VNiVERSiDAD D SALAMANCA

CAMPUS DE EXCELENCIA INTERNACIONAL

Gamificación y aprendizaje basado en juegos para la educación en hábitos de vida saludable en la infancia

Tesis doctoral

Programa de Doctorado Formación en la Sociedad del Conocimiento

Doctoranda

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Salamanca, Junio 2021

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Universidad de Salamanca

TESIS DOCTORAL

Programa Oficial de Doctorado:

FORMACIÓN EN LA SOCIEDAD DEL CONOCIMIENTO

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HACEN CONSTAR

Que dicho trabajo tiene suficientes méritos teóricos contrastados adecuadamente mediante las validaciones oportunas, publicaciones relacionadas y aportaciones novedosas. Por todo ello considera que procede su defensa pública.

En Salamanca, a16 de junio de 2021.

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DEDICATORIA

A mi bebe,
que será parte del futuro y de la transformación de esta sociedad.

DECLARACIÓN

Por la presente declaro que, excepto cuando se haga referencia específica al trabajo de otros, el contenido de esta disertación es original y no se ha presentado en su totalidad o en parte para su consideración para ninguna otra titulación en esta o cualquier otra universidad.

Esta investigación es mi propio trabajo y contiene los resultados de la colaboración con otros investigadores especificados en el texto y los reconocimientos y contribuciones resultantes de esta tesis en revistas y conferencias internacionales.

Esta tesis ha sido desarrollada en la Universidad de Salamanca bajo el programa de Doctorado “Formación en la Sociedad del Conocimiento”.

Nazaret Gómez del Río
Junio 2021

AGRADECIMIENTOS

> “Mientras enseño continúo buscando, indagando. Enseño porque busco, porque indagué, porque indago y me indagó. Investigo para comprobar, comprobando intervengo, interviniendo educo y me educo. Investigo para conocer lo que aún no conozco y comunicar o anunciar la novedad.”- Paulo Freire

Cuando me senté a escribir estas líneas, me di cuenta de lo afortunada que soy por poder contar con tanta personas que me ha ayudado y acompañado a lo largo de este camino. Quiero empezar dando las gracias a este Programa de Doctorado “Formación en la Sociedad del Conocimiento” de la Universidad de Salamanca, por darme la oportunidad de formarme, con estudiantes extranjeros de distintas partes del mundo.

En primer lugar, me gustaría agradecer a mis directores, la Dra. Carina Soledad González González y el Dr. Francisco José García Peñalvo por haberme aceptado, asesorado y supervisado continuamente, porque sin ellos, este trabajo no hubiera sido posible. A Carina S. González González por su continua orientación, por haber creído en mi, y demostrarme que con la gamificación todo es más divertido. A Francisco José García Peñalvo por acogerme como doctoranda, por su disponibilidad y dedicación para llevar a buen puerto esta tesis. Quiero nombrar también a Vicente Navarro Adelantado por su pasión en el mundo de la investigación, y guía al inicio de este viaje en Tenerife.

A Raquel Martín por su asertividad y su infinita ayuda con la parte de formación. Estoy segura de que los niños y niñas del proyecto se beneficiaron mucho de esa gran inteligencia emocional que transmites.

A Luis Navarro por ser junto a Vicente, un maestro en los juegos motores, diseñando las actividades y cuando era necesario improvisando. Saber motivar a los niños y niñas con cada juego es un maravilloso don.

A Mariana Cairós por sus consejos y ánimos durante el desarrollo del proyecto, especialmente al inicio. Gracias por estar siempre dispuesta a echarme una mano cuando me atascaba.

A Yeray del Cristo Barrios por sus habilidades con el ratón del ordenador y con las tijeras, por ser siempre sonrisas y energías.

A Belén Armas por su apoyo e implicación en la formación en los colegios.

A Pedro Toledo por su tranquilidad y recomendaciones en la parte tecnólogica.

A Carmela Quirce por su paciencia.

Así mismo, agradezco a los investigadores y colaboradores de PROVITAO de diferentes áreas con los que trabajé, que me han ayudado de diferentes formas durante el desarrollo de este proyecto, pero sobre todo, por su compromiso y vocación en sus profesiones: Salud (Norberto Marrero Gordillo, Honorio Armas Ramos, Josué Monzón Díaz, Mercedes Murray), Tecnología (Alberto Mora Carreño, Vanesa Muñoz Cruz, Pablo V. Torres Carrión) y Educación (Silvia Vera González, Elisenda Espino Espino, Isa Neves).

