente tiene efectos positivos sobre la aptitud muscular y la habilidad motriz. Además, esta intervención es una estrategia potencial para aumentar la actividad física y disminuir el tiempo de sedentarismo, pero su capacidad para aumentar la actividad física de intensidad moderada-vigorosa no está clara. De esta manera, los videojuegos activos combinados con el ejercicio multicomponente son una estrategia útil para mejorar algunos componentes de la tríada de inactividad pediátrica y, gracias al incremento de actividad física, romper con el estilo de vida obesogénico en niños/as con sobrepeso u obesidad.
- **Artículo V.** Una intervención de 5 meses con videojuegos activos combinada con ejercicio multicomponente parece tener efectos positivos sobre la condición cardiorrespiratoria a intensidad submáxima, mostrando valores más bajos de frecuencia cardíaca y consumo de oxígeno a las mismas intensidades, y porcentajes más bajos de consumo de oxígeno según los valores individuales del pico de consumo de oxígeno. El porcentaje de grasa corporal y la puntuación Z del índice de masa corporal también se redujeron después de la intervención con videojuegos activos. Además, se encontraron mayores mejoras en los niños con mayor porcentaje de grasa.

7. Conclusions

- **Manuscript I.** Active videogames seem to be an effective tool to improve health-related physical fitness and is a promising tool for improving motor skills in children and adolescents, with positive effects on body mass index and body fat percentage, improvements in cardiorespiratory fitness and even possible improvements in motor skills, although more research is needed to confirm this last point. The effects of interventions with active videogames on muscle fitness or fat-free mass are not yet clear.

- **Manuscript II.** Active videogames seem to be a good strategy to improve some components of health-related physical fitness, controlling the body mass index status and body fat percentage, and enhancing cardiorespiratory fitness as long as interventions with active videogames are supervised and structured, and last at least 18 weeks; and also seem to be a promising tool to improve motor skills and muscle fitness in healthy-weight children and adolescents, which could be important in combating the triad of paediatric inactivity, although more research is needed.

- **Manuscript III.** A structured and supervised intervention using active videogames combined with multi-component exercise is an effective strategy to produce moderate-intensity physical activity and to increase the energy expenditure in children and adolescents with overweight and obesity. Ring Fit Adventures is a promising tool to increase energy expenditure, exceeding the energy expenditure of the other active videogames except BKOOL. The energy expenditure seems to be higher for boys in comparison with girls, but these differences might be partially due to disparities in body weight. In short, active videogames are an innovative and interesting tool that can increase energy expenditure and therefore help to fight childhood obesity and its future consequences by improving the energy balance.

- **Manuscript IV.** A 5-month intervention of active videogames combined with multicomponent training has positive effects on muscle fitness and motor skills. Furthermore, this intervention is a potential strategy to increase light physical activity and decrease sedentary time, but its ability to increase moderate-to-vigorous physical activity is unclear. Thus, active videogames combined with multicomponent exercise seem to be a useful strategy to improve some components of the pediatric inactivity triad and, thanks to the increase in physical activity, to break the obesogenic lifestyle of overweight or obese children.

- **Manuscript V.** A 5-month intervention using active videogames combined with multicomponent exercise has positive effects on cardiorespiratory fitness at submaximal intensity, showing lower heart rate and oxygen consumption values at the same intensities and lower percentages of oxygen consumption according to their individual peak values of oxygen consumption. The body fat percentage and the z-score of body mass index were also reduced after the active videogames intervention. In addition, greater improvements were found in children with the highest fat percentage.

8. Aportaciones principales de la tesis

La aportación principal de esta tesis es la evidencia de la efectividad de los VJA para mejorar la condición física en niños/as con sobrepeso u obesidad. Una intervención con VJA es eficaz para mejorar la composición corporal, condición cardiorrespiratoria en intensidades sub-máximas y fuerza muscular. Los VJA pueden ser también una buena estrategia para mejorar la habilidad motriz e incrementar la actividad física, aumentando el gasto energético.

Esta aportación se traduce en la posibilidad de alianza con las nuevas tecnologías en vez de luchar contra ellas ya que esta tesis ha evidenciado los beneficios de los VJA para sustituir comportamientos sedentarios promovidos por la sociedad tecnológica actual. Los VJA son una oportunidad de aprovechar las preferencias de los jóvenes por el ocio de pantalla con el objetivo de incrementar el gasto energético y afrontar el problema mundial de la obesidad infantil.

9. Futuras líneas de investigación

Las futuras líneas de investigación derivadas de los estudios que componen esta Tesis Doctoral se pueden dividir en varios apartados: a) diseñar intervenciones que saquen el máximo partido a los VJA, b) diseñar nuevos VJA enfocados a la mejora de la CF, especialmente la mejora de condición cardiorrespiratoria y fuerza, además de la composición corporal en niños/as y adolescentes con sobrepeso u obesidad, con estímulos e intensidades suficientes y adaptados por edades, que sean atractivos y motivantes, c) desarrollar propuestas de intervención con VJA para prevenir o tratar la triada pediátrica de la inactividad.

En base a los resultados y conclusiones obtenidas durante la investigación de VJA, en la que se ha observado que los VJA parecen ser efectivos y tienen potencial para mejorar la CF y la habilidad motriz en población infantil con sobrepeso u obesidad, el siguiente paso es sacar el máximo partido a esta herramienta con diseños de intervenciones con VJA que busquen optimizar los resultados en cuanto a la mejora de la CF y habilidad motriz, y especialmente con niños/as y adolescentes con sobrepeso u obesidad. Una propuesta puede ser la implementación de un diseño como el del presente proyecto, con una combinación con ejercicio multicomponente que te asegure un estímulo suficiente en busca de la mejora. Es la primera vez que se hace una intervención de este tipo, combinando VJA con entrenamiento multicomponente más convencional, por lo que se necesitarían más artículos con muestras más amplias, equitativas entre grupos y con una metodología científica y protocolos adecuados para saber realmente el potencial de estas intervenciones. Es necesario cuantificar la mejora en la composición corporal, condición cardiorrespiratoria y fuerza muscular tras la realización de la intervención con VJA, pero también la intensidad, el gasto energético, la adherencia, el disfrute y la motivación de la propia intervención.

Otra posible futura línea de investigación es el diseño de nuevos VJA cuyo objetivo principal sea la realización de ejercicio físico para niños/as, similar al Ring Fit Adventures pero totalmente pensado para niños, incluso con diferentes herramientas, como mancuernas o lastres, gomas elásticas de fortalecimiento, steps, balón medicinal… a parte del aro de fortalecimiento. La idea es combinar las dinámicas de Kinect Adventures, Wii Fit y Ring Fit Adventures para crear VJA adecuados para cada grupo de edad con los que se busque maximizar la dosis de ejercicio de una forma lúdica y atractiva, e incluso de esta manera no sería tan necesario combinar los VJA con ejercicio de tipo convencional ya que los VJA supondrían el estímulo suficiente. Cabe destacar que, una de las principales limitaciones de la mayoría de los VJA, que de forma innovadora ha solventado el Ring Fit Adventures es un estímulo de fuerza con autocargas o cargas externas.

Para terminar, y en relación a la última idea, en esta tesis se le ha otorgado bastante importancia al concepto de triada pediátrica de la inactividad. Primeramente, aunque este concepto está definido, no se han identificado puntos de corte o datos normativos para determinar si se cumple la tríada de la inactividad pediátrica, es decir, la dinapenia y el analfabetismo físico pediátrico. Una gran aportación a la investigación futura sería la posibilidad de detectar esta tríada pediátrica de la inactividad en la consulta del pediatra a través de pruebas sencillas que podrían realizarse en la propia consulta. Por otro lado, una de las posibles estrategias para intentar hacer frente a este problema de la infancia son las intervenciones con VJA, aunque para que sean efectivas deberán ser optimizadas con las dos propuestas anteriores: combinando la intervención de VJA con entrenamiento multicomponente convencional o diseñando nuevos VJA que aborden el fortalecimiento muscular y la habilidad motriz, además de incrementar notablemente la AF. Cabe destacar que los VJA parecen ser bastante efectivos para mejorar la habilidad motriz, aunque de momento no se ha podido realizar un análisis cuantitativo. No obstante, futuras investigaciones podrían centrarse en los efectos de los VJA en la habilidad motriz, ya que, aunque no forma parte de los componentes de la CF, se ha visto su estrecha relación con una buena CF, con la AF y participación deportiva y con la salud y el correcto desarrollo físico durante la infancia y adolescencia. Aunque necesita ser investigado, parece que los VJA más efectivos para la mejora de la habilidad motriz son aquellos que requieren mucho movimiento y de diferente tipo: desplazamientos, saltos, lanzamientos, golpeos… En relación con esta idea, otra futura línea de investigación podría ser la incorporación de VJA como tarea escolar en EF o en actividades extraescolares para captar a esta población infantil con dificultades motoras, debilidad muscular, un déficit de AF y con rechazo al ejercicio físico y baja adherencia a las actividades deportivas. El objetivo principal sería romper con esa actividad física y rechazo al ejercicio físico a través de un programa de ejercicio físico con VJA que mejore la fuerza muscular y la habilidad motriz; esta mejora podrá conducir a un incremento en la AF y a una mayor adherencia a otras actividades deportivas.

Parece que los VJA tienen mucho potencial en cuanto a la promoción de AF y a la mejora de la CF y la habilidad motriz, lo que se traduce en una infancia más saludable. Sin embargo, se debe continuar investigando para sacar el máximo partido a esta herramienta con la idea de buscar una alianza con las nuevas tecnologías en lugar de intentar luchar contra ellas, ya que muchas actividades lúdicas de los jóvenes tienen relación con las tecnologías y las pantallas. La sociedad está evolucionando hacia una sociedad tecnológica y puede ser que el ejercicio físico también necesite esta evolución.

Por último, y yendo más allá del proyecto de tesis, al observar el estímulo provocado por los VJA de mayor intensidad, se ha planteado la utilización de los mismo en otros ámbitos. Concretamente, se está implementando un protocolo de ejercicio con el Ring Fit Adventures como un test de cribado para la detección de déficit de hormona de crecimiento. En este test, el/la niño/a acude al Hospital Clínico Universitario Lozano Blesa en ayunas.

Antes de comenzar el test de ejercicio, se extrae un tubo de sangre para el posterior análisis. A continuación, se realiza el test de ejercicio de aproximadamente 20 minutos, utilizando el videojuego activo Ring Fit Adventures y se coloca una banda de frecuencia cardíaca para registrar la frecuencia cardíaca con el objetivo de controlar la intensidad del ejercicio. Tras la finalización del test de ejercicio, se extrae un segundo tubo de sangre para el posterior análisis. De esta manera vemos que los VJA como herramienta de ejercicio físico no deben limitarse a un tipo de población, sino que pueden tener multitud de posibilidades.

10. Referencias bibliográficas

1. World Health Organization. Regional Office for Europe. WHO European Regional Obesity : Report 2022. 2022.
2. World Health Organization. Regional Office for Europe. European Programme of Work 2022-2025: United Action for Better Health [Internet]. 2021. Available from: http://apps.who.int/bookorders.
3. World Health Organization. Regional Office for Europe. WHO European ministerial conference on counteracting obesity : conference report. WHO Regional Office for Europe; 2007. 32 p.
4. World Health Organization. Consideration of the evidence on childhood obesity for the Commission on Ending Childhood Obesity Report of the Ad hoc Working Group on Science and Evidence for Ending Childhood Obesity [Internet]. 2016. Available from: http://www.who.int
5. World Health Organization. Global Nutrition Targets 2025: Childhood Overweight Policy Brief. 2014.
6. Gore FM, Bloem PJ, Patton GC, Ferguson J, Joseph V, Coffey C, et al. Global burden of disease in young people aged 10-24 years: a systematic analysis. Lancet [Internet]. 2011;377:2093–102. Available from: www.thelancet.com
7. Lee CMY, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol. 2008 Jul;61(7):646–53.
8. Schröder H, Ribas L, Koebnick C, Funtikova A, Gomez SF, Físo M, et al. Prevalence of abdominal obesity in Spanish children and adolescents. do we need waist circumference measurements in pediatric practice? PLoS One. 2014 Jan 27;9(1).

9. Gasol Foundation. Estudio Pasos 2019. Physical activity, Sedentarism and Obesity of Spanish youth. 2019.

10. Ara I, Moreno LA, Leiva MT, Gutin B, Casajús JA. Adiposity, physical activity, and physical fitness among children from Aragón, Spain. Obesity. 2007 Aug;15(8):1918–24.

11. Townsend N, Scriven A. The health consequences of obesity. In: Public Health Mini-Guides: Obesity. Elsevier; 2014.

12. Sakers A, De Siqueira MK, Seale P, Villanueva CJ. Adipose-tissue plasticity in health and disease. Cell. 2022 Feb 3;185(3):419–46.

13. Poston L, Harthoorn LF, Van Der Beek EM. Obesity in Pregnancy: Implications for the Mother and Lifelong Health of the Child. A Consensus Statement. Pediatr Res [Internet]. 2011;69:175–80. Available from: www.pedresearch.org

14. Townsend N, Wilson L, Bhatnagar P, Wickramasinghe K, Rayner M, Nichols M. Cardiovascular disease in Europe: Epidemiological update 2016. European Heart Journal Oxford University Press; Nov 7, 2016 p. 3232–45.

15. McCrindle BW. Cardiovascular Consequences of Childhood Obesity. Can J Cardiol. 2015 Feb 1;31(2):124–30.

16. Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. Tracking of obesity and physical activity from childhood to adulthood: The Physical Activity Longitudinal Study. Int J Pediatr Obes. 2009;4(4):281–8.

17. Llewellyn A, Simmonds M, Owen CG, Woolacott N. Childhood obesity as a predictor of morbidity in adulthood: A systematic review and meta-analysis. Obes Rev. 2016 Jan 1;17(1):56–67.

18. Maltoni G, Zioutas M, Deiana G, Biserni GB, Pession A, Zucchini S. Gender differences in weight gain during lockdown due to COVID-19 pandemic in adolescents with obesity. Nutr Metab Cardiovasc Dis [Internet]. 2021 Jun

30;31(7):2181–5. Available from: https://doi.org/10.1016/j.numecd.2021.03.018
19. Vogel M, Geserick M, Gausche R, Beger C, Poulain T, Meigen C, et al. Age- and weight group-specific weight gain patterns in children and adolescents during the 15 years before and during the COVID-19 pandemic. Int J Obes. 2022 Jan 1;46(1):144–52.
20. Pellegrini M, Ponzo V, Rosato R, Scumaci E, Goitre I, Benso A, et al. Changes in weight and nutritional habits in adults with obesity during the "lockdown" period caused by the COVID-19 virus emergency. Nutrients. 2020 Jul 1;12(7):1–11.
21. Drozdz D, Alvarez-Pitti J, Wójcik M, Borghi C, Gabbianelli R, Mazur A, et al. Obesity and cardiometabolic risk factors: From childhood to adulthood. Nutrients MDPI; Nov 1, 2021.
22. Wotrld Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. 2018.
23. World Health Organization. Physical inactivity a leading cause of disease and disability , warns WHO [Internet]. 2002 [cited 2017 Oct 14]. Available from: https://www.mendeley.com/viewer/?fileId=46d755bc-5f0c-05e1-644c-4012f529f427&documentId=1c4ad7cf-bea4-39bd-9e4c-881f5751e6d8
24. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc Heal. 2020 Jan 1;4(1):23–35.
25. Ding D, Lawson KD, Kolbe-Alexander TL, Finkelstein EA, Katzmarzyk PT, van Mechelen W, et al. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. Lancet. 2016 Sep 24;388(10051):1311–24.
26. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. Lancet. 2012;380(9838):219–29.

27. de Souto Barreto P. Why are we failing to promote physical activity globally? Bulletin of the World Health Organization Jun, 2013.

28. European Commission. 5º Eurobarometer: Sport and physical activity. [Internet]. 2022 [cited 2023 Jan 2]. Available from: https://europa.eu/eurobarometer/surveys/detail/2668

29. Colegios Oficiales de Educadores/as Físico Deportivos/as. El Gobierno publica los mínimos estatales para el currículo de Educación Física en Primaria. https://www.consejo-colef.es/. 2022.

30. the Leibniz Institute for Prevention Research and Epidemiology - BIPS. IDEFICS - Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS. Identification and prevention of Dietary- and lifestyle-induced health EFfects in Children and infantS: Publishable Final Activity Report. 2012.

31. Agencia Españolade Seguridad Alimentaria y Nutrición. Ministerio de Consumo. Estudio ALADINO 2019: Estudio sobre la Alimentación, Actividad Física, Desarrollo Infantil y Obesidad en España 2019. Madrid; 2020.

32. Ruiz E, Ávila JM, Castillo A, Valero T, del Pozo S, Rodriguez P, et al. The ANIBES study on energy balance in Spain: Design, protocol and methodology. Nutrients. 2015 Feb 4;7(2):970–98.

33. Roberts C, Freeman J, Samdal O, Schnohr CW, Looze ME, Nic Gabhainn S, et al. The Health Behaviour in School-aged Children (HBSC) study: Methodological developments and current tensions. Int J Public Health. 2009;54(SUPPL. 2).

34. Moreno LA, De Henauw S, González-Gross M, Kersting M, Molnár D, Gottrand F, et al. Design and implementation of the healthy lifestyle in europe by nutrition in adolescence cross-sectional study. Int J Obes. 2008;32:S4–11.

35. Roman-Viñas B, Marin J, Sánchez-López M, Aznar S, Leis R, Aparicio-Ugarriza

R, et al. Results from Spain's 2016 report card on physical activity for children and youth. J Phys Act Heal. 2016 Nov 1;13(11):S279–83.

36. Faigenbaum AD, Rial Rebullido T, MacDonald JP. Pediatric Inactivity Triad: A Risky PIT. Curr Sports Med Rep. 2018 Feb 9;17(2):45–7.

37. Chaput JP, Willumsen J, Bull F, Chou R, Ekelund U, Firth J, et al. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. International Journal of Behavioral Nutrition and Physical Activity BioMed Central Ltd; Dec 1, 2020.

38. Fang K, Mu M, Liu K, He Y. Screen time and childhood overweight/obesity: A systematic review and meta-analysis. Child Care Health Dev. 2019;45(5):744–53.

39. Carson V, Hunter S, Kuzik N, Gray CE, Poitras VJ, Chaput JP, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: An update. Appl Physiol Nutr Metab. 2016;41(6):S240–65.

40. Bucksch J, Sigmundova D, Hamrik Z, Troped PJ, Melkevik O, Ahluwalia N, et al. International Trends in Adolescent Screen-Time Behaviors from 2002 to 2010. J Adolesc Heal. 2016 Apr 1;58(4):417–25.

41. Mielgo-Ayuso J, Aparicio-Ugarriza R, Castillo A, Ruiz E, Avila JM, Aranceta-Bartrina J, et al. Sedentary behavior among Spanish children and adolescents: findings from the ANIBES study. BMC Public Health. 2017 Jan 19;17(1):1–9.

42. Biddle SJH, O'Connell S, Braithwaite RE. Sedentary behaviour interventions in Young People: A Meta-Analysis. Vol. 45, British Journal of Sports Medicine. 2011. p. 937–42.

43. Gába A, Pedišić Ž, Štefelová N, Dygrýn J, Hron K, Dumuid D, et al. Sedentary behavior patterns and adiposity in children: A study based on compositional data analysis. BMC Pediatr. 2020 Apr 2;20(1).

44. Wu XY, Han LH, Zhang JH, Luo S, Hu JW, Sun K. The influence of physical

activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. PLoS One. 2017 Nov 1;12(11).

45. Amini H, Habibi S, Islamoglu AH, Isanejad E, Uz C, Daniyari H. COVID-19 pandemic-induced physical inactivity: the necessity of updating the Global Action Plan on Physical Activity 2018-2030. Environmental Health and Preventive Medicine BioMed Central Ltd; Dec 1, 2021.

46. Marques A, Minderico C, Martins S, Palmeira A, Ekelund U, Sardinha LB. Cross-sectional and prospective associations between moderate to vigorous physical activity and sedentary time with adiposity in children. Int J Obes. 2016 Jan 1;40(1):28–33.

47. Júdice PB, Silva AM, Berria J, Petroski EL, Ekelund U, Sardinha LB. Sedentary patterns, physical activity and health-related physical fitness in youth: A cross-sectional study. Int J Behav Nutr Phys Act. 2017 Mar 4;14(1).

48. Marques A, Santos R, Ekelund U, Sardinha LB. Association between physical activity, sedentary time, and healthy fitness in youth. Med Sci Sports Exerc. 2014 Mar 26;47(3):575–80.

49. Stoner L, Rowlands D, Morrison A, Credeur D, Hamlin M, Gaffney K, et al. Efficacy of Exercise Intervention for Weight Loss in Overweight and Obese Adolescents: Meta-Analysis and Implications. Sport Med. 2016 Nov 1;46(11):1737–51.

50. Ara I, Vicente-Rodríguez G, Moreno LA, Gutin B, Casajus JA. Child obesity can be better reduced through vigorous physical activity rather than through energy intake restriction.

51. Caspersen CJ, Powell K E, Christenson G M. Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. Public

Heal Rep. 1985;100(2):126–31.

52. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription - Tenth Edition. Nobel M, Millholen A, editors. Wolters Kluwer Health ; 2018. 1–651 p.

53. Keating SE, Johnson NA, Mielke GI, Coombes JS. A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity. Obes Rev. 2017 Aug 1;18(8):943–64.

54. Dias KA, Ingul CB, Tjønna AE, Keating SE, Gomersall SR, Follestad T, et al. Effect of High-Intensity Interval Training on Fitness, Fat Mass and Cardiometabolic Biomarkers in Children with Obesity: A Randomised Controlled Trial. Sport Med. 2018 Mar 1;48(3):733–46.

55. Casonatto J, Fernandes RA, Batista MB, Cyrino ES, Coelho-e-Silva MJ, de Arruda M, et al. Association between health-related physical fitness and body mass index status in children. J Child Heal Care. 2016 Sep 1;20(3):294–303.

56. Dumith SC, Ramires V, Souza A, Souza Moraes D, Godoy Petry F, Soldera Oliveira E, et al. Overweight/Obesity and Physical Fitness Among Children and Adolescents. Vol. 7, Journal of Physical Activity and Health. 2010.

57. Ceschia A, Giacomini S, Santarossa S, Rugo M, Salvadego D, Da Ponte A, et al. Deleterious effects of obesity on physical fitness in pre-pubertal children. Eur J Sport Sci. 2016 Feb 17;16(2):271–8.

58. Moliner-Urdiales D, Ruiz JR, Vicente-Rodriguez G, Ortega FB, Rey-Lopez JP, España-Romero V, et al. Associations of muscular and cardiorespiratory fitness with total and central body fat in adolescents: The HELENA study. Br J Sports Med. 2011 Feb;45(2):101–8.

59. Garcia-Pastor T, Salinero JJ, Sanz-Frias D, Pertusa G, Del Coso J. Body fat percentage is more associated with low physical fitness than with sedentarism and

diet in male and female adolescents. Physiol Behav. 2016 Oct 15;165:166–72.

60. Chen W, Hammond-Bennett A, Hypnar A, Mason S. Health-related physical fitness and physical activity in elementary school students. BMC Public Health. 2018 Jan 30;18(1).

61. García-Hermoso A, Ramírez-Vélez R, Saavedra JM. Exercise, health outcomes, and pædiatric obesity: A systematic review of meta-analyses. J Sci Med Sport. 2019 Jan 1;22(1):76–84.

62. Marson EC, Delevatti RS, Prado AKG, Netto N, Kruel LFM. Effects of aerobic, resistance, and combined exercise training on insulin resistance markers in overweight or obese children and adolescents: A systematic review and meta-analysis. Vol. 93, Preventive Medicine. Academic Press Inc.; 2016. p. 211–8.

63. García-Hermoso A, Ramírez-Vélez R, Ramírez-Campillo R, Peterson MD, Martínez-Vizcaíno V. Concurrent aerobic plus resistance exercise versus aerobic exercise alone to improve health outcomes in paediatric obesity: A systematic review and meta-Analysis. Br J Sports Med. 2018 Feb 1;52(3):161–6.

64. Lee J. Influences of exercise interventions on overweight and obesity in children and adolescents. Public Health Nurs. 2021 May 1;38(3):502–16.

65. Headid RJ, Park SY. The impacts of exercise on pediatric obesity. Clin Exp Pediatr. 2021;64(5):196–207.

66. American College of Sports Medicine. Exercise is Medicine: A Global Health Initiative. 2021.

67. EXERNET: Red de ejercicio físico y salud.

68. Joensuu L, Syväoja H, Kallio J, Kulmala J, Kujala UM, Tammelin TH. Objectively measured physical activity, body composition and physical fitness: Cross-sectional associations in 9- to 15-year-old children. Eur J Sport Sci. 2018 Jul 3;18(6):882–92.

69. Pahkala K, Hernelahti M, Heinonen OJ. Body mass index, fitness and physical activity from childhood through adolescence. Br J Sport Med [Internet]. 2013;47:71–7. Available from: http://dx.doi.

70. Viña J, Sanchis-Gomar F, Martinez-Bello V, Gomez-Cabrera MC. Exercise acts as a drug; The pharmacological benefits of exercise. Br J Pharmacol. 2012 Sep;167(1):1–12.

71. Tsiros MD, Coates AM, Howe PRC, Walkley J, Hills AP, Wood RE, et al. Adiposity is related to decrements in cardiorespiratory fitness in obese and normal-weight children. Pediatr Obes. 2016 Apr 1;11(2):144–50.

72. Beedie C, Mann S, Jimenez A, Kennedy L, Lane AM, Domone S, et al. Death by effectiveness: Exercise as medicine caught in the efficacy trap! Br J Sports Med. 2016 Mar 1;50(6):323–4.

73. Toemen L, Santos S, Roest AA, Jelic G, van der Lugt A, Felix JF, et al. Body fat distribution, overweight, and cardiac structures in school-age children: A population-based cardiac magnetic resonance imaging study. J Am Heart Assoc. 2020 Jul 7;9(13).

74. O'Malley GC, Shultz SP, Thivel D, Tsiros MD. Neuromusculoskeletal Health in Pediatric Obesity: Incorporating Evidence into Clinical Examination. Curr Obes Rep. 2021 Dec 1;10(4):467–77.

75. Dimitri P, Bishop N, Walsh JS, Eastell R. Obesity is a risk factor for fracture in children but is protective against fracture in adults: A paradox. Bone. 2012 Feb;50(2):457–66.

76. Julian V, O'Malley G, Metz L, Weghuber D, Courteix D, Fillon A, et al. Does the severity of obesity influence bone density, geometry and strength in adolescents? Pediatr Obes. 2021 Dec 1;16(12).

77. Fintini D, Cianfarani S, Cofini M, Andreoletti A, Ubertini GM, Cappa M, et al.

The Bones of Children With Obesity. Frontiers in Endocrinology Frontiers Media S.A.; Apr 24, 2020.

78. Lopes KG, Rodrigues EL, da Silva Lopes MR, do Nascimento VA, Pott A, Guimarães R de CA, et al. Adiposity Metabolic Consequences for Adolescent Bone Health. Nutrients. 2022 Aug 1;14(16).

79. Tomkinson GR, Carver KD, Atkinson F, Daniell ND, Lewis LK, Fitzgerald JS, et al. European normative values for physical fitness in children and adolescents aged 9-17 years: Results from 2 779 165 Eurofit performances representing 30 countries. Br J Sports Med. 2018 Nov 1;52(22):1445–56.

80. Armstrong N, Welsman J, Winsley R. Is Peak VO2 a Maximal Index of Children's Aerobic Fitness? Int J Sport Med. 1996;17(5):356–9.

81. Bhammar DM, Adams-Huet B, Babb TG. Quantification of Cardiorespiratory Fitness in Children with Obesity. Med Sci Sports Exerc. 2019 Nov 1;51(11):2243–50.

82. Marinus N, Bervoets L, Massa G, Verboven K, Stevens A, Takken T, et al. Altered gas-exchange at peak exercise in obese adolescents: Implications for verification of effort during cardiopulmonary exercise testing. J Sports Med Phys Fitness. 2017 Dec 1;57(12):1687–94.

83. Hansen D, Marinus N, Remans M, Courtois I, Cools F, Calsius J, et al. Exercise tolerance in obese vs. lean adolescents: A systematic review and meta-analysis. Obes Rev. 2014 Nov 1;15(11):894–904.

84. Mintjens S, Menting MD, Daams JG, van Poppel MNM, Roseboom TJ, Gemke RJBJ. Cardiorespiratory Fitness in Childhood and Adolescence Affects Future Cardiovascular Risk Factors: A Systematic Review of Longitudinal Studies. Vol. 48, Sports Medicine. Springer International Publishing; 2018. p. 2577–605.

85. Ornelas RT, Silva AM, Minderico CS, Sardinha LB. Changes in cardiorespiratory

fitness predict changes in body composition from childhood to adolescence: Findings from the European youth heart study. Phys Sportsmed. 2011;39(2):78–86.

86. García-Hermoso A, Izquierdo M, Alonso-Martínez AM, Faigenbaum A, Olloquequi J, Ramírez-Vélez R. Association between Exercise-Induced Changes in Cardiorespiratory Fitness and Adiposity among Overweight and Obese Youth: A Meta-Analysis and Meta-Regression Analysis. Children. 2020 Sep 21;7(9):147.

87. Parrett AL, Valentine RJ, Arngrímsson SÁ, Castelli DM, Evans EM. Adiposity and aerobic fitness are associated with metabolic disease risk in children. Appl Physiol Nutr Metab. 2011 Feb;36(1):72–9.

88. Smith JJ, Eather N, Weaver RG, Riley N, Beets MW, Lubans DR. Behavioral Correlates of Muscular Fitness in Children and Adolescents: A Systematic Review. Sport Med. 2019;

89. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum AD, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. Sport Med. 2014;44(9):1209–23.

90. Garcia-Vicencio S, Coudeyre E, Kluka V, Cardenoux C, Jegu AG, Fourot A V., et al. The bigger, the stronger? Insights from muscle architecture and nervous characteristics in obese adolescent girls. Int J Obes. 2016 Feb 1;40(2):245–51.

91. Ervin RB, Fryar CD, Wang CY, Miller IM, Ogden CL. Strength and body weight in US children and adolescents. Pediatrics. 2014 Sep 1;134(3):e782–9.

92. Riddiford-Harland DL, Steele JR, Baur LA. Upper and lower limb functionality: Are these compromised in obese children? Int J Pediatr Obes. 2006;1(1):42–9.

93. Haapala EA, Väistö J, Lintu N, Tompuri T, Brage S, Westgate K, et al. Adiposity, physical activity and neuromuscular performance in children. J Sports Sci. 2016 Sep 16;34(18):1699–706.

94. Herda TJ, Ryan ED, Kohlmeier M, Trevino MA, Gerstner GR, Roelofs EJ.

Examination of muscle morphology and neuromuscular function in normal weight and overfat children aged 7-10 years. Scand J Med Sci Sport. 2018 Nov 1;28(11):2310–21.

95. Stricker PR, Faigenbaum AD, McCambridge TM. Resistance Training for Childrenand Adolescents. Pediatrics [Internet]. 2020 Jun 1;145(6). Available from: www.safesport.org

96. Benson AC, Torode ME, Fiatarone Singh MA. Muscular strength and cardiorespiratory fitness is associated with higher insulin sensitivity in children and adolescents. Int J Pediatr Obes. 2006;1(4):222–31.

97. Vaara JP, Fogelholm M, Vasankari T, Santtila M, Häkkinen K, Kyröläinen H. Associations of maximal strength and muscular endurance with cardiovascular risk factors. Int J Sports Med. 2014;35(4):356–60.

98. Blakeley CE, Van Rompay MI, Schultz NS, Sacheck JM. Relationship between muscle strength and dyslipidemia, serum 25(OH)D, and weight status among diverse schoolchildren: A cross-sectional analysis. BMC Pediatr. 2018 Feb 2;18(1).

99. Gil-Cosano JJ, Gracia-Marco L, Ubago-Guisado E, Labayen I, Adelantado-Renau M, Cadenas-Sanchez C, et al. Inflammatory markers and bone mass in children with overweight/obesity: the role of muscular fitness. Pediatr Res. 2020 Jan 1;87(1):42–7.

100. Rodriguez-Ayllon M, Cadenas-Sanchez C, Esteban-Cornejo I, Migueles JH, Mora-Gonzalez J, Henriksson P, et al. Physical fitness and psychological health in overweight/obese children: A cross-sectional study from the ActiveBrains project. J Sci Med Sport. 2018 Feb 1;21(2):179–84.

101. Barnett LM, Lai SK, Veldman SLC, Hardy LL, Cliff DP, Morgan PJ, et al. Correlates of Gross Motor Competence in Children and Adolescents: A Systematic

Review and Meta-Analysis. Sport Med. 2016 Nov 1;46(11):1663–88.

102. Cattuzzo MT, dos Santos Henrique R, Ré AHN, de Oliveira IS, Melo BM, de Sousa Moura M, et al. Motor competence and health related physical fitness in youth: A systematic review. J Sci Med Sport. 2016 Feb 1;19(2):123–9.

103. Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. Fundamental Movement Skills in Children and Adolescents Review of Associated Health Benefits. Sport Med. 2010;40(12):1019–35.

104. Milne N, Leong GM, Hing W. The relationship between children's motor proficiency and health-related fitness. J Paediatr Child Health. 2016 Aug 1;52(8):825–31.

105. Jaakkola T, Yli-Piipari S, Huotari P, Watt A, Liukkonen J. Fundamental movement skills and physical fitness as predictors of physical activity: A 6-year follow-up study. Scand J Med Sci Sport. 2016 Jan 1;26(1):74–81.

106. Han A, Fu A, Cobley S, Sanders RH. Effectiveness of exercise intervention on improving fundamental movement skills and motor coordination in overweight/obese children and adolescents: A systematic review. J Sci Med Sport. 2018 Jan 1;21(1):89–102.

107. Molina-Garcia P, H Migueles J, Cadenas-Sanchez C, Esteban-Cornejo I, Mora-Gonzalez J, Rodriguez-Ayllon M, et al. Fatness and fitness in relation to functional movement quality in overweight and obese children. J Sports Sci. 2019 Apr 18;37(8):878–85.

108. Khodaverdi Z, Bahram A, Stodden D, Kazemnejad A. The relationship between actual motor competence and physical activity in children: Mediating roles of perceived motor competence and Health-Related physical fitness. J Sports Sci. 2016;34(16):1523–9.

109. Hu D, Zhou S, Crowley-Mchattan ZJ, Liu Z. Factors that influence participation in

physical activity in school-aged children and adolescents: A systematic review from the social ecological model perspective. Int J Environ Res Public Health. 2021 Mar 2;18(6):1–20.

110. Oh Y, Yang S. Defining exergames & exergaming. In: Proceedings of Meaningful Play [Internet]. 2010. p. 1–17. Available from: https://meaningfulplay.msu.edu/proceedings2010/mp2010_paper_63.pdf

111. Christison AL, Evans TA, Bleess BB, Wang H, Aldag JC, Binns HJ. Exergaming for Health: A Randomized Study of Community-Based Exergaming Curriculum in Pediatric Weight Management. Games Health J. 2016 Dec 1;5(6):413–21.

112. Peng W, Lin J-HH, Crouse J. Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. Cyberpsychology, Behav Soc Netw. 2011 Nov 1;14(11):681–8.

113. Sween J, Wallington SF, Sheppard V, Taylor T, Llanos AA, Adams-Campbell LL. The role of exergaming in improving physical activity: A review. J Phys Act Heal. 2014;11(4):864–870.

114. Gao Z, Chen S, Pasco D, Pope Z. A meta-analysis of active video games on health outcomes among children and adolescents. Obes Rev. 2015 Sep 1;16(9):783–94.

115. LeBlanc AG, Chaput JP, McFarlane A, Colley RC, Thivel D, Biddle SJH, et al. Active Video Games and Health Indicators in Children and Youth: A Systematic Review. PLoS One. 2013 Jun 14;8(6).

116. Biddiss E, Irwin J. Active Video Games to Promote Physical Activity in Children and Youth A Systematic Review. Arch Pediatr Adolesc Med [Internet]. 2010 Jul;164(7):664–72. Available from: http://archpedi.jamanetwork.com/

117. Barnett A, Cerin E, Baranowski T. Active video games for youth: A systematic review. J Phys Act Heal. 2011;8(5):724–37.