Además, me gustaría agradecer especialmente a los niños y niñas, y a sus familias que han participado en este estudio, así como a las escuelas y profesores que colaboraron con el proyecto.

Gracias a todos mis amigos que llevan meses aguantando mis conversaciones monotemáticas sobre la tesis.

Gracias especialmente a mis amigas, Tania, Inma, Jana, Nicole, Patri y Ary, por compartir mis alegría y mis tristezas, por todo vuestro cariño y amor. Gracias por las noches de chicas, de risas y hermandad. Sin importar lo lejos que estemos, ¡Las quiero chicas!

Gracias a toda mi familia: a mi mamá por darme lo mejor de mi vida, raíces para ser fuerte y alas para volar; a mi hermana y a mi cuñado por seguir dándome ánimos para continuar; a mi tata por sus largas charlas y su apoyo incondicional; a mi suegros por su empuje y ayuda a lo largo del camino; a mi sobrino Miguel por enseñarme a disfrutar los fines de semana que desconectaba; a mi otro sobrino Joan por alegrarme las mañanas con sus sonrisas inocentes y sus juegos infantiles; a mi abuela Basi y a mi tío Jero por ser mi apoyo y sostén desde pequeña; a mi abuelo Juan, espero que dónde estés, sepas lo maravilloso que fue tenerte y lo mucho que me enseñaste de la vida.

Finalmente, quiero dar las gracias a mi esposo Joaquín por su paciencia infinita, por aguantarme cuando ni yo misma lo hacia, por ser mi compañero de vida y en los próximos meses también papá. Gracias por empezar conmigo este nueva aventura de formar una familia.

¡Muchas gracias a todos!

RESUMEN

Introducción: La obesidad ha ido aumentando de forma progresiva en las últimas décadas, y en la población pediátrica se ha convertido en uno de los problemas más graves de la salud pública. Los estudios sobre obesidad destacan la situación en España, con una elevada prevalencia, con Canarias y el sur de la península a la cabeza de la lista en esta enfermedad. Aunque, la obesidad infantil tiene una etiología compleja y multifactorial, donde intervienen factores genéticos, y ambientales, los hábitos alimenticios poco saludables y el estilo de vida sedentario son los principales factores de su aparición.

La motivación personal de individuo es especialmente importante para la adhesión a los cambios de hábitos de vida, y la adherencia al ejercicio y la actividad física suelen ser difíciles de mantener a largo plazo. Se sabe que en los niños y niñas, las razones para abandonar la actividad física están relacionadas principalmente con la dificultad para adaptarse a los horarios, la negativa a seguir la rutina, la insatisfacción con los resultados, entre otros motivos. Por lo tanto, es necesario trabajar no solo con personas afectadas por la obesidad, sino también educar a sus familiares, ya que es en el entorno familiar donde se adquieren y perpetúan los estilos de vida. Asimismo, los hábitos de vida saludables deben comenzar a funcionar desde la infancia, y para los niños y niñas el juego es una forma natural de aprender y puede ser una excelente estrategia para aplicar en programas de intervención educativa. La tecnología también proporciona herramientas muy útiles para apoyar a los niños y niñas en sus juegos y educación. Existen diferentes estudios sobre programas educativos que demuestran la eficacia del gasto calórico asociado con el uso de videojuegos activos, así como la efectividad del uso de tecnologías y la gamificación con niños y niñas para la promoción de hábitos saludables a corto plazo. Sin embargo, hay muy pocos estudios sobre si las intervenciones educativas sobre hábitos saludables con gamificación y videojuegos funcionan a largo plazo.

Objetivos: Evaluar la influencia del programa de intervención educativa gamificado en menores con obesidad que promueva la adquisición y permanencia de hábitos de vida saludables y que implique también a las familias.

Metodología: El diseño del estudio fue cuasi experimental, con un total de 46 participantes separados en dos grupos (experimental y control) pertenecientes a la zona

norte de la isla de Tenerife, Canarias. Se realizó un estudio longitudinal a largo plazo (3 años). El grupo experimental participó durante 9 meses en una intervención educativa sobre hábitos saludables y realizó ejercicio físico a través del juego motor y herramientas TICs. Ambos grupos y sus familias se beneficiaron de una sesión formativa sobre hábitos de vida saludables.

Resultados: Los resultados muestran mejoras significativas entre los grupos experimental y control en cuanto a sus conocimientos sobre la alimentación saludable, su adherencia a la dieta mediterránea, una mejora del comportamiento y un mayor sentido de la responsabilidad, así como un mayor control sobre cuestiones como el estrés social y la depresión.