118. Bailey BW, McInnis K. Energy cost of exergaming: A comparison of the energy

cost of 6 forms of exergaming. Arch Pediatr Adolesc Med. 2011 Jul;165(7):597–602.

119. Ho RST, Chan EKY, Liu KKY, Wong SHS. Active video game on children and adolescents' physical activity and weight management: A network meta-analysis. Scand J Med Sci Sport. 2022 Aug 1;32(8):1268–86.

120. McNarry MA, Mackintosh KA. Investigating the relative exercise intensity of exergames in prepubertal children. Games Health J. 2016 Apr 1;5(2):135–40.

121. Perron RM, Graham CA, Feldman JR, Moffett RA, Hall EE. Do exergames allow children to achieve physical activity intensity commensurate with national guidelines? [Internet]. Vol. 4, Int J Exerc Sci. 2011. Available from: http://www.intjexersci.com

122. Quinn M. Introduction of Active Video Gaming Into the Middle School Curriculum as a School-Based Childhood Obesity Intervention. J Pediatr Heal Care. 2013 Jan;27(1):3–12.

123. Lamboglia CMGF, Silva VTBL da, Vasconcelos Filho JE de, Pinheiro MHNP, Munguba MC da S, Silva Júnior FVI, et al. Exergaming as a strategic tool in the fight against childhood obesity: A systematic review. Majdzadeh R, editor. J Obes [Internet]. 2014;2013:1–8. Available from: https://doi.org/10.1155/2013/438364

124. Gao Z, Chen S. Are field-based exergames useful in preventing childhood obesity? A systematic review. Int Assoc Study Obes. 2014;15(8):1–16.

125. Liang Y, Lau PWC. Effects of active videogames on physical activity and related outcomes among healthy children: A systematic review. Games Health J. 2014;3:122–44.

126. Azevedo LB, Burges Watson D, Haighton C, Adams J. The effect of dance mat exergaming systems on physical activity and health - Related outcomes in secondary schools: Results from a natural experiment. BMC Public Health. 2014

Sep 12;14(1).

127. Ye S, Lee J, Stodden D, Gao Z. Impact of Exergaming on Children's Motor Skill Competence and Health-Related Fitness: A Quasi-Experimental Study. J Clin Med. 2018 Sep 7;7(9):261.

128. Coknaz D, Mirzeoglu AD, Atasoy HI, Alkoy S, Coknaz H, Goral K. A digital movement in the world of inactive children: favourable outcomes of playing active video games in a pilot randomized trial. Eur J Pediatr. 2019 Oct 1;178(10):1567–76.

129. Maloney AE, Stempel A, Wood ME, Patraitis C, Beaudoin C. Can Dance Exergames Boost Physical Activity as a School-Based Intervention? Games Health J. 2012 Dec 1;1(6):416–21.

130. Gao Z, Lee JE, Zeng N, Pope ZC, Zhang Y, Li X. Home-Based Exergaming on Preschoolers' Energy Expenditure, Cardiovascular Fitness, Body Mass Index and Cognitive Flexibility: A Randomized Controlled Trial. J Clin Med. 2019 Oct 21;8(10):1745.

131. Graves LEF, Ridgers ND, Atkinson G, Stratton G. The Effect of Active Video Gaming on Children's Physical Activity, Behavior Preferences and Body Composition. Pediatr Exerc Sci [Internet]. 2010;22:535–46. Available from: http://www.newconceptgaming.com/products/ps2-compatible-

132. Maloney AE, Carter Bethea T, Kelsey KS, Marks JT, Paez S, Rosenberg AM, et al. A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. Obesity. 2008 Sep;16(9):2074–80.

133. Lau PWC, Wang JJ, Maddison R. A Randomized-Controlled Trial of School-Based Active Videogame Intervention on Chinese Children's Aerobic Fitness, Physical Activity Level, and Psychological Correlates. Games Health J. 2016 Dec 1;5(6):405–12.

134. Adamo KB, Rutherford JA, Goldfield GS. Effects of interactive video game cycling on overweight and obese adolescent health. Appl Physiol Nutr Metab. 2010;35(6):805–15.

135. Trost SG, Sundal D, Foster GD, Lent MR, Vojta D. Effects of a pediatricweight management program with and without active video games a randomized trial. JAMA Pediatr. 2014;168(5):407–13.

136. Foley L, Jiang Y, Ni Mhurchu C, Jull A, Prapavessis H, Rodgers A, et al. The effect of active video games by ethnicity, sex and fitness: Subgroup analysis from a randomised controlled trial. Int J Behav Nutr Phys Act. 2014 Apr 3;11(1):S66–7.

137. Irandoust KK, Taheri M, H'Mida C, Rodrigues G, Trabelsi K, Ammar A, et al. Exergaming and Aquatic Exercises Affect Lung Function and Weight Loss in Obese Children. Int J Sports Med. 2020 Oct 28;

138. Maddison R, Foley L, Ni Mhurchu C, Jiang Y, Jull A, Prapavessis H, et al. Effects of active video games on body composition: A randomized controlled trial. Am J Clin Nutr. 2011 Jul 1;94(1):156–63.

139. Staiano AE, Beyl RA, Guan W, Hendrick CA, Hsia DS, Newton RL. Home-based exergaming among children with overweight and obesity: a randomized clinical trial. Pediatr Obes. 2018 Nov 1;13(11):724–33.

140. Staiano AE, Abraham AA, Calvert SL. Adolescent Exergame Play for Weight Loss and Psychosocial Improvement: A Controlled Physical Activity Intervention. Obesity. 2012 Jun 14;

141. Argarini R, Herawati L, Irwadi I, Arum Cahyaning Putri E, Meinar Sari G. Fundamental Movement Skill Approach to Combat Childhood Obesity in Surabaya, Indonesia: Potential Effects of Video Games Based Exercises (Exergaming). Talent Dev Excell [Internet]. 2020;12(1):3026–34. Available from: http://www.iratde.com

142. Christison A, Khan HA. Exergaming for health: A community-based pediatric weight management program using active video gaming. Clin Pediatr (Phila). 2012 Apr;51(4):382–8.

143. Calcaterra V, Larizza D, Codrons E, De Silvestri A, Brambilla P, Abela S, et al. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. J Pediatr Endocrinol Metab. 2013 Apr;26(3–4):271–6.

144. Duman F, Kokaçya MH, Doğru E, Katayıfcı N, Canbay Ö, Aman F. The role of active video-accompanied exercises in improvement of the obese state in children: A prospective study from Turkey. JCRPE J Clin Res Pediatr Endocrinol. 2016 Sep 1;8(3):334–40.

145. Staiano AE, Marker AM, Beyl RA, Hsia DS, Katzmarzyk PT, Newton RL. A randomized controlled trial of dance exergaming for exercise training in overweight and obese adolescent girls. Pediatr Obes. 2017 Apr 1;12(2):120–8.

146. Wagener TL, Fedele DA, Mignogna MR, Hester CN, Gillaspy SR. Psychological effects of dance-based group exergaming in obese adolescents. Pediatr Obes. 2012 Oct;7(5).

147. Maloney AE, Threlkeld KA, Cook WL. Comparative Effectiveness of a 12-Week Physical Activity Intervention for Overweight and Obese Youth: Exergaming with "Dance Dance Revolution." Games Health J. 2012 Apr;1(2):96–103.

148. De Brito-Gomes JL, Perrier-Melo RJ, Melo De Oliveira SF, De Sá Pereira Guimarães FJ, Da Cunha Costa M. Physical effort, energy expenditure, and motivation in structured and unstructured active video games: A randomized controlled trial. Hum Mov. 2016 Sep 1;17(3):190–8.

149. Bonney E, Ferguson G, Burgess T, Smits-Engelsman B. Benefits of Activity-Based Interventions among Female Adolescents Who Are Overweight and Obese. Pediatr Phys Ther. 2019;31(4):338–45.

150. Fu Y, Burns RD. Effect of an Active Video Gaming Classroom Curriculum on Health-Related Fitness, School Day Step Counts, and Motivation in Sixth Graders. J Phys Act Heal. 2018 Sep 1;15(9):644–50.

151. Ye S, Pope ZC, Lee JE, Gao Z. Effects of school-based exergaming on urban children's physical activity and cardiorespiratory fitness: A quasi-experimental study. Int J Environ Res Public Health. 2019 Nov 1;16(21).

152. Smits-Engelsman BCM, Jelsma LD, Ferguson GD. The effect of exergames on functional strength, anaerobic fitness, balance and agility in children with and without motor coordination difficulties living in low-income communities. Hum Mov Sci. 2017 Oct 1;55:327–37.

153. Cifci C, Baspinar SG. The Effects of Active Video Games on Strength, Vertical Jumping and Flexibility in Children Aged 12 to 15 Years Old. Int J Appl Exerc Physiol. 2020;9(6):70–7.

154. Owens SG, Garner Iii JC, Loftin JM, Van Blerk N. Changes in physical activity and fitness after 3 months of home wii fit use. J Strength Cond Res [Internet]. 2011;25(11):3191–7. Available from: www.nsca-jscr.org

155. Huang H-H, Cook L, Harrison J, O'keefe N, Schultz K, Curtis DA. Exercise by playing active video gaming in overweight and obese children. J Phys Ther Sport Med [Internet]. 2017;1(1). Available from: http://www.alliedacademies.org/journal-physical-therapy-sports-medicine/

156. Hassan MA, Liu W, McDonough DJ, Su X, Gao Z. Comparative Effectiveness of Physical Activity Intervention Programs on Motor Skills in Children and Adolescents: A Systematic Review and Network Meta-Analysis. Int J Environ Res Public Health. 2022 Sep 21;19(19):11914.

157. Fu Y, Burns RD, Constantino N, Zhang P. Differences in Step Counts, Motor Competence, and Enjoyment between an Exergaming Group and a Non-

Exergaming Group. Games Health J. 2018 Oct 1;7(5):335–40.

158. Medeiros P, Felden ÉPG, Zequinão MA, Cordeiro PC, de Freitas KTD, dos Santos JOL, et al. Positive effect of a motor intervation program with exergames: A blind randomized trial. Int J Game-Based Learn. 2020 Oct 1;10(4):55–64.

159. McGann J, Issartel J, Hederman L, Conlan O. Hop.Skip.Jump.Games: The effect of "principled" exergameplay on children's locomotor skill acquisition. Br J Educ Technol. 2019;

160. Vernadakis N, Papastergiou M, Zetou E, Antoniou P. The impact of an exergame-based intervention on children's fundamental motor skills. Comput Educ. 2015;83:90–102.

161. Mombarg R, Jelsma D, Hartman E. Effect of Wii-intervention on balance of children with poor motor performance. Res Dev Disabil [Internet]. 2013;34(9):2996–3003. Available from: http://dx.doi.org/10.1016/j.ridd.2013.06.008

162. Sheehan DP, Katz L. The effects of a daily, 6-week exergaming curriculum on balance in fourth grade children. J Sport Heal Sci. 2013;2(3):131–7.

163. Sheehan DP, Katz L. The impact of a six week exergaming curriculum on balance with grade three school children using the wii FIT+TM. Int J Comput Sci Sport. 2012;11(3):5–22.

164. Johnson TM, Ridgers ND, Hulteen RM, Mellecker RR, Barnett LM. Does playing a sports active video game improve young children's ball skill competence? J Sci Med Sport. 2016 May 1;19(5):432–6.

165. Gao Z, Zeng N, Pope ZC, Wang R, Yu F. Effects of exergaming on motor skill competence, perceived competence, and physical activity in preschool children. J Sport Heal Sci. 2019 Mar 1;8(2):106–13.

166. de Medeirosa P, Capistranoa R, Almeida M, Aparecida S, Silva T, Cardoso F.

Exergames as a tool for the acquisition and development of motor skills and abilities: A systematic review. Rev Paul Pediatr. 2017;35:464–71.

167. Page ZE, Barrington S, Edwards J, Barnett LM. Do active video games benefit the motor skill development of non-typically developing children and adolescents: A systematic review. J Sci Med Sport. 2017 Dec 1;20(12):1087–100.

168. Joronen K, Aikasalo A, Suvitie A. Nonphysical effects of exergames on child and adolescent well-being: a comprehensive systematic review. Scand J Caring Sci. 2017 Sep 1;31(3):449–61.

169. Fu Y, Burns RD, Gomes E, Savignac A, Constantino N. Trends in sedentary behavior, physical activity, and motivation during a classroom-based active video game program. Int J Environ Res Public Health. 2019 Aug 2;16(16).

170. Andrade A, Correia CK, Coimbra DR. The Psychological Effects of Exergames for Children and Adolescents with Obesity: A Systematic Review and Meta-Analysis. Cyberpsychology, Behav Soc Netw. 2019 Nov 1;22(11):724–35.

171. Dos Santos IK, de Medeiros RC da SC, de Medeiros JA, de Almeida-Neto PF, de Sena DCS, Cobucci RN, et al. Active video games for improving mental health and physical fitness—an alternative for children and adolescents during social isolation: An overview. Int J Environ Res Public Health. 2021 Feb 2;18(4):1–13.

172. Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions [Internet]. Version 5.1.0. 2011 [cited 2020 Jun 1]. Available from: https://handbook-5-1.cochrane.org/front_page.htm

173. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ [Internet]. 2021 Mar 29;n71. Available from: https://www.bmj.com/lookup/doi/10.1136/bmj.n71

174. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al.

Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015: Elaboration and explanation. Vol. 349, BMJ (Online). BMJ Publishing Group; 2015.

175. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366.

176. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355.

177. Esparza Ros FV-CRM-JM. Protocolo internacional para la valoración antropométrica, 2019. Sociedad Internacional para el Avance de la Cineantropometría I 2019, editor. 2019. 1–154 p.

178. Gracia-Marco L, Ortega FB, Jiménez-Pavón D, Rodríguez G, Castillo MJ, Vicente-Rodríguez G, et al. Adiposity and bone health in Spanish adolescents. the HELENA study. Osteoporos Int. 2012 Mar;23(3):937–47.

179. Weber DR, Moore RH, Leonard MB, Zemel BS. Fat and lean BMI reference curves in children and adolescents and their utility in identifying excess adiposity compared with BMI and percentage body fat. Am J Clin Nutr. 2013 Jul 1;98(1):49–56.

180. Nilsson M, Ohlsson C, Mellström D, Lorentzon M. Sport-specific association between exercise loading and the density, geometry, and microstructure of weight-bearing bone in young adult men. Osteoporos Int. 2013 May;24(5):1613–22.

181. Adams JE, Engelke K, Zemel BS, Ward KA. Quantitative computer tomography in children and adolescents: The 2013 ISCD pediatric official positions. Vol. 17, Journal of Clinical Densitometry. Elsevier Inc.; 2014. p. 258–74.

182. Howley ET, Basseti DR, Welch HG. Criteria for maximal oxygen uptake: review and commentary. Med Sci Sport Exerc. 1995;1292–301.

183. Focke A, Strutzenberger G, Jekauc D, Worth A, Woll A, Schwameder H. Effects of age, sex and activity level on counter-movement jump performance in children and adolescents. Eur J Sport Sci. 2013 Sep;13(5):518–26.

184. Asmussen E, Bonde-Petersen F. Storage of Elastic Energy in Skeletal Muscles in Man. Acta physiol scand. 1974;91(3):385–92.

185. Beenakker EAC, Van Der Hoeven JH, Fock JM, Maurits NM. Reference values of maximum isometric muscle force obtained in 270 children aged 4-16 years by hand-held dynamometry. Neuromuscul Disord [Internet]. 2001;11(5):441–6. Available from: www.elsevier.com/locate/nmd

186. Esliger DW, Rowlands A V, Hurst TL, Catt M, Murray P, Eston RG. Validation of the GENEA Accelerometer. Accelerometer Med Sei Sport Exerc [Internet]. 2011;43(6):1085–93. Available from: http://www.acsm-msse.org

187. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: How many days of monitoring are needed? 2000;32(2):426–31. Available from: http://www.msse.org

188. van Hees VT, Renström F, Wright A, Gradmark A, Catt M, Chen KY, et al. Estimation of daily energy expenditure in pregnant and Non-Pregnant women using a Wrist-Worn Tri-Axial accelerometer. PLoS One. 2011;6(7).

189. Schaefer CA, Nigg CR, Hill JO, Brink LA, Browning RC. Establishing and evaluating wrist cutpoints for the GENEActiv accelerometer in youth. Med Sci Sports Exerc. 2014;46(4):826–33.

190. Romanzini M, Petroski EL, Ohara D, Dourado AC, Reichert FF. Calibration of ActiGraph GT3X, Actical and RT3 accelerometers in adolescents. Eur J Sport Sci. 2014;14(1):91–9.

191. Keytel LR, Goedecke JH, Noakes TD, Hiiloskorpi H, Laukkanen R, van der Merwe L, et al. Prediction of energy expenditure from heart rate monitoring during

submaximal exercise. J Sports Sci. 2005 Mar;23(3):289–97.

192. Achten J, Jeukendrup AE. Heart Rate Monitoring Applications and Limitations. Vol. 33, Sports Med. 2003.

193. Durkalec-Michalski K, Woåniewicz M, Bajerska J, Jeszka J. Comparison of accuracy of various non-calorimetric methods measuring energy expenditure at different intensities. Hum Mov. 2013 Jun 1;14(2):161–7.

194. Webster EK, Ulrich DA. Evaluation of the psychometric properties of the Test of Gross Motor Development-third edition. J Mot Learn Dev. 2017 Jun 1;5(1):45–58.

195. Ultrich D, Webster K. Test of Gross Motor Development - 3rd edition (TGMD-3) [Internet]. [cited 2020 Jun 1]. Available from: https://sites.google.com/a/umich.edu/tgmd-3/home

196. Ulrich DA. Test of Gross Motor Development: examiner's manual. Third Edit. Austin Tex: Pro-ED; 2019.

197. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. Arch Dis Child. 1976;51:170–9.

198. Kozieł SM, Malina RM. Modified Maturity Offset Prediction Equations: Validation in Independent Longitudinal Samples of Boys and Girls. Sport Med. 2018 Jan 1;48(1):221–36.

199. Lanfer A, Hebestreit A, Ahrens W, Krogh V, Sieri S, Lissner L, et al. Reproducibility of food consumption frequencies derived from the children's eating habits questionnaire used in the IDEFICS study. Int J Obes. 2011 Apr 1;35:S61–8.

200. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children's Eating Behaviour Questionnaire. Vol. 42, J. Child Psychol. Psychiat. 2001.

201. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The

Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011 Oct 29;343(7829).

202. Fritz CO, Morris PE, Richler JJ. Effect size estimates: Current use, calculations, and interpretation. J Exp Psychol Gen. 2012;141(1):2–18.

203. Cohen J. Statistical power analysis for the behavioral sciences. Academic press; 2013.

204. Comeras-Chueca C, Villalba-Heredia L, Pérez-Llera M, Lozano-Berges G, Marín-Puyalto J, Vicente-Rodríguez G, et al. Assessment of active video games' energy expenditure in children with overweight and obesity and differences by gender. Int J Environ Res Public Health. 2020 Sep 2;17(18):1–17.

205. Ridley K, Olds TS. Assigning energy costs to activities in children: A review and synthesis. Med Sci Sports Exerc. 2008;40(8):1439–46.

206. Smallwood SR, Morris MM, Fallows SJ, Buckley JP. Physiologic responses and energy expenditure of kinect active video game play in schoolchildren. Arch Pediatr Adolesc Med. 2012 Nov;166(11):1005–9.

207. Clevenger KA, Howe CA. Energy Cost and Enjoyment of Active Videogames in Children and Teens: Xbox 360 Kinect. Games Health J. 2015 Aug 1;4(4):318–24.

208. Graf DL, Pratt L V., Hester CN, Short KR. Playing active video games increases energy expenditure in children. Pediatrics. 2009 Aug;124(2):534–40.

209. Lanningham-Foster L, Foster RC, McCrady SK, Jensen TB, Mitre N, Levine JA. Activity-Promoting Video Games and Increased Energy Expenditure. J Pediatr. 2009 Jun;154(6):819–23.

210. Barkman J, Pfeiffer K, Diltz A, Peng W. Examining energy expenditure in youth using XBOX kinect: Differences by player mode. J Phys Act Heal. 2016;13(6):S41–3.

211. Lau PWC, Liang Y, Lau EY, Choi CR, Kim CG, Shin MS. Evaluating physical

and perceptual responses to exergames in chinese children. Int J Environ Res Public Health. 2015 Apr 13;12(4):4018–30.

212. O'Donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children with obesity and children of a healthy weight. Pediatr Obes. 2014;9(4):310–7.

213. Graves LEF, Ridgers ND, Stratton G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. Eur J Appl Physiol. 2008;104(4):617–23.

214. White K, Schofield G, Kilding AE. Energy expended by boys playing active video games. J Sci Med Sport. 2011 Mar;14(2):130–4.

215. Siegmund LA, Naylor B. JB, Santo S. AS, Barkley E. JE. The effect of a peer on VO2 and game choice in 6-10 year old children. Front Physiol. 2014;5 JUN.

216. Canabrava KLRR, Faria FR, Lima JRP d. P de, Guedes DP, Amorim PRSS. Energy Expenditure and Intensity of Active Video Games in Children and Adolescents. Res Q Exerc Sport. 2018 Jan 2;89(1):47–56.

217. Moholdt T, Weie S, Chorianopoulos K, Wang AI, Hagen K. Exergaming can be an innovative way of enjoyable high-intensity interval training. Exerc Med. 2017;3:258.

218. Quan M, Pope Z, Gao Z. Examining Young Children's Physical Activity and Sedentary Behaviors in an Exergaming Program Using Accelerometry. J Clin Med. 2018;

219. Vallabhajosula S, Holder JB, Bailey EK. Effect of Exergaming on Physiological Response and Enjoyment during Recess in Elementary School-Aged Children: A Pilot Study. Games Health J. 2016 Oct 1;5(5):325–32.

220. Verhoeven K, Abeele V Vanden, Gers B, Seghers J. Energy Expenditure During Xbox Kinect Play in Early Adolescents: The Relationship with Player Mode and

Game Enjoyment. Games Health J. 2015 Dec 1;4(6):444–51.

221. Sousa N, Mendes R, Monteiro G, Abrantes C. Progressive resistance strength training and the related injuries in older adults: The susceptibility of the shoulder. Aging Clinical and Experimental Research. 2014.

222. Hwang J, I-Min Lee, Fernandez AM, Charles HH, Lu AS, Lee I-M, et al. Exploring Energy Expenditure and Body Movement of Exergaming in Children of Different Weight Status. Pediatr Exerc Sci [Internet]. 2019 Nov;31(4):438–47. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=141454780&login.asp&lang=es&site=ehost-live

223. Goldfield GS, Adamo KB, Rutherford J, Murray M. The effects of aerobic exercise on psychosocial functioning of adolescents who are overweight or obese. J Pediatr Psychol. 2012;37(10):1136–47.

224. Maddison R, Mhurchu CN, Jull A, Prapavessis H, Foley LS, Jiang Y. Active video games: the mediating effect of aerobic fitness on body composition. Int J Behav Nutr Phys Act [Internet]. 2011;9(54). Available from: http://www.anzctr.org.au

225. Kuzik N, Carson V, Andersen LB, Sardinha LB, Grøntved A, Hansen BH, et al. Physical Activity and Sedentary Time Associations with Metabolic Health Across Weight Statuses in Children and Adolescents. Obesity. 2017 Oct 1;25(10):1762–9.

226. Santos A, Silva-Santos S, Duncan M, Lagoa MJ, Vale S, Mota J. Relationship among changes in sedentary time, physical activity, and body mass index in young schoolchildren: A 3-year longitudinal study. Pediatr Exerc Sci. 2018 Aug 1;30(3):426–32.

227. Gao Z, Zeng N, McDonough DJ, Su X. A Systematic Review of Active Video Games on Youth's Body Composition and Physical Activity. Int J Sports Med [Internet]. 2020 Aug 1;41(9):561–73. Available from:

http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=144924034&login.asp&lang=es&site=ehost-live

228. Mack I, Bayer C, Schäffeler N, Reiband N, Brölz E, Zurstiege G, et al. Chances and Limitations of Video Games in the Fight against Childhood Obesity—A Systematic Review. Eur Eat Disord Rev. 2017 Jul 1;25(4):237–67.

229. Oliveira CB, Pinto RZ, Saraiva BTCC, Tebar WR, Delfino LD, Franco MR, et al. Effects of active video games on children and adolescents: A systematic review with meta-analysis. Scand J Med Sci Sports [Internet]. 2020 Jan 1;30(1):4–12. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=140158106&login.asp&lang=es&site=ehost-live

230. Kari T. Promoting Physical Activity and Fitness with Exergames. In: Transforming Gaming and Computer Simulation Technologies across Industries. 2016.

231. Kari T. Can exergaming promote physical fitness and physical activity? Int J Gaming Comput Simulations. 2014;6:59–77.

232. Van Biljon A, Longhurst GK. The influence of exergaming on the functional fitness in overweight and obese children. Recreat Danc. 2012;18(4):984–91.

233. Bardid F, De Meester A, Tallir I, Cardon G, Lenoir M, Haerens L. Configurations of actual and perceived motor competence among children: Associations with motivation for sports and global self-worth. Hum Mov Sci. 2016 Dec 1;50:1–9.

234. De Meester A, Maes J, Stodden D, Cardon G, Goodway J, Lenoir M, et al. Identifying profiles of actual and perceived motor competence among adolescents: associations with motivation, physical activity, and sports participation. J Sports Sci. 2016 Nov 1;34(21):2027–37.

235. Engel AC, Broderick CR, van Doorn N, Hardy LL, Parmenter BJ. Exploring the Relationship Between Fundamental Motor Skill Interventions and Physical

Activity Levels in Children: A Systematic Review and Meta-analysis. Sport Med. 2018 Aug 1;48(8):1845–57.

236. Ruiz JR, Cavero-Redondo I, Ortega FB, Welk GJ, Andersen LB, Martinez-Vizcaino V. Cardiorespiratory fitness cut points to avoid cardiovascular disease risk in children and adolescents; What level of fitness should raise a red flag? A systematic review and meta-analysis. Br J Sports Med. 2016 Dec 1;50(23):1451–8.

237. Johansson L, Brissman M, Morinder G, Westerståhl M, Marcus C. Reference values and secular trends for cardiorespiratory fitness in children and adolescents with obesity. Acta Paediatr Int J Paediatr. 2020 Aug 1;109(8):1665–71.

238. Fraser BJ, Rollo S, Sampson M, Magnussen CG, Lang JJ, Tremblay MS, et al. Health-Related Criterion-Referenced Cut-Points for Musculoskeletal Fitness Among Youth: A Systematic Review. Sport Med. 2021 Dec 1;51(12):2629–46.

239. Iannotti RJ, Claytor RP, Horn TS, Chen R. Heart rate monitoring as a measure of physical activity in children. Med Sci Sports Exerc. 2004 Nov;36(11):1964–71.

11. Apéndice

11.1 Características de las revistas [Journal characteristics]

Factor de impacto y clasificación de cada revista en el "*ISI Web of Knowledge – Journal Citation Reports"* dentro de sus áreas correspondientes.

[*Impact factor and ranking of each journal in "ISI Web of Knowledge – Journal Citation Reports" within their subject categories.]*

Artículos publicados [Published manuscripts]

Artículo *[Manuscript]*	Revista *[Journal]*	Factor de impacto *[Impact factor]*
I, III, IV	International Journal of Environmental Research and Public Health JCR 2021 (Public, environmental & occupational health - Social Sciences Citation Index): 45/182 – Q1	**4.614**
II, V	JMIR Serious Games JCR 2021 (Public, environmental & occupational health - Science Citation Index Expanded): 103/210 – Q2	**3,364**

11.2 Contribución de la doctoranda en el proyecto EXERGAMES

El proyecto de VIDEOACTIVO se puso en marcha justo con la contratación de la doctoranda, por lo que ha podido participar en cada una de las fases de desarrollo del proyecto, tanto en la preparación del proyecto con el reclutamiento y la preparación de los materiales y las sedes donde se realizaró la intervención, como en el desarrollo de las valoraciones y de la intervención, con la posterior exportación de datos y creación de la base de datos para la difusión de los resultados. No obstante, cabe destacar que el grupo de investigación llevaba trabajando un par de años previamente con VJA, desarrollando el proyecto piloto en un colegio de Utebo (Zaragoza) en el que se entrenó a 8 niños con sobrepeso u obesidad de 9 a 11 años durante cinco meses con la Nintendo Wii ®, y encontrando mejoras significativas en la masa libre de grasa, la dinamometría de brazo derecho, el porcentaje de grasa, y en la densidad mineral ósea y contenido mineral óseo.

Las diferentes tareas de la doctoranda incluyeron la adquisición de los materiales para el desarrollo de la intervención, adecuación de los espacios de las dos sedes (Pabellón universitario en el Campus Plaza San Francisco y el Colegio Público San Braulio), reclutamiento tanto en el primer como en el segundo año de proyecto contactando con las familias facilitadas desde los hospitales y centros médicos, realización de las reuniones informativas en colegios y centros médicos, reuniones informativas a los participantes potenciales, planificación y desarrollo de las sesiones de intervención con VJA, dinamización de las sesiones, la planificación de diferentes pruebas o mediciones a realizar tanto en la evaluación inicial como en el resto de evaluaciones, la recogida y exportación de datos, la confección de las bases de datos incluyendo hasta cuatro evaluaciones, y el análisis de los datos obtenidos. Una vez obtenidos los datos de las mediciones, la doctoranda confeccionó la base de datos y verificó la ausencia de errores de manera previa al comienzo de los diferentes análisis llevados a cabo. A partir de dichos análisis, se han elaborado diferentes artículos que componen parte de la presente Tesis Doctoral. Las tareas de divulgación en congresos y la realización de publicaciones científicas también ha sido otra de las contribuciones de la doctoranda.

12. Agradecimientos

Esta Tesis Doctoral es fruto de más de 4 años de trabajo como investigadora predoctoral en el Grupo GENUD de la Universidad de Zaragoza, y durante el camino tuve la suerte de rodearme de personas que me acompañaron y me apoyaron. Todas ellas forman parte de esta tesis también, y es que, sin mis directores de tesis, sin mis compañeros, y sin mi familia y amigos, nada de esto hubiera sido posible. No es una forma de hablar o algo que quede bonito decir, siempre me he sentido arropada y he tenido ayuda cuando la he necesitado, y no solo me refiero a la ayuda en el ámbito académico, que también, sino que formáis parte de esta tesis a nivel personal, compartiendo momentos buenos, disfrutando y celebrando, pero también apoyando en momentos malos, escuchando y aconsejando.

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Desde la primera clase también noté un creciente interés por la investigación y por documentarme para adquirir conocimientos respaldados por investigación científica. Nos enseñaste materia, pero sobre todo nos diste las herramientas para poder aprender en base a la investigación científica.

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also laughing and having coffees that were the best medicine. Thank you for all you have done for me and for helping me to get used to a new country. I have learned so many things from you that helped my professional and personal development. You are a brilliant researcher and you will achieve whatever you propose.

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afrontar obstáculos y si tienes miedo de intentar algo, enseñarme a intentarlo con miedo. Quiero agradecer especialmente a ***David*** todo su apoyo, su ayuda y todo lo que ha hecho por mí. Gracias por transmitirme ese espíritu luchador y de superación y por enseñarme a afrontar los problemas de una mejor manera y con más calma. Te "aguanté" el ritmo en el primer entreno y te lo voy a intentar aguantar en todos los que nos quedan.

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13. Material suplementario incluido en los artículos de la Tesis Doctoral

13.1 MATERIAL SUPLEMENTARIO ARTÍCULO 1

Table S1: PRISMA 2020 item Checklist

Section and topic	Item #	Checklist item	Location where item is reported
Title			
Title	1	Identify the report as a systematic review.	**1**
Abstract			
Abstract	2		**1 and 2**
Introduction			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	**3 and 4**
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	**4**
Methods			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	**5**
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	**4**
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	**4**
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	**5**
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	**5**
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	**6**
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	**6**
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	**5**
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	**6**
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	**6**
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	**6**
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	**6**
	13d	Describe any methods used to synthesise results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	**6**
	13e	Describe any methods used to explore possible causes of heterogeneity among	**6**

		study results (e.g. subgroup analysis, meta- regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesised results.	**NS**
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	**NS**
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	**6**
Results			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram (see fig 1).	**6 and 7**
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	**NS**
Study characteristics	17	Cite each included study and present its characteristics.	**9 to 17**
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	**7 and 8**
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	**8 to 15**
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	**7, 8 and 16**
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	**16 to 24**
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	**17 to 24**
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesised results.	**NS**
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	**NS**
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	**NS**
Discussion			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	**17 to 24**
	23b	Discuss any limitations of the evidence included in the review.	**17 to 24**
	23c	Discuss any limitations of the review processes used.	**25**
	23d	Discuss implications of the results for practice, policy, and future research.	**25 and 26**
Other information			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	**4**
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	**NS**
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	**NS**
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	**26**
Competing interests	26	Declare any competing interests of review authors.	**26**
Availability of data, code, and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	**NS**

Table S2: Descriptive characteristics of included non-controlled trials

Study	Participants		Intervention	Training	Variables and test used	Outcomes
	N	Years				
Argarini et al., 2020 [67]	n= 17 male (7) female (10)	8.30 ± 1.55	Xbox Kinect	Period: 4 weeks Frequency: 3 sessions per week Duration: 30-40 min[i] per session	Body weight BMI[c] %BF[a] (Skin thickness) MC[g] (catch, vertical jump and kick)	A significant improvement in vertical jump was observed. There was also significant decline on body weight, BMI, and %BF.
Huang et al., 2017 [63]	n= 10 male (8) female (2)	8.0 ± 1.8	Nintendo Wii and Xbox Kinect	Period: 8 weeks Frequency: two sessions per week Duration: 60 min per session	BMI %BF MF[h] (one-minute half sit-up test and handheld dynamometer: quadriceps in seated position and hamstrings prone position) CRF[d] (20-m shuttle run test) Flexibility (sit and reach)	There were improvements in quadriceps muscle strength, muscle endurance test (sit-ups) and flexibility. The body composition showed a slight improvement during the midterm of the program, but the effect was not maintained throughout the program. There was no significant change on hamstring muscle strength and CRF.
Duman et al., 2016 [63]	n= 50 male (21) female (29)	12.16 ± 0.99	TE[J]+AVG[b]: Callisthenic and aerobic exercises for 20 min + AVG for 25 minutes	Period: 8 weeks Frequency: 3 days per week	BMI FM[f] (triceps skinfold thickness) Waist circumference CRF MF (50-m run, squats in 120 seconds, time up and down 20 stairs and jumps over a rope in 30 seconds)	TE+AVG showed decreases in BMI, FM and waist circumference; TE+AVG showed higher CRF and MF (performance in all tests)
Calcaterra et al., 2013 [65]	n= 22 male (13) female (9)	13.23 ± 1.76	EXE[e]+AVG: a combination of circuit-based aerobics, strength and resistance exercises with interactive video game exercises	Period: 12 weeks Frequency: twice a week Duration: 90 min per session	BMI Waist circumference %BF (bioelectrical impedance) CRF (during a submaximal	BMI, waist circumference and %BF decreased significantly; CRF and MF improved significantly.

					treadmill test) MF (Hand-grip dynamometry)	
Christison et al., 2012 [66]	n= 40 male (26) female (22)	11.2 ± 2.2	DDR; Exerbike XG ; Nintendo Wii; Makoto Interactive Arena; Lightspace Play Floor; Cybex Trazer; Treadwall; Xavix system	Period: 10 weeks Frequency: 2h per week	BMI	BMI and BMI z-score decreased significantly

[a]%BF: body fat percentage, [b]AVG: active video game, [c]BMI: body mass index, [d]CRF: cardiorespiratory fitness, [e]EXE: exercise, [f]FM: fat mass, [g]MC: motor competence, [h]MF: musculoskeletal fitness, [i]min: minutes, [j]TE: traditional exercise.

Table 1: Quality assessment of randomized controlled trials.