Conclusión: Los hallazgos de este proyecto sugieren que un programa de intervención educativa gamificado y apoyado en las TIC ayuda a motivar y promover mejoras en los hábitos de vida de los niños y niñas.

Palabras clave: obesidad infantil, educación, gamificación, videojuegos activos.

ABSTRACT

Obesity has been increasing progressively in recent decades, and in the pediatric population it has become one of the most serious public health problems. Studies on obesity highlight the situation in Spain, with a high prevalence, and the Canary Islands and the south of the peninsula at the top of the list in this disease. Although, childhood obesity has a complex and multifactorial etiology, where genetic and environmental factors intervene, unhealthy eating habits and sedentary lifestyle are the main factors of its appearance.

The personal motivation of the individual is especially important for adherence to lifestyle changes. Adherence to exercise and physical activity is often difficult to maintain in the long term. In children, the reasons for abandoning physical activity are mainly related to difficulty in adapting to schedules, refusal to follow the routine, dissatisfaction with the results, among other reasons. Therefore, it is necessary to work not only with people affected by obesity, but also to educate their families, since it is in the family environment where lifestyles are acquired and perpetuated. Likewise, healthy lifestyle habits should start in childhood, and for children, play is a natural way to learn and can be an excellent strategy to apply in educational intervention programs.

Technology also provides very useful tools to support children in their play and education. There are different studies on educational programs that demonstrate the efficacy of caloric expenditure associated with the use of active video games, as well as the effectiveness of the use of technologies and gamification with children for the promotion of healthy habits in the short term. However, there are very few studies on whether educational interventions on healthy habits with gamification and video games work in the long term.

Objectives: To evaluate the influence of a gamified educational intervention program in children with obesity that promotes the acquisition and maintenance of healthy lifestyle habits and also involves the families.

Methodology: The study design was quasi-experimental, with a total of 46 participants separated into two groups (experimental and control) belonging to the northern area of the island of Tenerife, Canary Islands. A long-term longitudinal study (3 years) was carried out. The experimental group participated for 9 months in an educational

intervention on healthy habits and performed physical exercise through motor games and ICT tools. Both groups and their families benefited from a training session on healthy lifestyle habits.

Results: The results show significant improvements between the experimental and control groups in terms of their knowledge of healthy eating and adherence to the Mediterranean diet, improved behavior and a greater sense of responsibility, as well as greater control over issues such as social stress and depression.

Conclusion: The findings of this project suggest that a gamified and ICT-supported educational intervention program helps to motivate and promote improvements in children's lifestyles.

Keywords: childhood obesity, education, gamification, active video games.

Índice

PREFACIO

Obesidad infantil y estado actual del problema

En 2004, la OMS declara la obesidad como la epidemia del s. XXI tras alcanzar proporciones mundiales, aunque ya desde 1998 en su informe mundial de la salud hablaba de la obesidad como un problema de salud emergente. Los progresos en la lucha contra la obesidad infantil han sido lentos e irregulares, y en 2014 se estableció la Comisión para acabar con la obesidad infantil con el objetivo de examinar las estrategias existentes, elaborando un conjunto de recomendaciones destinadas a combatir la obesidad adaptadas a los diferentes contextos mundiales [1, 2].

Esta epidemia afecta principalmente a los países desarrollados y en vías de desarrollo, aunque ya no es exclusivo de países de altos ingresos y empieza a estar presente en países pobres, afectando a toda la población desde la infancia hasta la edad adulta.

La obesidad ha ido aumentando de forma progresiva en las últimas décadas, y en la población pediátrica se ha convertido en uno de los problemas más graves de la salud pública, estimándose que cerca de 41 millones de niños y niñas menores de cinco años tenían sobrepeso u obesidad en 2016, y si se mantienen las tendencias actuales, el número aumentará a 70 millones para 2025 [1, 3].

Los responsables del crecimiento de las cifras de obesidad infantil en el mundo son los cambios en los estilos de vida, y el desarrollo social y laboral que han sufrido la mayoría de las poblaciones: los alimentos tradicionales han sido reemplazados por alimentos más ricos en calorías, grasas, y azúcares, además de favorecerse una mala alimentación basada en bollería (industria alimentaria) aperitivos, sal y pobre en fruta, verdura, hortalizas, legumbres y pescado. Se realiza poca o ninguna actividad física debido, entre otras razones, al mayor nivel de urbanización y mecanización, a la evolución de los sistemas de transporte, los cambios en políticas sociales y sanitarias, el planteamiento urbano que deja poco espacio a zona verdes, y al largo tiempo que pasan los escolares realizando actividades de ocio sedentarias frente al ordenador o al televisor son algunos de ellos [4].