Study	Bias arising from the randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Irandoust et al (2020) [62]	+	+	+	+	+	+
Bonney et al (2019) [61]	+	+	+	+	+	+
Staiano et al (2018) [54]	+	+	+	+	+	+
Staiano et al (2017) [52]	+	+	+	+	+	+
Christison et al (2016) [42]	?	+	?	+	+	+
Foley et al (2014) [44]	+	+	+	+	+	+
Trost et al (2014) [55]	?	+	?	+	+	+

Staiano et al (2013) [56]	+	+	?	+	+	+
Maloney et al (2012) [57]	+	+	+	+	+	+
Goldfield et al (2012) [60]	+	+	?	+	+	+
Maddison et al (2011) [51]	+	+	+	+	+	+
Maddison et al (2011) [59]	+	+	+	+	+	+
Adamo et al (2010) [58]	+	+	+	+	+	+

Table 2: Descriptive characteristics of included studies with overweight and obese children.

Study	Participants			Study design	Intervention	Control	Training	Variables and test used	Outcomes
	Population, N	Sex	Age (years)						
Irandoust et al (2020) [62]	59	Male (n=59)	Primary school (6-11 years)	RCT[a]	Nintendo Wii and Xbox Kinect (n=21; mean 8.9, SD 1.2 years)	CG[b] 1: aquatic exercise intervention (n=18; mean 9.3, SD 1.3 years); CG 2: no intervention (n=20; mean 8.95, SD 1.2 years)	Period: 12 weeks; frequency: 3 days per week; duration: 60 min per session	Weight and BMI	AVG[c] and CG 1 observed decreased weight and BMI compared with CG 2.
Bonney et al.(2019) [61]	52	Female (n=52)	13-16 years	RCT	Wii Fit (n=26)	Task-oriented functional training (n=26)	Period: 14 weeks; frequency: once a week; duration: 45 min per session	CRF[d] (20-min shuttle run test); MF[e] (knee extensors, ankle plantar flexors isometric strength with a handheld dynamometer); and MC[f] (Movement ABC-2[g])	Both AVG and CG demonstrated significant improvement in CRF, MF, and MC. No between-group differences were observed.
Staiano et al (2018) [54]	45	Male (54%); female (46%)	Mean 11.2, SD 0.8 years	RCT	Xbox Kinect (n=22)	No intervention (n=23)	Period: 24 weeks; frequency: 3 days per week; duration: 60 min per session	BMI; %BF[h]; and FM[i] (DXA[j])	Positive effects were observed on BMI z-score and weight z-score for AVG but not on FM and %BF.
Staiano et al (2017) [52]	41	Female (n=41)	14-18 years	RCT	Xbox Kinect (n=22; mean 15.3, SD 1.2 years)	No intervention (n=19; mean 16.1, SD 1.4 years)	Period: 12 weeks; frequency: 60 min per week	BMI; WC[k]; and FM and %BF (DXA)	No effects on BMI, WC, FM, and %BF were observed.
Christison et al	80	Male (n=34);	Mean 10.1, SD 1.3 years	RCT	Nintendo Wii, DDR[l], Exerbike	No intervention (only didactic session; n=21)	Period: 10 weeks;	BMI; WC; and CRF (20-min shuttle run)	No effects of intervention on BMI, WC, and

(2016) [42]		female (n=46)			XG, Makoto interactive Arena, Lightspace Pay floor, Cybex Trazer, and Zavix system (n=59)		frequency: 2 hours per week		CRF were observed.
Foley et al (2014) [44]	322	Male (n=235); female (n=87)	Mean 11.6, SD 1.1 years	RCT	EyeToy (PlayStation; n=160)	No intervention (n=162)	Period: 12 weeks and 24 weeks; children were encouraged to meet the recommendations of 60 min per day and to substitute periods of traditional inactive video games	BMI; FM; and %BF (bioelectrical impedance)	Positive effects on BMI, z-score BMI, and %BF for AVG were observed.
Trost et al (2014) [55]	69	Male (n=24); female (n=41)	Mean 10.0, SD 1.7 years	RCT	CPWMP[m] with AVG with Xbox Kinect (n=31)	CPWMP only (n=38)	Period: 8 weeks and 16 weeks; frequency and duration: nonreported	BMI and BMI z-score	Groups with AVG showed higher decreases in BMI, BMI z-score, and overweight rate than CG.
Staiano et al (2013) [56]	54	Male (44.4%); female (55.6%)	15-19 years	RCT	Competitive AVG with Nintendo Wii (n=19); co-operative AVG with Nintendo Wii (n=19)	No intervention (n=16)	Period: 10 weeks and 20 weeks; frequency: 30-60 min per school day	Weight	Participants in co-operative AVG lost more weight than CG; competitive AVG also lost weight.
Maloney et al (2012) [57]	65	Male (n=31); female (n=34)	9-17 years	RCT	DDR (n=32; mean 12.9, SD 2.36 years)	No intervention (n=33; mean 11.73, SD 2.38 years)	Period: 12 weeks; frequency and duration: nonreported	Weight and CRF (3-min step test)	No effects on weight and CRF were observed.
Van Biljon et al (2012) [50]	31	Male and female	9-12 years	Non-RCT	Nintendo Wii (n=11)	CG1: with access to sedentary video games (n=10); CG2: no intervention (n=10)	Period: 6 weeks; frequency: 3 days per week; duration: 30 min per session	MC (Bruininks-Oseretsky Test)	Improvements in MC for AVG compared with both CGs were observed.
Wagener et al (2012) [53]	40	Male (n=31; female (n=34)	Mean 14, SD 1.66 years	Non-RCT	Dance-based exergaming (n=21)	No intervention (n=19)	Period: 10 weeks; frequency: 3 days per week; duration: 40 min per session	BMI z-score	No changes in BMI z-score were observed.
Goldfield et al (2012) [60]	26	Male (n=12; female (n=14)	12-17 years	RCT	Interactive video game cycling intervention	Exercise: stationary bike music intervention (n=13;	Period: 10 weeks; frequency: twice per week;	BMI; %BF and FFM[n] (bioelectrical impedance); and	AVG and CG showed improvements in CRF and %BF;

					(Gamebike; n=13; mean 15.1, SD 1.8 years)	mean 13.9, SD 1.4 years)	duration: 60 min per session	CRF (submaximal aerobic fitness with a cycle ergometer)	no group by time effects on body weight, BMI, FM, FFM, %BF, or CRF; psychological benefits of these aerobic exercise were related to improved aerobic fitness but not to changes in body composition.
Maddison et al (2011) [59]	322	Male (n=235); female (n=87)	Mean 11.6, SD 1.1 years	RCT	EyeToy (PlayStation; n=160)	No intervention (n=162)	Period: 12 weeks and 24 weeks; children were encouraged to meet 60 min per day and to substitute periods	BMI; %BF (bioelectrical impedance); and CRF (20-min shuttle test)	AVG positively affected %BF. This effect was most likely mediated through improved CRF.
							of traditional inactive video games		
Maddison et al (2011) [51]	322	Male (n=235); female (n=87)	Mean 11.6, SD 1.1 years	RCT	EyeToy (PlayStation; n=160)	No intervention (n=162)	Period: 12 weeks and 24 weeks; children were encouraged to meet the recommendations of 60 min per day and to substitute periods of traditional inactive videogame	BMI; WC; %BF (bioelectrical impedance); and CRF (20-min shuttle test)	Positive effect on BMI, BMI z-score, FM, and %BF was observed, favoring AVG.
Adamo et al (2010) [58]	26	Male and female	12-17 years	RCT	Interactive video game cycling intervention (n=13; mean	Exercise: stationary bike music intervention (n=13; mean 13.9, SD 1.4 years)	Period: 10 weeks; frequency: twice per week; duration: 60 min per session	BMI; %BF and FFM (bioelectrical impedance); WC; and CRF (submaximal	AVG and CG showed improvements in CRF; no group by time effects on body weight,
					15.1, SD 1.8 years)			aerobic fitness with a cycle ergometer)	BMI, FM, FFM, %BF, or CRF; positive time effects were found on %BF when both AVG and CG were combined and compared at baseline.

[a]RCT: randomized controlled trial.
[b]CG: control group.
[c]AVG: active video game.
[d]CRF: cardiorespiratory fitness.
[e]MF: musculoskeletal fitness.
[f]MC: motor competence.
[g]Movement ABC-2: Movement Assessment Battery for Children-Second Edition.
[h]%BF: body fat percentage.
[i]FM: fat mass.
[j]DXA: dual-energy x-ray absorptiometry.
[k]WC: waist circumference.
[l]DDR: Dance Dance Revolution.
[m]CPWMP: Comprehensive Pediatric Weight Management Program.
[n]FFM: fat-free mass.

13.2 MATERIAL SUPLEMENTARIO ARTÍCULO 2

Supplementary 1: PRISMA 2020 item Checklist

Section and topic	Item #	Checklist item	Location where item is reported
Title			
Title	1	Identify the report as a systematic review.	**1**
Abstract			
Abstract	2		**1**
Introduction			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	**2 and 3**
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	**3**
Methods			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	**4**
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	**3**
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	**3**
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	**4**
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	**3 and 4**
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	**5**
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	**5**
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	**5**
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	**5 and 6**
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	**5**
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	**5 and 6**
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	**5**
	13d	Describe any methods used to synthesise results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	**5 and 6**
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta- regression).	**5 and 6**
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesised results.	**NS**
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	**NS**
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	**6**
Results			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram (see fig 1).	**5 and 8**
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	**NS**
Study characteristics	17	Cite each included study and present its characteristics.	**8 to 12**
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	**6 and 7**
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	**6 to 12**
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	**6 to 8**
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	**12 to 18**
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	**12 to 18**
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesised results.	**NS**
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	**NS**
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	**NS**
Discussion			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	**13 to 18**
	23b	Discuss any limitations of the evidence included in the review.	**13 to 18**

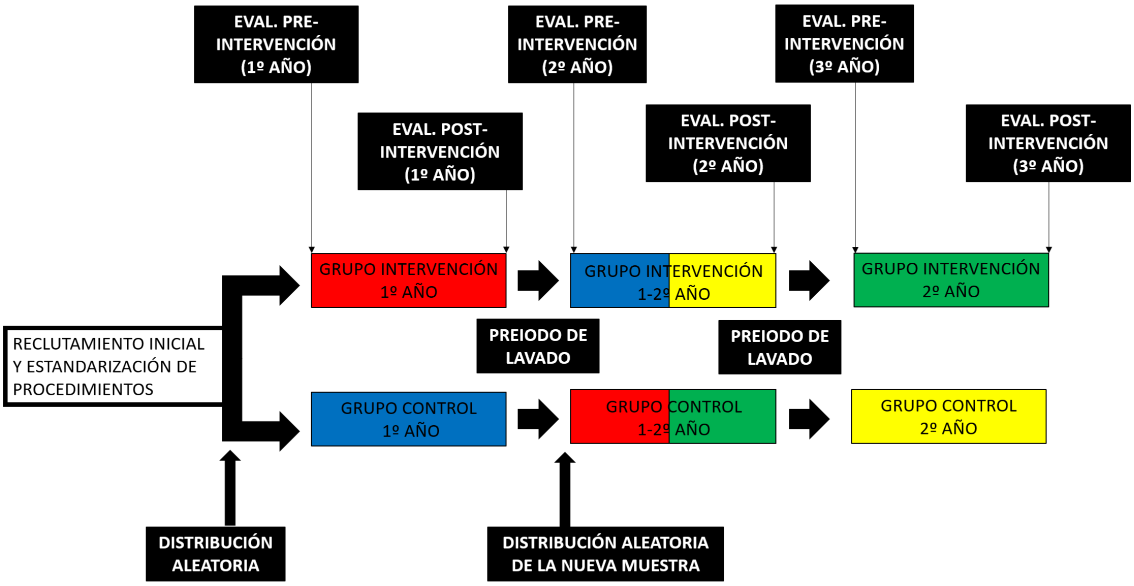
	23c	Discuss any limitations of the review processes used.	**19**
	23d	Discuss implications of the results for practice, policy, and future research.	**19**
Other information			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	**3**
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	**NS**
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	**NS**
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	**20**
Competing interests	26	Declare any competing interests of review authors.	**20**
Availability of data, code, and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	**NS**

Supplementary 2: Descriptive characteristics of included non-controlled trials

Ref.	Study	Participants		Intervention	Training	Variables and test used	Outcomes
		N	Years				
72	George et al., 2016	n= 15 male (7) female(8)	7.9 ± 2.12	Nintendo Wii	Period: 6 weeks Frequency: 2 days per week Duration: 20 min minimum per session	CRF (6-min walk test in meters) MSC (Movement Assessment Battery for Children)	AVG showed significant improvements in some tests of MSC but no significant changes in CRF
73	Gao et al., 2016	n= 95 male (57) female (38)	10.31 ± 0.53 years	Xbox Kinect Nintendo Wii	Period: 6 weeks Frequency: once a week Duration: 50 min per day	CRF (Half-mile run test)	AVG showed no significant effects on CRF.
78	Smits-Engelsman et al., 2016	n= 18 (+ n=17 with motor coordination difficulties) male and female	8.0 ± 1.2	Nintendo Wii	Period: 5 weeks Frequency: 5 days per week Duration: 20 min minimum per session	MF (long jump, lateral step-up, sit to stand and stair climbing) Anaerobic fitness (10x5-m sprint and 10x5-m slalom) MSC (Bruininks-Oseretsky Test-2)	AVG showed improvements in MF, AF and MSC except for stair climbing test and balance
64	Bethea et al., 2012	n= 28 male and female	9.9 ± 0.7	DDR	Period: 12 and 30 weeks Frequency: 3 days per week Duration: 30 min per session	BMI %BF CRF (20-m shuttle run test)	AVG improved CRF, but no significant effects were found in BMI, although there were decreases in BMI and BMI z-score
63	Owens et al., 2011	n= 12 (and 9 adults) male and female	10 ± 1.6	Nintendo Wii Fit	Period: 3 months Home-use	BMI %BF (bioelectrical impedance) MF (push-up test) CRF (in treadmill using the Bruce Ramp Protocol)	AVG showed improvements in CRF but no significant effects were found in BMI, %BF and MF.

14. Anexos

14.1 Anexo 1. Diseño del estudio inicialmente planificado



14.2 Anexo 2. Dictamen del Comité de Ética de Investigación

GOBIERNO DE ARAGON
Departamento de Sanidad

Informe Dictamen Favorable
Proyecto Investigación Biomédica
C.P. - C.I. PI18/106
06 de junio de 2018

Dña. María González Hinjos, Secretaria del CEIC Aragón (CEICA)

CERTIFICA

1º. Que el CEIC Aragón (CEICA) en su reunión del día 06/06/2018, Acta Nº 11/2018 ha evaluado la propuesta del investigador referida al estudio:

Título: Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva

Investigador Principal: José Antonio Casajús Mallén, Universidad de Zaragoza

Versión protocolo: Versión 2.0
Documento de información y consentimiento Padres: Versión 2.0
Documento de información y consentimiento hijos: versión 1.0

2º. Considera que

- El proyecto se plantea siguiendo los requisitos de la Ley 14/2007, de 3 de julio, de Investigación Biomédica y su realización es pertinente.
- Se cumplen los requisitos necesarios de idoneidad del protocolo en relación con los objetivos del estudio y están justificados los riesgos y molestias previsibles para el sujeto.
- Es adecuado el tratamiento de los datos y los documentos dirigidos a obtener el consentimiento de los participantes.
- El alcance de las compensaciones económicas previstas no interfiere con el respeto a los postulados éticos.
- La capacidad de los Investigadores y los medios disponibles son apropiados para llevar a cabo el estudio.

3º. Por lo que este CEIC emite **DICTAMEN FAVORABLE a la realización del proyecto**.

Lo que firmo en Zaragoza

GONZALEZ HINJOS MARIA - DNI 03857456B
Firmado digitalmente por GONZALEZ HINJOS MARIA - DNI 03857456B
Fecha: 2018.06.11 10:11:54 +02'00'

María González Hinjos
Secretaria del CEIC Aragón (CEICA)

Página 1 de 1

Tel. 976 71 5836 Fax. 976 71 55 54 Correo electrónico mgonzalezh.ceic@aragon.es

14.3 Anexo 3. Consentimiento informado

HOJA DE INFORMACIÓN PARA PADRES/MADRES/TUTORES:
"Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva."

Por la presente, se le **invita** a usted y a su hijo/a a participar en este estudio. Se trata de un **estudio de investigación**, lo que supone que se va a llevar a cabo por primera vez un tipo de intervención que puede tener beneficios para el tratamiento de algunos factores de riesgo de síndrome metabólico.

Información de utilidad:

1. *Objetivos del estudio*
   a. Evaluar la efectividad de un programa de videojuegos activos sobre los **factores de riesgo cardiometabólico**, en niños y niñas con sobrepeso/obesidad.
   b. Estudiar la **adherencia a la practica de actividad física** y los cambios en parámetros de hábitos saludables.

2. *Beneficios derivados del estudio*

Si usted decide que su hijo/a participe en este estudio, recibirá completa información sobre su composición corporal (porcentaje de grasa corporal), y también se le entregará un informe con las determinaciones sanguíneas (perfil lipídico entre otras). Además, su hijo/a recibirá una intervención de 9 meses de duración con videojuegos activos (explicada en detalle en la siguiente página).

3. *Posibles acontecimientos adversos*

No se prevé ningún acontecimiento adverso, más allá de los propios de la actividad física. De manera **poco probable**, durante la realización de las pruebas y los entrenamientos, podría ocurrir dolor muscular (tipo agujetas), caídas, contusiones o procesos más graves como desmayos.

4. *Voluntariedad*

El participante lo hace de forma voluntaria, pudiéndose retirar del estudio en cualquier momento, habiendo sido informado explícitamente de la finalidad del mismo. Esto no conllevará ningún tipo de discriminación ni consecuencias.

5. *Anonimato*

Los datos obtenidos en el estudio pertenecen tan solo a la persona voluntaria y al entorno investigador, manteniéndose siempre la más estricta confidencialidad. El participante decidirá si quiere conocer o no los datos de la investigación y será informado, si así lo desea, de los resultados durante el proceso. Al finalizar el estudio, usted obtendrá un informe detallado de los principales resultados obtenidos.

6. *Hallazgos inesperados*

En el caso de encontrar algún hallazgo inesperado durante la realización de las pruebas, o en los análisis posteriores se procederá a contactar con el

Hoja informativa versión 2.0

-1-

padre, madre o tutor directamente e informarle de lo encontrado, para que contacte con su médico pediatra correspondiente.

7. *Mediciones*

Las siguientes **mediciones** se realizarán en cuatro ocasiones a todos los participantes, durante desarrollo del proyecto; concretamente en septiembre/octubre 2018; mayo/junio 2019; septiembre/octubre 2019 y mayo/junio 2020.

En el laboratorio del grupo GENUD de la Universidad de Zaragoza:

1. Peso, altura y perímetro de cintura, y valoración de la composición corporal: (masa grasa, magra y ósea) mediante absorciometría fotónica dual de rayos X (DXA). La cantidad de radiación que recibirá durante esa evaluación de rayos X es mínima, y sería comparable con la recibida por un viaje en avión de unas 3 horas.
2. Maduración sexual: Un médico experimentado valorará el estadío Tanner de cada participante.
3. Prueba de esfuerzo: Se evaluará la resistencia cardiorrespiratoria mediante un test progresivo continuo hasta el agotamiento que consistirá en correr sobre una cinta rodante. La prueba se controlará en todo momento electrocardiográficamente y con análisis de gases.
4. Fuerza muscular isométrica: se utilizarán una galga extensiométrica y un dinamómetro manual para calcular la fuerza del cuádriceps y presión manual respectivamente del participante (dos repeticiones). Este test pretende medir la fuerza de la pierna y la mano.
5. Salto sobre plataforma de fuerzas: el participante tendrá que realizar varios saltos verticales sobre una plataforma en el suelo. Este test pretende medir la fuerza del tren inferior.
6. Se evaluará la presión arterial con un tensiómetro.
7. Se evaluarán los niveles de actividad física mediante el uso de acelerómetros, prestados durante una semana.
8. Se evaluará la dieta mediante cuestionarios de recuerdo 24h en los que se debe recordar todo lo que se ha comido el día anterior.

En su Centro de Salud habitual:

9. Se tomarán muestras sanguíneas (3 tubos de 5mL) en ayunas para evaluar el perfil lipídico, férrico, y otros parámetros relacionados con la obesidad.

Aleatorización

Después de la primera evaluación los participantes se dividirán en 2 grupos aleatorios: Ejercicio y Control. Ambos grupos tendrán la oportunidad de acudir a varias sesiones de educación en estilos de vida saludable. Además, el grupo ejercicio realizará el programa de intervención. Al cabo del primer año, los grupos se permutarán y el grupo Control pasará a realizar la intervención.

Programa de intervención
La idea de esta intervención es que niños/as que no son muy propensos/as a la practica deportiva, realicen actividad física de manera entretenida con el objetivo de aumentar su gasto calórico e incrementar su interés por la practica de actividad física. La actividad tendrá lugar en dos ubicaciones diferentes en Zaragoza (por determinar) con una duración total de 9 meses, y una frecuencia de 3 sesiones por semana (alrededor de 45-60 minutos por sesión), en diferentes horarios. Los niños/as jugarán con videojuegos activos (tipo Wii U o ciclismo virtual) y tendrán entrenadores con ellos indicando que corresponde hacer cada día, y controlando la correcta ejecución de cada sesión. La intensidad será controlada de manera individualizada.

Para más información acerca de las pruebas pueden contactar directamente con los investigadores principales:

Dr. José Antonio Casajús y **Alejandro González de Agüero**
Profesores de la Universidad de Zaragoza
E-mail: joseant@unizar.es y alexgonz@unizar.es

HOJA DE CONSENTIMIENTO PARA PADRES/MADRES/TUTORES:
"Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva."

D./Dña. .... con DNI…………….…………. teléfono de contacto ……………………………………….. como madre/padre/tutor *(tachar lo que no proceda)* de ……………………………………… …………………………...…… con fecha de nacimiento …………/…………..…………/………..… declaro que:

☐ He leído y comprendo la información que se me ha entregado.

☐ Comprendo que la participación es voluntaria.

☐ Comprendo que mi hijo/a se puede retirar del estudio:
1. Cuando quiera.
2. Sin tener que dar explicaciones.
3. Sin que esto repercuta en los cuidados médicos caso de enfermedad o lesión derivadas del estudio.

☐ Deseo ser informado de datos de los resultados obtenidos y otros de carácter personal que se obtengan en el curso de la investigación, incluidos los descubrimientos inesperados que se puedan producir, siempre que esta información sea necesaria para evitar un grave perjuicio para mi salud o la de mis familiares biológicos.

Se me ha informado que todos los datos obtenidos en este estudio serán confidenciales y se trataran conforme establece la Ley Orgánica de Protección de Datos de carácter personal 15/99. Todas las muestras serán anonimizadas con un código numérico. Se me ha informado de que la donación/información recibida solo se utilizara para los fines específicos del estudio.

Y por tanto, presto libremente mi **conformidad** para que mi hijo/a pueda participar en el estudio.

Firma del padre/madre o tutor/tutora   Fecha y lugar
(tachar lo que no proceda)

El investigador principal, en nombre de todo el equipo investigador, agradece enormemente su desinteresada participación en este estudio, y espera que su intervención termine de manera satisfactoria para usted y su hijo/a.

Reciba un cordial saludo,

José Antonio Casajús Mallén

HOJA DE INFORMACIÓN PARA NIÑOS/NIÑAS:
"Videojuegos activos frente la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva"

<u>Información del proyecto:</u>

Nos ponemos en contacto contigo para invitarte a participar en nuestro proyecto de investigación.

Para nosotros es muy importante que participes porque en estos últimos años el sedentarismo (estar sentado o tumbado mucho tiempo) esta siendo un problema común que afecta a la salud de los niños y niñas de tu edad. Por eso lo que queremos en nuestro proyecto es comprobar si realizar una serie de actividades con videojuegos todas las semanas durante varios meses puede beneficiar y prevenir esos problemas en niños/as como tu.

Pero antes de decidir si vas a participar o no tienes que leer y entender este documento entero, y después puedes hacer todas las preguntas que quieras antes de firmarlo si finalmente decides participar.

<u>Participar en el proyecto:</u>

Tu decides si quieres participar en el proyecto. No pasa nada si no quieres participar, es un proyecto voluntario y no habrá ninguna desventaja para ti si no quieres participar. Al ser un proyecto de libre participación, podrás abandonar si así lo deseas en cualquier momento del estudio, incluso después de haber entregado el consentimiento firmado, o incluso con alguna prueba ya realizada. Además de tener tu consentimiento, también necesitaremos la aceptación de tus padres en la participación de este proyecto. A pesar de que tus padres puedan estar de acuerdo, tú eres libre de participar o no.

<u>¿Qué pruebas te vamos a hacer? (Evaluación):</u>

Como parte del estudio, te pediremos que participes en las siguientes pruebas:

-Unas pruebas médicas básicas, que incluirán medidas sencillas como la altura, el peso y el perímetro de cintura.

- Estudiaremos la composición corporal (cantidad de hueso, grasa y músculo) total que tenéis, mediante absorciometría

Versión 1.0

fotónica dual de rayos X (DXA). La prueba consiste en estar tumbado en una camilla unos 10 minutos aproximadamente.
-Un médico comprobará como de desarrollado te encuentras a nivel madurativo.
-Una prueba de esfuerzo en la que tendrás que correr sobre una cinta rodante hasta que no puedas más y te canses.
-Unas pruebas de fuerza de manos (apretar todo lo fuerte que puedas un aparato) y de piernas (estirar todo lo que puedas de un cable y también saltos).
-Se obtendrán muestras de sangre para evaluar varios parámetros relacionados con la obesidad, solo si tú estás de acuerdo.
-Se evaluará la presión arterial.
-Llevar un acelerómetro (un aparato del tamaño de una caja de cerillas colocado en un cinturón a la altura de la cintura) durante unos días que nos ayudará a registrar la actividad física que realizáis.
-Responder sencillas preguntas para registrar todos los alimentos que has comido el día anterior.

El número de evaluaciones que realizaremos serán 4. La primera en Sept/Oct 2017, la segunda en Mayo/Jun 2018, la tercera en Sept/Oct 2018, y la cuarta en Mayo/Jun 2019.

Las pruebas se llevarán a cabo en la sede del grupo GENUD de la Universidad de Zaragoza encargado de la investigación. Deberéis acudir a la dirección C/Pedro Cerbuna nº12, cp:50009, Zaragoza, España. Para la realización de las mismas deberéis llevar ropa interior deportiva para la primera parte, y ropa deportiva para la segunda.

Tu información será confidencial (privada):

Los resultados obtenidos son para uso exclusivo de la investigación. Las pruebas físicas, como por ejemplo las medidas corporales (peso o talla) o las muestras de sangre, podrían informarnos de tu estado de salud. Si tú y tus padres estáis de acuerdo, se os informará de cualquier anomalía que detectemos. Las respuestas que des a las preguntas de los cuestionarios son totalmente privadas. Tu decides si quieres conocer los resultados o no.

Formación de grupos y programa de actividades:

Versión 1.0

Después de la primera evaluación haremos 2 grupos con todos los niños y niñas que queráis participar en el proyecto. A los 2 grupos se os volverá a evaluar con las pruebas y en las fechas que antes os hemos dicho, y se os darán talleres educativos en estilos de vida saludable. Además se harán 3-4 sesiones de videojuegos semanales de unos 30-45 minutos (Wii U, ciclismo virtual, realidad virtual…), pero por grupos (durante unos meses el primer grupo, y los meses siguientes el otro grupo).

Si tienes cualquier duda o consulta acerca del proyecto o sobre lo que tendrás que hacer, por favor comunícanoslo y te informaremos de la mejor manera posible.
Nuestros datos de contacto son:

Dr. José Antonio Casajús Mallén y Alejandro González de Agüero
Universidad de Zaragoza
E-mail: joseant@unizar.es y alexgonz@unizar.es

HOJA DE CONSENTIMIENTO INFORMADO PARA NIÑOS/NIÑAS:
“Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva”

Con la firma de este documento, acepto la participación en el estudio arriba descrito

Yo,
……
………………………………. (Nombre y apellidos del participante).

Dirección:
……
…………………………………

Teléfonos de contacto:
……
………………………..

He leído la hoja de información que se me ha entregado.
He podido hacer preguntas sobre el estudio y he recibido suficiente información sobre el mismo.
He hablado con José Antonio Casajús o con Alejando González de Agüero (E-mail: joseant@unizar.es o alexgonz@unizar.es).
Comprendo que la participación es voluntaria.
Comprendo que podemos retirarnos cuando queramos, sin tener que dar explicaciones y sin que esto tenga consecuencias en mis cuidados médicos.

Versión 1.0

Deseo ser informado sobre los resultados del estudio: SI / NO (marque lo que proceda).
Acepto que las muestras derivadas de este estudio puedan ser utilizadas en futuras investigaciones (relacionadas con ésta).
Se me ha informado que todos los datos obtenidos en este estudio serán confidenciales y se tratarán conforme establece la Ley Orgánica de Protección de Datos de Carácter Personal 15/99. Todas las muestras serán anonimizadas con un código numérico.

He recibido una copia firmada de este Consentimiento Informado.

Firma del participante:

…………………………………………………………………………………………
……………

Fecha: ………………………………

He explicado la naturaleza y el propósito del estudio al padre/madre/tutor y participante mencionado.

Firma del investigador:

…………………………………………………………………………………………

Fecha: ……………………………………………

Versión 1.0

14.4 Anexo 4. Cuestionario: Recuerdo de 24 horas

Hoja de Menús PRIMER DÍA

Fecha:

Día de la semana:

LUGAR Y HORA	ALIMENTOS (si se conoce la marca, apuntarla también)	CANTIDADES (apuntar también unidades: gramos, litros…)
DESAYUNO		
Lugar: Hora: Con quién:		
ALMUERZO		
Lugar: Hora: Con quién:		
COMIDA		
Lugar: Hora: Con quién:		

MERIENDA		
Lugar: Hora: Con quién:		
CENA		
Lugar: Hora: Con quién:		
RECENA		
Lugar: Hora: Con quién:		

14.5 Anexo 5. Cuestionario: Children's Eating Habits Questionnaire (CEHQ

1 **Durante el mes pasado, ¿cuántas veces comió o bebió su hijo/a los siguientes alimentos y bebidas? Por favor, indique únicamente aquellos alimentos y bebidas que sabe, es decir, lo que su hijo/a comió en su presencia.**
Por favor seleccione una respuesta por fila.

Durante el pasado mes...	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Vegetales							
Legumbres (lentejas, garbanzos, judías, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Patatas (cocidas, no fritas)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Patatas fritas, croquetas de patata	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Otros vegetales cocinados (acelgas, borraja, broccoli, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Vegetales crudos (mezclados en la ensalada, lechuga, zanahoria, tomate, pepino, etc.)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Frutas frescas							
Frutas frescas (incluir también el zumo hecho en casa) **sin** azúcar añadido	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Frutas frescas (incluir también el zumo hecho en casa) **con** azúcar añadido	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Bebidas							
Agua (agua del grifo, agua con gas, agua mineral)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Zumos de frutas (fruta 100%) envasados (zumo de naranja, de melocotón, de piña, etc.)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Bebidas carbonatadas azucaradas (Coca cola, Fanta, Sprite, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Bebidas carbonatadas edulcoradas artificialmente (Coca cola light, Coca cola Zero, Pepsi Light, etc.)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Bebidas azucaradas no carbonatadas (Nestea, bebidas deportivas tipo Aquarius, zumos con menos del 100% de fruta, etc.)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7

Durante el pasado mes…	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Bebidas							
Bebidas edulcoradas artificialmente, no carbonatadas (Nestea Light, bebidas deportivas light tipo Aquarius Light, etc.)	1	2	3	4	5	6	7
Café y similares (cappuccino, eEko, etc): a) No azucarado	1	2	3	4	5	6	7
b) Azucarado (con azúcar, miel, etc)	1	2	3	4	5	6	7
Té, infusiones y similares (té verde, té rojo, manzanilla, poleo): a) No azucarado	1	2	3	4	5	6	7
b) Azucarado (con azúcar, miel, etc)	1	2	3	4	5	6	7
Cereales de desayuno							
Cereales de desayuno azucarados o con azúcar añadido y muesli azucarado (Smacks, Frosties, Miel pops, etc.)	1	2	3	4	5	6	7
Papilla, copos de avena, cereales no azucarados, muesli sin azúcar	1	2	3	4	5	6	7
Leche							
Leche sin azúcar (no olvides la leche que se le añade al café, al té o a los cereales)	1	2	3	4	5	6	7
Leche azucarada o con sabores (con cacao, chocolate, miel, azúcar, etc.)	1	2	3	4	5	6	7
¿Qué tipo de leche consume habitualmente su hijo/a? *Selecciona una única respuesta.*	a) Entera .... 1 b) Semi-desnatada/Desnatada .... 2 c) Ambos tipos de leche .... 3 d) Mi hijo no bebe leche .... 4 e) No lo sé 7						

Durante el pasado mes…	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Yogur							
Yogur natural o kéfir no azucarado	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Yogur azucarado y de sabores y bebidas lácteas fermentadas (Actimel®, LC1®, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
¿Qué tipo de yogur consume habitualmente su hijo/a? *Selecciona una única respuesta.*	a) Entero ○ 1 b) Desnatado ○ 2 c) Ambos tipos de yogur ○ 3 d) Mi hijo no come yogur ○ 4 e) No lo sé ○ 7						

Durante el pasado mes…	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Pescado							
Pescado enlatado (atún en lata, anchoas en lata, sardinas en lata)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Pescado hervido, a la plancha, asado en el horno, crudo, sin freír y no rebozado	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Pescado frito y/o rebozado y varitas de pescado	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Carne y productos cárnicos							
Productos loncheados y conservados, productos cárnicos listos para cocinar (fiambres, embutidos, jamón, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Carne a la plancha, hervida, asada al horno, ni rebozada ni frita (ternera, cerdo, cordero, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Carne frita (ternera, cerdo, cordero, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7
Carne de ave a la plancha, hervida, asada al horno, ni rebozada ni frita (pollo, pavo, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7

Carne de ave frita (pollo, pavo, etc)	1	2	3	4	5	6	7

Durante el pasado mes...	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Huevos y mayonesa							
Huevos fritos, revueltos o tortilla	1	2	3	4	5	6	7
Huevos duros o escalfados	1	2	3	4	5	6	7
Mayonesa y productos a base de mayonesa (ali-oli, Ligeresa, salsa rosa, etc)	1	2	3	4	5	6	7
Productos sustitutivos de la carne y productos de soja							
Tofu, tempé, leche de soja, yogures de soja, etc.	1	2	3	4	5	6	7
Queso							
Queso en lonchas o para cortar (manchego, Emmental, Parmesano, de cabra, etc)	1	2	3	4	5	6	7
Queso para untar (Philadelphia, Millán, quesitos, tranchettes, etc	1	2	3	4	5	6	7
Queso rallado	1	2	3	4	5	6	7
¿El queso que consume habitualmente su hijo/a es bajo en grasa? *Por favor, selecciona una única respuesta.*	a) Sí ..... 1 b) No ..... 2 c) Mi hijo no come queso ..... 3 d) No lo sé 7						
Durante el pasado mes...	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Productos para untar							
Mermelada, miel	1	2	3	4	5	6	7
Crema de chocolate o a base de frutos secos (Nocilla, Nutella, crema de cacahuete, etc)	1	2	3	4	5	6	7
Mantequilla, margarina en pan	1	2	3	4	5	6	7

Productos de bajo contenido graso en pan (tipo mantequilla, mermelada Light..	1	2	3	4	5	6	7
Ketchup (también como condimento para alimentos fritos)	1	2	3	4	5	6	7
Aceite vegetal para cocinar y/o para ensaladas							
Aceite de oliva	1	2	3	4	5	6	7

Durante el pasado mes...	Nunca/ menos de una vez al mes	1-3 veces por semana	4-6 veces por semana	1 vez al día	2 veces al día	3 veces al día	4 o más veces al día
Productos a base de cereales							
Pan blanco, panecillos blancos, biscotes blancos	1	2	3	4	5	6	7
Pan integral, panecillos integrales, biscotes integrales	1	2	3	4	5	6	7
Pasta, fideos, arroz y otros cereales refinados	1	2	3	4	5	6	7
Pasta, fideos, arroz y otros cereales integrales	1	2	3	4	5	6	7
Cuscús, bulgur, etc.	1	2	3	4	5	6	7
Pizza como plato principal	1	2	3	4	5	6	7
Hamburguesas, hot dog, kebab, falafel, sándwiches no preparados en casa, etc.	1	2	3	4	5	6	7
Aperitivos							
Frutos secos y semillas (nueces, almendras, pipas, cacahuetes, etc)	1	2	3	4	5	6	7
Frutas secas (dátiles, pasas, orejones, etc)	1	2	3	4	5	6	7
Ganchitos, patatas de bolsa, palomitas de maíz (Doritos, Riskettos, Triskis, Cheetos, Lays, etc)	1	2	3	4	5	6	7
Napolitanas de jamón york y queso, saladitos, galletas saladas, etc.	1	2	3	4	5	6	7
Chocolate, barritas a base de chocolate (mars, lions, kit kat, conguitos, lacasitos…)	1	2	3	4	5	6	7
Caramelos, gominolas, chucherías, etc.	1	2	3	4	5	6	7
Galletas, pastelitos envasados, tartas (Donuts,	1	2	3	4	5	6	7

Bollycao, napolitanas, cañas de chocolates, etc)							
Helados, polos, sorbetes de fruta, barritas a base de leche o fruta (Mágnum, Cornetto, Calippo, etc)	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7

14.6 Anexo 6. Cuestionario: Children Eating Behaviour Questionnaire (CEBQ)

Paciente	Visita	Fecha actual		
		Día	Mes	Año

Cuestionario Infantil de Comportamiento Alimentario – CEBQ

Instrucciones

Por favor, lea las siguientes afirmaciones y marque con una cruz la respuesta más apropiada (únicamente una), para todas y cada una de ellas, en relación al comportamiento alimentario de su hijo/a.