Además, la obesidad infantil tiene una etiología compleja y multifactorial, donde intervienen factores genéticos, y ambientales [5]. Aunque existe cierta predisposición genética, los hábitos alimenticios poco saludables y el estilo de vida sedentario son los principales factores de su aparición [6]. Esto se confirma con la escasa proporción de pacientes diagnosticados de obesidad a causa de una enfermedad genética o por trastornos hormonales, así como la asociación entre la práctica de actividad física de los

padres y madres y sus hijos, y su peso, demostrándose así que el peso viene determinado por factores de carácter modificable, no solo por los genes [7]. Tampoco se puede menospreciar influencia de otros factores de riesgo como obesidad en los padres y madres, el bajo nivel educativo y socioeconómico familiar, disfrutar de pocas horas de sueño, el elevado peso al nacer, o la lactancia materna artificial exclusiva que han demostrado un papel importante en el desarrollo y mantenimiento de la obesidad en la edad adulta en diferentes poblaciones estudiadas [8-13]. Por ejemplo, en los países con una alta renta per cápita, los niños y niñas de familias con un nivel socioeconómico más bajo son más propensos a tener sobrepeso u obesidad en comparación con aquellos niños y niñas de familias con un mayor nivel socioeconómico [14].

El sobrepeso y la obesidad son el quinto factor de riesgo de defunción en el mundo, y se le atribuyen cerca de tres millones de muertes al año [1, 15]. Los problemas de salud derivados de padecer sobrepeso u obesidad se calculan en el 58% de la carga de diabetes, el 21% de cardiopatías isquémicas, y entre el 8% y 42% de algunos cánceres y estos riesgos crecen en proporción al aumento de peso corporal y representan una carga importante para la calidad de vida. Antes de que se manifiesten las enfermedades crónicas, generalmente ocurren varios factores de riesgo, y la acumulación de estos factores de riesgo no solo se manifiesta en adultos sino también en niños y niñas pequeños y adolescentes [16. 17]. Por ello, para la identificación de los síntomas del conocido como síndrome metabólico (una tríada de hipertensión, dislipidemia y alteración de la tolerancia a la glucosa) que aumenta estos factores de riesgo se han establecido valores de referencia para niños y niñas en el European IDEFICS (*Identification and Prevention of Dietary-and Lifestyle-Induced Health Effects in Children and Infants*) [18, 19].

A pesar de que aún se desconoce cuál es la estrategia óptima para contrarrestar los factores de riesgo cardiometabólico en los menores, cada vez es mayor la evidencia científica que muestra cómo la actividad física parece ser una de las opciones de tratamiento y prevención más relevantes de las patologías cardiovasculares y metabólicas más frecuentes en países desarrollados [20].

No obstante, una reciente editorial subrayó que la mayor parte de los estudios que utilizan el ejercicio como medicina presentan una muy baja adherencia al mismo fuera de las estrictas condiciones del laboratorio [21]. Es por este motivo que es necesario desarrollar intervenciones educativas atractivas para la población infantil, donde se logre la adherencia al ejercicio físico, que al mismo tiempo contribuya a reducir el tiempo en conductas sedentarias, un factor clave para luchar contra esta enfermedad. Y aunque está ampliamente demostrado que el incremento en los niveles de actividad físico es un elemento fundamental para ayudar a mejorar y disminuir los factores de riesgo cardiometabólico y de resistencia a la insulina en niños y niñas, la realidad es que, lejos de aumentar el ejercicio realizado, los menores diagnosticados con sobrepeso y

obesidad prefieren actividades sedentarias en mayor medida que aquellos que no sufren esta enfermedad, pues en general, no disfrutan con la práctica deportiva y el ejercicio físico [22. 23]. Es necesario el uso de nuevas alternativas al ejercicio tradicional, buscando principalmente el disfrute y la adherencia. En este sentido, los avances tecnológicos han abierto un nuevo abanico de posibilidades con la aparición de los videojuegos activos que permiten enfocar las intervenciones desde una perspectiva más atractiva para la población infantil [24]. Los videojuegos activos abarcan distintas modalidades, incluyendo la simulación de distintas actividades deportivas, el baile y juegos basados en la captura en vídeo del propio movimiento corporal, convirtiéndose en un apoyo audiovisual e interactivo ante la propia práctica de ejercicio. Entre otros estudios, se catalogaron varios tipos de videojuegos activos en función de intensidad en equivalentes metabólicos (MET), llegando a alcanzar en el caso de algunos niveles de los videojuegos de baile la categoría de actividad física vigorosa según el criterio de la OMS [25].

La Sociedad Española para el Estudio de la Obesidad (SEEDO), confirma que el 44,5% de los niños y niñas españoles sufre de exceso de peso, y esto significa que prácticamente uno de cada dos niños tiene exceso de peso con respecto a los patrones de crecimiento que establece la OMS. Solo Italia y Chipre superan estas cifras a nivel europeo, según el estudio IDEFICS (Identification and prevention of Dietary-and lifestyle-induced health Effects In Children and infants) cuyo objetivo era valorar los riesgos del sobrepeso y la obesidad en niños y niñas, y sus consecuencias asociadas a largo plazo en toda la Unión Europea [26]. La comparación de los resultados de los últimos estudios epidemiológicos realizados en España, el estudio Paidos (1984) y el estudio EnKid (1998-2000), pone de manifiesto el aumento del IMC de la población infantil y, por tanto, del aumento en la prevalencia de obesidad infantil en España entre los años 1984 y 1998. Sin embargo, un estudio reciente señala que, aunque en España la prevalencia de la obesidad infantil sigue siendo alta, en los últimos 12 años esta no ha aumentado [27].

Esta prevalencia de la obesidad infantil en España, y en especial en Canarias, se plasma en diversos estudios desarrollados en todo el ámbito nacional, entre los que destaca el estudio ENKIND, realizado entre 1998 y 2000 en la población española de entre 2 a 24 años, diseñado para evaluar los hábitos alimentarios y el estado nutricional de la población infantil y juvenil española. Establece una prevalencia del 26,3% entre sobrepeso y obesidad (obesidad 13,9 %; sobrepeso 12,4 %). Este estudio determina para Canarias una prevalencia total entre obesidad y sobrepeso de un 32,8 %, (obesidad del 18% y sobrepeso de un 14,8 %) [28].

Estos resultados se suman a los dados por el estudio ALADINO de 2011 [29] donde especifica que la población infantil con edades comprendidas entre los 6 y 9 años, presentan una prevalencia de un 26,2% de sobrepeso y 18,3% de obesidad. En Canarias, los resultados fueron un 21,2% y 28,4% respectivamente, siendo la comunidad

autónoma española con el mayor índice de obesidad infantil, junto con Andalucía. En su última actualización en 2019 [30], se observa una tendencia descendente del exceso de peso desde 2011 y estabilización respecto a 2015, aunque la prevalencia de sobrepeso y obesidad de los escolares de 6 a 9 años en España sigue siendo elevada (la prevalencia de sobrepeso es del 23,3% y la prevalencia de obesidad del 17,3%).

Todos estos estudios reflejan que España tiene una elevada prevalencia de obesidad, con Canarias y el sur de la península a la cabeza de la lista.

La asociación entre la obesidad infantil y los factores de riesgo de enfermedades crónicas, su persistencia en la edad adulta y el escaso éxito en su tratamiento hace que los esfuerzos de los gobiernos y organismos sanitarios se centren en la prevención en esta etapa de la vida, sabiendo que la mayoría de las conductas y hábitos se adquieren a edades tempranas, se vuelve crucial promover desde todos los ámbitos los estilos de vida saludables. Desde hace unos años han ido apareciendo políticas sociales, investigaciones y programas educativos para su prevención y tratamiento desde distintas áreas (escuela, sociedad, familias).

En este sentido, la OMS adoptó en mayo de 2004 la “Estrategia Mundial sobre régimen alimentario, actividad física y salud” (2), y continua con “El Plan de Acción 2013-2020 de la Estrategia Mundial para la Prevención y el Control de las Enfermedades no Transmisibles” [31], ambos planes presentan una serie de medidas para fomentar la alimentación saludable y la actividad física, reduciendo el riesgo de padecer una enfermedad crónica, incrementar la concienciación de la población, o establecer y aplicar políticas y planes de acción que lo apoyen.