Si quisiera corregir una respuesta, por favor, tache completamente la respuesta y marque la deseada.

		Nunca [1]	Rara vez [2]	Algunas veces [3]	Frecuen-temente [4]	Siempre [5]
1	A mi hijo/a le encanta la comida	☐	☐	☐	☐	☐
2	Mi hijo/a come más cuando está preocupado	☐	☐	☐	☐	☐
3	Mi hijo/a tiene un gran apetito	☐	☐	☐	☐	☐
4	Mi hijo/a termina su comida muy rápido	☐	☐	☐	☐	☐
5	Mi hijo/a tiene interés en las comidas y los alimentos	☐	☐	☐	☐	☐
6	Mi hijo/a siempre está pidiendo algo de beber	☐	☐	☐	☐	☐
7	Mi hijo/a rechaza los alimentos que no conoce cuando se le ofrecen por primera vez	☐	☐	☐	☐	☐
8	Mi hijo/a come despacio	☐	☐	☐	☐	☐
9	Mi hijo/a come menos cuando está enfadado	☐	☐	☐	☐	☐
10	Mi hijo/a disfruta probando nuevos alimentos	☐	☐	☐	☐	☐
11	Mi hijo/a come menos cuando está cansado	☐	☐	☐	☐	☐
12	Mi hijo/a siempre está pidiendo comida	☐	☐	☐	☐	☐
13	Mi hijo/a come más cuando está molesto o irritado	☐	☐	☐	☐	☐
14	Si se le permitiera, mi hijo/a comería demasiado	☐	☐	☐	☐	☐
15	Mi hijo/a come más cuando está nervioso o inquieto	☐	☐	☐	☐	☐
16	Mi hijo/a disfruta de una gran variedad de alimentos	☐	☐	☐	☐	☐
17	Mi hijo/a deja comida en el plato al final de la comida	☐	☐	☐	☐	☐
18	A mi hijo/a le cuesta más de 30 minutos terminar de comer	☐	☐	☐	☐	☐
19	Si fuera por él (ella), mi hijo/a estaría comiendo la mayoría del tiempo	☐	☐	☐	☐	☐
20	Mi hijo/a espera con ganas las horas de las comidas	☐	☐	☐	☐	☐
21	Mi hijo/a se llena antes de terminar de comer	☐	☐	☐	☐	☐
22	Mi hijo/a disfruta comiendo	☐	☐	☐	☐	☐
23	Mi hijo/a come más cuando está contento/a	☐	☐	☐	☐	☐
24	Es difícil complacer a mi hijo/a con las comidas	☐	☐	☐	☐	☐
25	Mi hijo/a come menos cuando está disgustado	☐	☐	☐	☐	☐
26	Mi hijo/a se llena fácilmente con la comida	☐	☐	☐	☐	☐
27	Mi hijo/a come más cuando no tiene nada que hacer	☐	☐	☐	☐	☐
28	Incluso cuando está lleno, mi hijo/a está dispuesto a comer su comida favorita	☐	☐	☐	☐	☐
29	Si se le diera la oportunidad, mi hijo/a estaría bebiendo continuamente a lo largo de todo el día	☐	☐	☐	☐	☐
30	Mi hijo/a no puede comerse la comida si ha tomado algo antes	☐	☐	☐	☐	☐
31	Si se le diera la oportunidad, mi hijo/a estaría siempre tomando algo de beber	☐	☐	☐	☐	☐
32	Mi hijo/a está interesado en probar alimentos que no ha probado antes	☐	☐	☐	☐	☐
33	Mi hijo/a decide que no le gusta una comida, incluso sin haberla probado	☐	☐	☐	☐	☐
34	Si se le diera la oportunidad, mi hijo/a estaría siempre comiendo algo	☐	☐	☐	☐	☐
35	Mi hijo/a come cada vez más lento durante el transcurso de las comidas	☐	☐	☐	☐	☐

14.7 Anexo 7. TGMD-3

Test de Desarrollo Motor Grueso – Tercera Edición
TDMG-3
Formulario Normalizado de Registro del Evaluador
Versión en Castellano. Traducido de Dale A. Ulrich

Sección 1. Información identificativa

Nombre del niño o Nº identificación #:______________________________Fecha:____________

Nombre del evaluador:__________________Filiación:____________________________Dirección Email del evaluador:________________________

Fecha de evaluación: __________________Fecha de nacimiento:____________________ Género: Hombre / Mujer Edad en años:_____________

Estado del peso del niño/a: Peso bajo / Peso normal / Sobrepeso Lugar de residencia del niño/a: Ciudad / Alrededores de ciudad / Pequeña ciudad o rural Dominancia de mano: Derecha / Izquierda / Sin establecerse Dominancia de pie: Derecha / Izquierda / Sin establecerse

Sección 2. Anotaciones de resultado

- La indicación de todos los ítems requiere que inicialmente se le ofrezca al niño/a una buena demostración de la habilidad, que incluya todos los criterios de rendimiento; que se le ofrezca un intento de práctica seguido de los dos intentos que se evalúan.
- El resultado de cada criterio de rendimiento es:
  - 1 = se realiza correctamente
  - 0 = no se realiza correctamente
- El **resultado de los criterios de rendimiento** se calculan sumando todos los criterios de rendimiento de cada habilidad.
- El **resultado de habilidad** se calculan sumando todos los resultados de los criterios de rendimiento de cada habilidad.
- El **resultado del subtest de locomoción** se calcula sumando los 6 resultados de las habilidades de locomoción.
- El **resultado del subtest de habilidades** con balón se calcula sumando los 7 resultados de las habilidades con balón.
- El resultado total del test motriz grueso se calcula con la suma total de los resultados del subtest de locomoción y el resultado del subtest de habilidades con balón.
- Hemos aprendido que hay un efecto de perturbación por quien evalúa el test cuando éste está inseguro de cómo se puntúa un criterio de rendimiento.
- Cuando se testa a un niño/a, si estás inseguro de si el niño/a realiza un criterio de rendimiento correctamente, incluye otro intento y simplemente observa ese criterio de rendimiento y puntúalo.
- Cuando se testa a niños/as con una discapacidad o niños/as muy pequeños/as que parecen distraerse fácilmente, se recomienda tenerlos de pie en un lugar pequeño de referencia (small poly spot) u otra zona marcada e indicarles que deben estar de pie en ese lugar y ver la demostración. También ayuda el uso de una zona de referencia o marcada que señale la posición de inicio del niño/a en las habilidades de locomoción. Ofrecer a estos niños/as una mayor estructuración durante el test debería ser de ayuda.

Sección 3. Subtest de registro del rendimiento

Subtest de Locomoción

Habilidad	Material	Indicaciones	Criterios de rendimiento	Intento 1	Intento 2	Resultado
1. Carrera	18,3 m de espacio libre para correr y dos conos o marcas	Coloca dos conos a 15,2 m de distancia. Asegúrate que hay al menos 2,4-3,1 m de espacio tras cada cono como distancia de seguridad para parar. Dile al niño/a que debe correr veloz de un cono al otro cuando le digas "Ya". Repite el segundo intento	1. Los brazos se mueven en oposición a las piernas con los codos doblados			
			2. Breve periodo de ambos pies sin contacto con suelo			
			3. Reducido apoyo del pie en el suelo con el talón o punta del pie (no apoyo plano)			
			4. La pierna libre doblada alrededor de 90 grados manteniendo el pie cerca de las nalgas			
				Resultado de la habilidad		
2. Galope	7,6 m de espacio libre y dos conos o marcas	Coloca dos conos a 7,6 m de distancia. Dile al niño/a que galope de un cono al otro y pare. Repite el segundo intento	1. Brazos flexionados y balanceándose hacia delante			
			2. Un paso adelante con el pie delantero seguido del trasero apoyando detrás o al lado del delantero (no delante del delantero)			
			3. Breve periodo de ambos pies sin contacto con la superficie			
			4. Se mantiene un patrón rítmico de cuatro galopes consecutivos			
				Resultado de la habilidad		
3. Salto a un pie	Un mínimo de 4,6 m de espacio libre y dos conos o marcas	Coloca dos conos a 4,6 m de distancia. Dile al niño/a que salte a la pata coja con un su pie dominante (establecido antes del test). Repite el segundo intento	1. La pierna libre se balancea hacia delante de manera pendular para generar fuerza			
			2. El pie de la pierna libre permanece detrás de la pierna de impulso (no cruza por delante)			
			3. Los brazos flexionados y oscilan hacia delante para generar fuerza			
			4. Se realizan 4 saltos a un pie (preferido) consecutivos antes de pararse			
				Resultado de la habilidad		
4. Skipping	Un mínimo de 9,1 m de espacio libre y dos conos o marcas	Coloca dos conos a 9,1 m de distancia. Marca dos líneas al final de los 9,1 m con dos nuevos conos o marcas. Dile al niño/a que salte skip de un cono a otro. Repite el segundo intento	1. Realiza un paso adelante seguido de un salto/impulso con el mismo pie			
			2. Los brazos se flexionan y mueven en oposición a la piernas para generar fuerza			
			3. Realiza 4 saltos de skipping consecutivos, rítmicos y alternativos			
				Resultado de la habilidad		
5. Salto horizontal	Un mínimo de 3,1 m de espacio libre y esparadrapo o marcas	Marca una línea de inicio en el suelo, colchoneta o alfombra. Coloca al niño/a detrás de la línea. Dile que salte lejos. Repite el segundo intento	1. Antes de despegar los pies, ambas rodillas están flexionadas y los brazos extendidos detrás de la espalda			
			2. Los brazos se extienden con fuerza hacia delante y arriba llegando por encima de la cabeza			
			3. Ambos pies se levantan del suelo juntos y aterrizan juntos			
			4. Ambos brazos se llevan atrás durante el aterrizaje			
				Resultado de la habilidad		

Test de Desarrollo Motor Grueso – Tercera Edición
TDMG-3
Formulario Normalizado de Registro del Evaluador
Versión en Castellano. Traducido de Dale A. Ulrich

Habilidad	Material	Indicaciones	Criterios de rendimiento	Intento 1	Intento 2	Resultado
6. Desplazamiento lateral	Un mínimo de 7,6 m de espacio libre, una línea recta y dos conos o marcas	Coloca los dos conos a 7,6 m de distancia en una línea recta. Dile al niño/a que se desplace lateralmente de un cono al otro. Deja que sea el niño/a quien decida en qué dirección se desplaza primero. Indica al niño/a que vuelva desplazándose lateralmente al punto de inicio. Repite el segundo intento	1. El cuerpo se sitúa de lado de modo que los hombros permanecen alineados con la línea del suelo (se valora sólo en la dirección preferida)			
			2. Un paso al lado con el pie delantero seguido del pie de detrás, ambos pies se levantan del suelo brevemente (se valora sólo la dirección preferida)			
			3. Realiza 4 desplazamientos laterales continuos en la dirección preferida			
			4. Realiza 4 desplazamientos laterales continuos en la dirección no preferida			
				Resultado de la habilidad		
			Resultado total del subtest de locomoción			

Subtest de habilidades de balón

Habilidad	Material	Indicaciones	Criterios de rendimiento	Intento 1	Intento 2	Resultado
1. Bateo a dos manos una bola estática	Una bola de plástico de 10,2 cm de diámetro, un bate de plástico y un palo de soporte u otro instrumento que mantenga la pelota en estático	Pon la bola en el palo de soporte a la altura de la cintura del niño/a. Dile que golpee la pelota fuerte al frente. Apunta al frente. Repite el segundo intento	1. La mano dominante que empuña el bate está arriba de la mano no preferida			
			2. La cadera/hombro del lado no dominante mira al frente			
			3. La cadera y el hombro rotan y vuelven durante la acción de golpeo			
			4. Realiza un paso con el pie no dominante			
			5. Golpea la bola enviándola al frente			
				Resultado de la habilidad		
2. Golpeo con raqueta tras bote	Una pelota de tenis, una pala/raqueta de plástico y una pared	Da la pala de plástico y la pelota al niño. Dile que deje caer la pelota desde alto para que bote (el bote debe llegar a la altura de la cadera), tras el bote, golpea la bola hacia la pared. Apunta a la pared. Repite el segundo intento	1. El niño/a realiza un movimiento atrás con la pala/raqueta cuando deja botar la bola			
			2. Realiza un paso con el pie no preferido/dominante			
			3. Golpea la bola hacia la pared			
			4. La pala continúa avanzando hacia el hombro no preferido/dominante			
				Resultado de la habilidad		
3. Bote de balón con una mano en estático	Un balón de 20,3-25,4 cm para 3-5 años de edad o baloncesto para niños de 6-10 años y una superficie plana	Dile al niño/a que bote el balón al menos 4 veces consecutivamente sin mover sus pies, utilizando una mano y parando el balón cogiéndolo. Repite el segundo intento	1. Contacta la bola con una mano aproximadamente a nivel de la cintura			
			2. Impulsa la bola con la punta de los dedos (no golpea a la bola)			
			3. Mantiene control de la bola durante al menos 4 botes consecutivos sin mover los pies para recuperar la bola			
				Resultado de la habilidad		

Test of Gross Motor Development–Third Edition

TGMD-3

Examiner Record Form–Norming

Dale A. Ulrich

Section 1. Identifying Information

Child's Name or ID #: ______________________________

Examiner's Name: ____________________ Affiliation: ____________________ Examiner's Email Address: ____________________

Date of Testing: ____________________ Date of Birth: ____________________

Gender: Male ☐ Female ☐ Age in Years: ____________ Child's Weight Status: Underweight ☐ Normal ☐ Overweight ☐

Child's Residential Location: City ☐ Suburb of City ☐ Rural or Small Town ☐ Preferred Hand: Right ☐ Left ☐ Not Established ☐ Preferred Foot: Right ☐ Left ☐ Not Established ☐

Section 2. Scoring Notes

- Directions for all test items require you to first give the child a good demonstration of the skill, which includes all of the performance criteria; give the child a practice trial, followed by two test trials that you score.
- Score each performance criterion as:
  - 1 = performs correctly
  - 0 = does not perform correctly
- **Performance criteria scores** are calculated by summing the score on trial 1 and trial 2 for each performance criterion.
- **Skill scores** are calculated by summing all of the performance criteria scores for each skill.
- The total **locomotor subtest score** is calculated by summing all 6 locomotor skill scores.
- The total **ball skills subtest score** is calculated by summing the 7 ball skill scores.
- The total **gross motor test score** is calculated by summing the total locomotor subtest score and the total ball skills subtest score.
- We have learned that test administrator bias occurs when the tester is unsure how to score a performance criterion. When testing a child, if you are unsure of whether the child performed a performance criterion correctly, administer another trial and just look at that performance criterion and score it.
- When testing children with a disability or very young children who appear to be distracted easily, it is recommended that you to have them stand on a small poly spot or other marker and tell them to stand on the marker and watch your demonstration. It is also helpful to use another poly spot or marker as the child's starting position for the locomotor skills. Giving these children more structure during your testing should be helpful.