En términos similares se expresa, el “III Plan Estratégico Nacional de Infancia y Adolescencia 2013-2016”, del Ministerio de Sanidad, Servicios Sociales e Igualdad, que en el objetivo estratégico 7, promueve actuaciones en materia de prevención, promoción y protección de la salud en la infancia y la adolescencia para alcanzar el máximo desarrollo de los derechos a la salud, dando prioridad a las poblaciones más vulnerables, y entre sus medidas se contempla fomentar una alimentación saludable y la práctica regular de actividad física, así como educación en prevención de la obesidad infantil” [32]. Asimismo, en el año 2005 surge la “Estrategia NAOS (Estrategia para la Nutrición, Actividad Física y Prevención de la Obesidad)”, desde el Ministerio de Sanidad y Consumo, a través de la Agencia Española de Seguridad Alimentaria y Nutrición (AESAN), con el objetivo de sensibilizar a la población del problema que la obesidad representa para la salud, y de impulsar todas las iniciativas que contribuyan a lograr que se adopten hábitos de vida saludables, estando presente en todos los ámbitos: la familia, el colegio, el sector empresarial y el sistema sanitario. Su lema es: “¡Come sano y muévete!”, y en 2011 se consolidó la Estrategia NAOS con la Ley 17/2011 de 5 de julio de seguridad alimentaria y nutrición [33].

Paralelamente a la estrategia NAOS, surgió en 2006 el Programa PERSEO (Programa Piloto Escolar de Referencia para la Salud y el Ejercicio, contra la Obesidad) cuyo principal objetivo es promover la adquisición de hábitos de alimentarios saludables y estimular la práctica de actividad física regular entre los escolares, para prevenirla aparición de obesidad y otras enfermedades. Este programa realizó en un conjunto de intervenciones sencillas en los centros escolares, dirigidas al alumnado de entre 6 y 10 años, implicando asimismo a las familias y actuando simultáneamente sobre el comedor y el entorno escolar para facilitar la elección de las opciones más sanas. Implantado en seis comunidades, entre ellas en Canarias, y dos ciudades autónomas, los resultados de dos años de intervención demostraron el efecto positivo en los hábitos de alimentación y actividad física en los participantes y entre sus conclusiones consideraban la implementación a largo plazo [34].

El Programa Thao-Salud Infantil, es otro ejemplo de programas que se desarrollaron dentro de la comunidad, llevada a cabo desde el 2007 hasta el 2015 por la AESAN y el Ministerio de Sanidad, Servicios Sociales e Igualdad, con el fin de prevenir la obesidad infantil en España. Era un programa municipal y comunitario de promoción de estilos de vida saludables dirigido a niños y niñas de 0 a 12 años, y sus familias. Promovía la alimentación equilibrada, variada y placentera, y la actividad física regular, los hábitos adecuados de descanso e interviene de manera transversal sobre los factores psicológicos, emocionales y la relación familiar y social. Se implementó desde el municipio gracias al liderazgo del alcalde o alcaldesa y los responsables políticos, mediante la coordinación de un técnico municipal: el “coordinador local”. Con una duración aproximada de un año escolar, implicaba a toda la comunidad (docentes, ciudadanía, comerciantes y empresas, a profesionales de la salud, entre otros actores) [35].

El Programa SI! creado y dirigido por el Dr. Valentín Fuster para promover hábitos de vida saludables y contribuir en la mejora de la salud cardiovascular y la calidad de vida de toda la sociedad. Este programa se desarrolla en la Comunidad de Madrid, con 98 escuelas participantes y 7000 mediciones (menores, familias, profesorado). Se han llevado a cabo estudios científicos para validar el programa con niños y niñas de 3-6 años, en 24 escuelas con mediciones de 2.000 estudiantes, sus familias y profesorado durante los cursos 2011-2012 y 2013-2014 y los resultados finales demuestran que si bien se adquieren conocimientos en los primeros años, no es hasta el tercer año de la intervención donde se logra más impacto en modificación de hábitos. El programa ha desarrollado su actuación en Primaria (de 6 a 12 años) durante 6 años (de 2014 a 2020), incluyendo un seguimiento de los niños y niñas que comenzaron su vida escolar con el “Programa SI!” [36].

El programa de educación multidisciplinario “¡Niñ@s en movimiento!” dirigido a niños y niñas de entre 7 y 12 años promueve cambios en los estilos de vida y en los hábitos

alimentarios insanos responsables de la ganancia de peso, siempre con el objetivo de conseguir una normalización del índice de masa corporal en el menor y en el entorno familiar, como herramienta para combatir la obesidad infantil. Los tres pilares del programa son el aumento de la actividad física para combatir el sedentarismo, la promoción de una alimentación sana y equilibrada, y el desarrollo afectivo y emocional, aumentando la autoestima y las relaciones sociales. También tienen programas destinados a menores de 5 a 7 años y a adolescentes de 13 a 18 años que se aplican en centros educativos, centros de atención primaria y hospitales [37].

El 'Plan de frutas y hortalizas en las escuelas' se trata de un programa europeo de promoción del consumo de frutas y verduras, propuesto por la Comisión Europea en 2008 y con carácter voluntario para los Estados Miembros, con el objetivo de promover hábitos de alimentación saludables, favoreciendo la prevención de la obesidad y de las enfermedades asociadas, dado que es conocido que el consumo de frutas y hortalizas incide sobre el mantenimiento y mejora de la salud de las personas. El plan consiste en la distribución de frutas y hortalizas frescas durante el recreo escolar para su degustación, fuera de los horarios habituales de otras comidas y comprende además distintos talleres de carácter educativo dirigidos a promover la participación de los escolares y reforzar el propósito de esta iniciativa. La Comunidad Autónoma de Canarias se adhirió al Plan desde sus comienzos en el curso escolar 2009-2010, y desde entonces ha continuado su desarrollo hasta la actualidad. La Comunidad Autónoma de Canarias se adhirió al Plan desde sus comienzos en el curso escolar 2009-2010, y desde entonces ha continuado su desarrollo hasta la actualidad. Durante el curso 2020, se beneficiaron de este plan de consumo de frutas y verduras un total de 86.207 escolares de 413 centros educativos de toda Canarias [38].

El proyecto "Videojuegos activos frente a la obesidad y el sedentarismo en niños y niñas de 9 a 11 años: una propuesta disruptiva", subvencionado desde el Ministerio de Economía, Industria y Competitividad desde 2016, tiene como propósito no solo conseguir que los participantes se muevan, incrementando de gasto energético sino también conseguir una actividad gratificante y divertida que los anime a participar en actividades físicas programadas, escolares y extraescolares. Se trata de un estudio que incluye a 92 niños y niñas de entre 9 y 11 años con sobrepeso u obesidad que divididos aleatoriamente en 2 grupos homogéneos (control-intervención). El grupo intervención seguirá un programa de ejercicio físico con videojuegos activos (3-4 días/semana) con 2 periodos de intervención de 9 meses [39].

"Activilandia" es un parque temático virtual desarrollado por el Ministerio de Sanidad como parte de una campaña que trata de promover una alimentación equilibrada y la práctica de ejercicio físico habitual en menores de entre 6 y 12 años para luchar contra el sobrepeso y la obesidad. En él se combinan contenidos lúdicos y educativos en forma de juegos, vídeos, y música. Aporta contenido informativo para las familias y educadores,

convirtiéndose en un recurso didáctico para su aplicación en el aula y en los hogares. La campaña se extendió a aproximadamente 14.000 colegios de primaria, públicos, privados y concertados de todo el país [40].

También se cita como programas de prevención y promoción de la salud, la iniciativa de Antena 3, "Objetivo Bienestar Junior" contra la obesidad infantil en España, con consejos e iniciativas que premian a los colegios "saludables".

Finalmente por todo lo anteriormente descrito se planteó el desarrollo de un estudio que valorase la efectividad de un modelo de intervención educativa gamificado utilizando videojuegos activos y juegos motores en el cambio de actitudes y hábitos saludables en niños y niñas con obesidad en comparación con el modelo actual de tratamiento que se lleva a cabo en las consultas médicas, así como servir de herramienta para la prevención y promoción de la salud en estilos de vida saludables desde el ámbito familiar. Dicho proyecto de investigación se tituló PROVITAO acrónimo de "Programa de Videojuegos Activos para el Tratamiento Ambulatorio de la Obesidad", Ref OBE05. La intervención que se describe y es objeto de estudio de esta tesis doctoral se encuentra enmarcada dentro de este proyecto de investigación.

Hipótesis, objetivos y organización

La hipótesis que se plantea en esta investigación es la siguiente:

"*La intervención propuesta es una herramienta eficaz para favorecer la adquisición de hábitos saludables en los niños y niñas y sus familias, y que repercute en la mejora de la calidad de vida, actual y futura, de los menores que padecen obesidad infantil.*"

Los principales objetivos de investigación de esta tesis doctoral se organizan en objetivos generales y específicos, tal y como se citan a continuación.

Objetivos generales:

1. Promover la adquisición y permanencia de hábitos de vida saludables en niños y niñas con sobrepeso/obesidad a través de la educación para la salud.
2. Evaluar la influencia del programa de intervención educativa en menores con sobrepeso/obesidad.
3. Promover una conciencia social sobre la importancia de la prevención de la obesidad infantil (complicaciones a corto y largo plazo, y costes sanitarios y sociales).