Section 3. Subtest Performance Record

Locomotor Subtest

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Run	60 feet (18.3 meters) of clear space to run, and two cones or markers	Place two cones 50 feet (15.2 meters) apart. Make sure there is at least 8–10 feet (2.4–3.1 meters) of space beyond the cone for a safe stopping distance. Tell the child to run fast from one cone to the other cone when you say, "Go." Repeat a second trial.	1. Arms move in opposition to legs with elbows bent			
			2. Brief period where both feet are off the surface			
			3. Narrow foot placement landing on heel or toes (not flat-footed)			
			4. Non-support leg bent about 90 degrees so foot is close to buttocks			
					Skill Score	
2. Gallop	25 feet (7.6 meters) of clear space, and two cones or markers	Place two cones 25 feet apart. Tell the child to gallop from one cone to the other cone and stop. Repeat a second trial.	1. Arms flexed and swinging forward			
			2. A step forward with lead foot followed with the trailing foot landing beside or a little behind the lead foot (not in front of the lead foot)			
			3. Brief period where both feet come off the surface			
			4. Maintains a rhythmic pattern for four consecutive gallops			
					Skill Score	
3. Hop	A minimum of 15 feet (4.6 meters) of clear space, and two cones or markers	Place two cones 15 feet apart. Tell the child to hop four times on his/her preferred foot (established before testing). Repeat a second trial.	1. Non-hopping leg swings forward in pendular fashion to produce force			
			2. Foot of non-hopping leg remains behind hopping leg (does not cross in front of)			
			3. Arms flex and swing forward to produce force			
			4. Hops four consecutive times on the preferred foot before stopping			
					Skill Score	
4. Skip	A minimum of 30 feet (9.1 meters) of clear space, and two cones or markers	Place two cones 30 feet apart. Mark off two lines at least 30 feet apart with cones/markers. Tell the child to skip from one cone to the other cone. Repeat a second trial.	1. A step forward followed by a hop on the same foot			
			2. Arms are flexed and move in opposition to legs to produce force			
			3. Completes four continuous rhythmical alternating skips			
					Skill Score	
5. Horizontal jump	A minimum of 10 feet (3.1 meters) of clear space, and tape or markers	Mark off a starting line on the floor, mat, or carpet. Position the child behind the line. Tell the child to jump far. Repeat a second trial.	1. Prior to take off both knees are flexed and arms are extended behind the back			
			2. Arms extend forcefully forward and upward reaching above the head			
			3. Both feet come off the floor together and land together			
			4. Both arms are forced downward during landing			
					Skill Score	

Locomotor Subtest (*continued*)

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
6. Slide	A minimum of 25 feet (7.6 meters) of clear space, a straight line, and two cones or markers	Place two cones 25 feet apart on a straight line. Tell the child to slide from one cone to the other cone. Let the child decide which direction to slide in first. Ask the child to slide back to the starting point. Repeat a second trial.	1. Body is turned sideways so shoulders remain aligned with the line on the floor (score on preferred side only)			
			2. A step sideways with the lead foot followed by a slide with the trailing foot where both feet come off the surface briefly (score on preferred side only)			
			3. Four continuous slides to the preferred side			
			4. Four continuous slides to the non-preferred side			
					Skill Score	

Locomotor Subtest Total Score ________

Ball Skills Subtest

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
1. Two-hand strike of a stationary ball	A 4-inch (10.2-centimeter) plastic ball, a plastic bat, and a batting tee or other device to hold ball stationary	Place ball on batting tee at child's waist level. Tell child to hit the ball hard, straight ahead. Point straight ahead. Repeat a second trial.	1. Child's preferred hand grips bat above non-preferred hand			
			2. Child's non-preferred hip/shoulder faces straight ahead			
			3. Hip and shoulder rotate and derotate during swing			
			4. Steps with non-preferred foot			
			5. Hits ball sending it straight ahead			
					Skill Score	
2. One-hand forehand strike of self-bounced ball	A tennis ball, a light plastic paddle, and a wall	Hand the plastic paddle and ball to child. Tell child to hold ball up and drop it (so it bounces about waist height); off the bounce, hit the ball toward the wall. Point toward the wall. Repeat a second trial.	1. Child takes a backswing with the paddle when the ball is bounced.			
			2. Steps with non-preferred foot			
			3. Strikes the ball toward the wall			
			4. Paddle follows through toward non-preferred shoulder			
					Skill Score	
3. One-hand stationary dribble	An 8–10 inch (20.3–25.4 centimeter) playground ball for ages 3–5 years, a basketball for ages 6–10 years, and a flat surface	Tell the child to bounce the ball at least four times consecutively without moving their feet, using one hand, and then stop by catching the ball. Repeat a second trial.	1. Contacts ball with one hand at about waist level			
			2. Pushes the ball with fingertips (not slapping at ball)			
			3. Maintains control of the ball for at least four consecutive bounces without moving the feet to retrieve the ball			
					Skill Score	

Ball Skills Subtest (*continued*)

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
4. Two-hand catch	A 4-inch (10.2-centimenter) plastic ball, 15 feet (4.6 meters) of clear space, and tape or a marker	Mark off two lines 15 feet apart. The child stands on one line and the tosser stands on the other line. Toss the ball underhand to the child aiming at the child's chest area. Tell the child to catch the ball with two hands. Only count a trial in which toss is near child's chest. Repeat a second trial.	1. Child's hands are positioned in front of the body with the elbows flexed			
			2. Arms extend reaching for the ball as it arrives			
			3. Ball is caught by hands only			
					Skill Score	
5. Kick a stationary ball	An 8–10 inch (20.3–25.4 centimeters) plastic, playground, or soccer ball; tape or a marker; a wall; and clear space for kicking	Mark off one line about 20 feet (6.1 meters) from the wall and a second line 8 feet (2.4 meters) beyond the first line. Place the ball on the first line closest to the wall. Tell the child to run up and kick the ball hard toward the wall. Repeat a second trial.	1. Rapid, continuous approach to the ball			
			2. Child takes an elongated stride or leap just prior to ball contact			
			3. Non-kicking foot placed close to the ball			
			4. Kicks ball with instep or inside of preferred foot (not the toes)			
					Skill Score	
6. Overhand throw	A tennis ball, a wall, and 20 feet (6.1 meters) of clear space	Attach a piece of tape on the floor 20 feet from the wall. Have the child stand behind the tape line facing the wall. Tell the child to throw the ball hard at the wall. Repeat a second trial.	1. Windup is initiated with a downward movement of hand and arm			
			2. Rotates hip and shoulder to a point where the non-throwing side faces the wall			
			3. Steps with the foot opposite the throwing hand toward the wall			
			4. Throwing hand follows through after the ball release, across the body toward the hip of the non-throwing side			
					Skill Score	
7. Underhand throw	A tennis ball, tape, a wall, and 15 feet (4.6 meters) of space	Attach a piece of tape 15 feet from the wall. Have the child stand behind the tape line facing the wall. Tell the child to throw the ball underhand and hit the wall. Repeat a second trial.	1. Preferred hand swings down and back reaching behind the trunk			
			2. Steps forward with the foot opposite the throwing hand			
			3. Ball is tossed forward hitting the wall without a bounce			
			4. Hand follows through after ball release to at least chest level			
					Skill Score	

Ball Skills Subtest Total Score ________

Total Gross Motor Score ________

14.8 Anexo 8. Planificación del entrenamiento con los diferentes objetivos a largo plazo

Mes	NOVIEMBRE																			
Semana	1º Semana					2º Semana					3º Semana					4º Semana				
Día	lunes 4	martes 5	miercoles 6	jueves 7	viernes 8	lunes 11	martes 12	miercoles 13	jueves 14	viernes 15	lunes 18	martes 19	miercoles 20	jueves 21	viernes 22	lunes 25	martes 26	miercoles 27	jueves 28	viernes 29
Wii	Evaluación Habilidad Motriz								Familiarización con los videojuegos							Wii Sport				
Xbox																Kinect Sport				
Esterillas																Baile				
Bkool																Nivel 1				
Ring Fit																Capítulo, MJ, básicos (maximo numero de repeticiones) o series				
Objetivo																RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM

Mes	DICIEMBRE																			
Semana	1º Semana					2º Semana					3º Semana					4º Semana				
Día	lunes 2	martes 3	miercoles 4	jueves 5	viernes 6	lunes 9	martes 10	miercoles 11	jueves 12	viernes 13	lunes 16	martes 17	miercoles 18	jueves 19	viernes 20	lunes 23	martes 24	miercoles 25	jueves 26	viernes 27
Wii	Wii Sport						Wii sport				Wii Sport									
Xbox	Kinect Adventures						Kinect Adventures				Kinect Adventures									
Esterillas	Baile						Baile				Baile									
Bkool	Nivel 1						Nivel 2				Nivel 2									
Ring Fit	Capítulo, MJ, básicos (maximo numero de						Capítulo, MJ, básicos (maximo numero de				Capítulo, MJ, básicos (maximo numero de									
Objetivo	RC RM EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM Flex EQ			RC RM EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM Flex EQ	RC RM EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM Flex EQ						
PACES																				

Mes	ENERO																								
Semana	1º Semana					2º Semana					3º Semana					4º Semana					5º semana				
Día	lunes 30	martes 31	miercoles 1	jueves 2	viernes 3	lunes 6	martes 7	miercoles 8	jueves 9	viernes 10	lunes 13	martes 14	miercoles 15	jueves 16	viernes 17	lunes 20	martes 21	miercoles 22	jueves 23	viernes 24	lunes 27	martes 28	miercoles 29	jueves 30	viernes 31
Wii							MSJJOO				MSJJOO					MSJJOO					Just Dance				
Xbox							Kinect Sport				Kinect Sport					Kinect Sport					Kinect Sport				
Esterillas							Baile				Baile					Baile					MSJJOO				
Bkool							Nivel 1				Nivel 2					Nivel 2					Nivel 3				
Ring Fit							Capítulo, MJ, básicos (maximo numero de				Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Reto					A tu aire				
Objetivo							RC RM EQ HM	RC RM EQ HM	FM Flex EQ HM	RC RM Flex EQ	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
							PACES									PACES									

Mes	FEBRERO																			
Semana	1º Semana					2º Semana					3º Semana					4º Semana				
Día	lunes 3	martes 4	miercoles 5	jueves 6	viernes 7	lunes 10	martes 11	miercoles 12	jueves 13	viernes 14	lunes 17	martes 18	miercoles 19	jueves 20	viernes 21	lunes 24	martes 25	miercoles 26	jueves 27	viernes 28
Wii	Just Dance					Just Dance					Just Dance					Just dance				
Xbox	Kinect Adventures					Kinect Adventures					Kinect Sport					Kinect Sport				
Esterillas	MSJJOO					MSJJOO					MSJJOO					MSJJOO				
Bkool	nivel 3					nivel 4					nivel 2					nivel 1				
Ring Fit	A tu aire					Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Capítulo, MJ, básicos (maximo numero de repeticiones) o series				
Objetivo	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
	PACES										PACES									
Material	Peso corporal					Bosu					Mancuernas					Gomas				
Mes	MARZO																			

Mes	MARZO																			
Semana	1º Semana					2º Semana					3º Semana					4º Semana				
Día	lunes 2	martes 3	miercoles 4	jueves 5	viernes 6	lunes 9	martes 10	miercoles 11	jueves 12	viernes 13	lunes 16	martes 17	miercoles 18	jueves 19	viernes 20	lunes 23	martes 24	miercoles 25	jueves 26	viernes 27
Wii	Wii Sport					Wii Sport					Wii Sport					MSJJOO				
Xbox	Kinect Adventures					Kinect Adventures					Kinect Adventures					Kinect Sport				
Esterillas	MSJJOO					Baile					Baile					Baile				
Bkool	nivel 2					nivel 2					nivel 3					nivel 3				
Ring Fit	RETO					Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Capítulo, MJ, básicos (maximo numero de repeticiones) o series					RETO				
Objetivo	RC RM EQ HM	FM RC Flex HM	FM RC Flex HM			RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
	PACES																			
Material	Peso corporal					Bosu					Mancuernas					Gomas				

Mes	ABRIL																			
Semana	1º Semana					2º Semana					3º Semana					4º Semana				
Día	lunes 30	martes 31	miercoles 1	jueves 2	viernes 3	lunes 6	martes 7	miercoles 8	jueves 9	viernes 10	lunes 13	martes 14	miercoles 15	jueves 16	viernes 17	lunes 20	martes 21	miercoles 22	jueves 23	viernes 24
Wii	MSJJOO											Rithim				Rithim				
Xbox	Kinect Sport											Kinect Sport				Kinect Sport				
Esterillas	Baile											MSJJOO				MSJJOO				
Bkool	nivel 2											nivel 1				nivel 2				
Ring Fit	A tu aire											Capítulo, MJ, básicos (maximo numero de				Capítulo, MJ, básicos (maximo numero de repeticiones) o series				
Objetivo	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM							RC RM EQ HM	RC RM EQ HM	FM Flex EQ HM	RC RM Flex EQ	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
	PACES																			
Material	Peso corporal					Bosu					Mancuernas					Gomas				

Mes	MAYO																								
Semana	1º Semana					2º Semana					3º Semana					4º Semana					5º semana				
Día	lunes 27	martes 28	miercoles 29	jueves 30	viernes 1	lunes 4	martes 5	miercoles 6	jueves 7	viernes 8	lunes 11	martes 12	miercoles 13	jueves 14	viernes 15	lunes 18	martes 19	miercoles 20	jueves 21	viernes 22	lunes 25	martes 26	miercoles 27	jueves 28	viernes 29
Wii	Wii Sport					Wii Sport					Wii Sport					MSJJOO					MSJJOO				
Xbox	Kinect Adventures					Kinect Adventures					Kinect Adventures					Kinect Sport					Kinect Sport				
Esterillas	MSJJOO					Baile					Baile					Rithim					Rithim				
Bkool	nivel 3					nivel 3					nivel 4					nivel 4					nivel 5				
Ring Fit	Reto					A tu aire					A tu aire					Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Capítulo, MJ, básicos (maximo numero de repeticiones) o series				
Objetivo	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
	PACES										PACES										PACES				
Material	Peso corporal					Bosu					Mancuernas					Gomas					Peso Corporal				

Mes	JUNIO														
Semana	1º Semana					2º Semana					3º Semana				
Día	lunes 1	martes 2	miercoles 3	jueves 4	viernes 5	lunes 8	martes 9	miercoles 10	jueves 11	viernes 12	lunes 15	martes 16	miercoles 17	jueves18	viernes 19
Wii	Wii Sport					Wii Sport					Wii Sport				
Xbox	Kinect Adventures					Kinect Adventures					Kinect Adventures				
Esterillas	MSJJOO					MSJJOO					MSJJOO				
Bkool	nivel 5					nivel 4					nivel 3				
	Reto				A tu	Capítulo, MJ, básicos (maximo numero de repeticiones) o series					Capítulo, MJ, básicos (maximo numero de repeticiones) o series				
Objetivo	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM	RC EQ HM	FM Flex EQ HM	FM Flex EQ HM	RC RM EQ	RC RM Flex HM
Material	Bosu					Mancuernas					Gomas				

14.9 Anexo 9: Cronograma del proyecto

	2017					2018												2019											
Activida d	ago	sept	o ct	nov	dic	ene	feb	mar	abr	may	jun	jul	ago	sep	oct	nov	dic	ene	feb	mar	abr	may	jun	jul	ago	sep	oct	nov	dic
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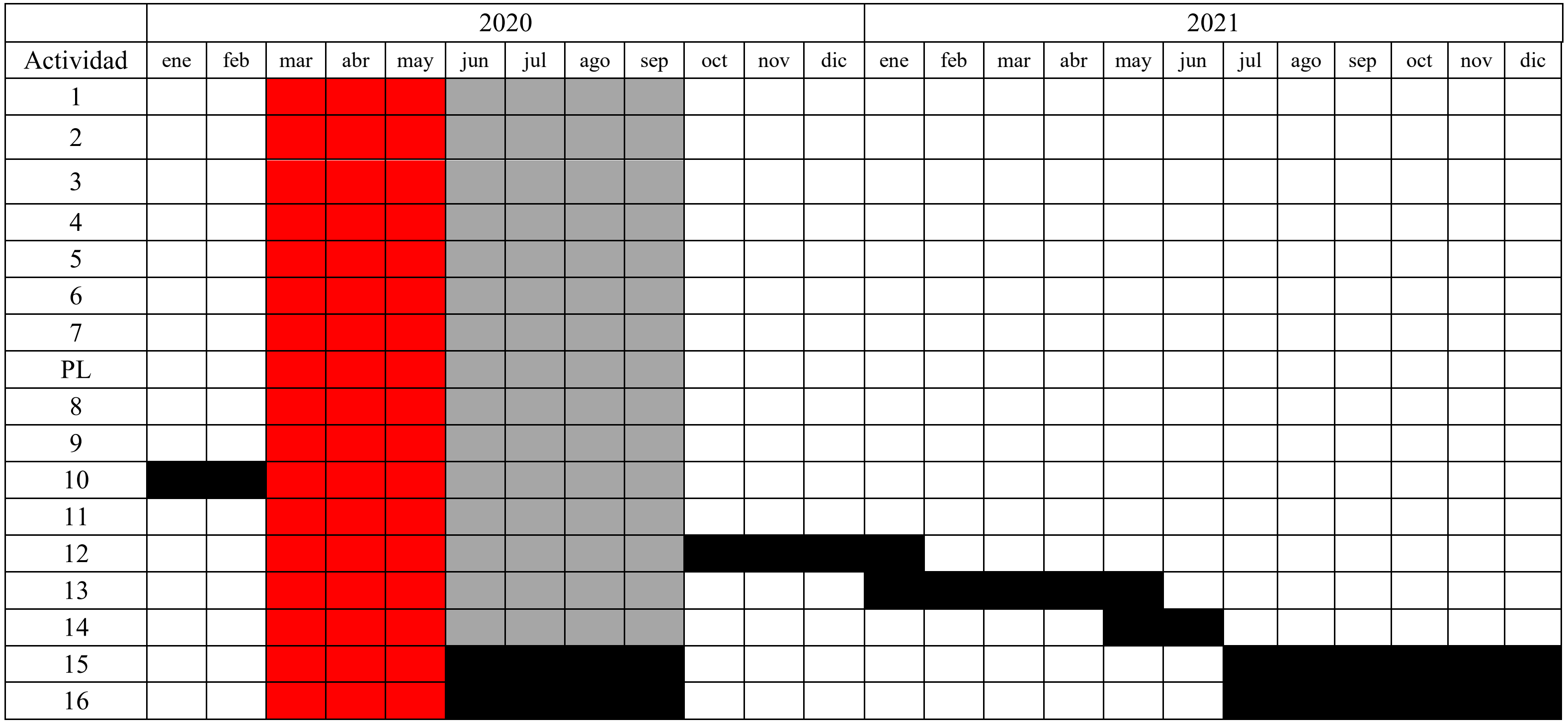

1. Diseño, redacción del proyecto y búsqueda de financiación
2. Estandarización de procedimientos y formación del personal
3. Reclutamiento inicial y estandarización de procedimientos
4. Divulgación del proyecto (prensa, televisión, entrevistas…)
5. Primera evaluación (pre-intervención 1)
6. Desarrollo del programa de intervención (1º año)
7. Segunda evaluación (Post-intervención 1º año)

PL: Periodo de lavado

8. Reclutamiento de participantes (2º año)
9. Primera evaluación (pre-intervención 2º año)
10. Desarrollo del programa de intervención (2º año)
11. Segunda evaluación (Post-intervención 2º año)
12. Repetición de la primera evaluación (pre-intervención 2º año)
13. Repetición del desarrollo del programa de intervención adaptado a las restricciones (2º año)
14. Repetición de segunda evaluación (Post-intervención 2º año)
15. Creación de base de datos previo al análisis (Análisis de las pruebas y exploraciones, extracción y creación de la base de datos)
16. Análisis de datos y diseminación/difusión de resultados obtenidos (publicaciones científicas, asistencia a congresos, charlas, prensa, televisión, entrevistas…