Objetivos específicos:

1. Diagnosticar la situación de los menores con sobrepeso/obesidad en relación con su estado físico y sus necesidades.
2. Valorar los hábitos y los estilos de vida (hábitos, costumbres y creencias) previos de los niños y niñas con exceso de peso y sus familias.
3. Dar información veraz sobre los hábitos de conducta saludables, y eliminar los mitos.
4. Crear un entorno familiar que refuerce el programa educativo en hábitos alimenticios saludables y actividad física frecuente.
5. Analizar la eficacia de la intervención para la promoción de hábitos saludables, mediante evaluaciones periódicas.
6. Comunicar y difundir las actividades y resultados obtenidos a toda la comunidad científica, médica y social.
7. Medir la motivación del niño o niña ante la actividad física desarrollada con juego motor y videojuego activo.

La presente tesis doctoral se presenta en la modalidad de compendio de artículos cuyos trabajos originales se encuentran publicados en revistas científicas indexadas en el Journal Citation Reports (JCR), según se detalla a continuación:

1 González-González, C.S.; Gómez del Río, N.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2021). Active game-based solutions for the treatment of childhood obesity. Sensors 2021, 21, 1266 **(JCR, Q1)**.
DOI: https://doi.org/10.3390/s21041266.
Disponible en: https://www.mdpi.com/1424-8220/21/4/1266

2 Gómez del Río, N.; González-González, C.S.; Toledo-Delgado, P.A.; Muñoz-Cruz, V.; García-Peñalvo, F. (2020). Health Promotion for Childhood Obesity: An Approach Based on Self-Tracking of Data. Sensors 2020, 20, 3778. **(JCR, Q1)**
DOI: https://doi.org/10.3390/s20133778.
Disponible en: https://www.mdpi.com/1424-8220/20/13/3778

3 Gómez del Río, N.; González-González, C.S.; Martín-González, R.; Navarro-Adelantado, V.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2019). Effects of a gamified educational program in the nutrition of children with obesity. Journal of medical systems, 43(7), 198. **(JCR, Q1)**
DOI: 10.1007/s10916-019-1293-6
Disponible en: https://link.springer.com/article/10.1007/s10916-019-1293-6

Además de los artículos anteriormente citados, que avalan la modalidad de tesis por compendio de publicaciones, se han realizado otras contribuciones científicas que se citan en la sección correspondiente, además de estar incluidas en las referencias bibliográficas del documento. Por lo tanto, se procede a presentar una relación de las publicaciones relacionadas con los diferentes objetivos de la tesis, teniendo en cuenta que, al dar respuesta a estos, algunos objetivos están íntimamente ligados y se responden en conjunto (Tabla 0):

Tabla 0. Relación de objetivos de la tesis doctoral con resultados publicados

Objetivo General	**Objetivo Específico**	**Resultados publicados**
1. Promover la adquisición y permanencia de hábitos de vida saludables en niños y niñas con sobrepeso/obesidad a través de la educación para la salud.	1. Diagnosticar la situación de los menores con sobrepeso/obesidad en relación con su estado físico y sus necesidades. 2. Valorar los hábitos y los estilos de vida previos de los niños y niñas con exceso de peso y sus familias. 3. Dar información veraz sobre los hábitos de conducta saludables, y eliminar los mitos. 4. Crear un entorno familiar que refuerce el programa educativo en hábitos alimenticios saludables y actividad física frecuente.	Presentación del diseño y programa de formación gamificado sobre hábitos de vida saludables [41,42] Exposición de videojuegos activos y herramientas tecnológicas que complementan la gamificación del programa [43,44]
2. Evaluar la influencia del programa de intervención educativa en menores con sobrepeso/obesidad.	5. Analizar la eficacia de la intervención para la promoción de hábitos saludables, mediante evaluaciones periódicas.	Resultados parciales de todas las áreas de estudio dentro del proyecto. [43,45] Resultados centrados en el aprendizaje de hábitos relacionados con la alimentación [46,47] Resultados centrados en el uso de los sensores y herramientas TIC [42,48] Exposición del estudio de caso único para dar una visión global del programa [49]
	7. Medir la motivación del niño o niña ante la actividad física desarrollada con juego motor y videojuego activo.	Resultados sobre la satisfacción respecto a los juegos de los participantes del programa [50,51]

3. Promover una conciencia social sobre la importancia de la prevención de la obesidad infantil (complicaciones a corto y largo plazo, y costes sanitarios y sociales).	6. Comunicar y difundir las actividades y resultados obtenidos a toda la comunidad científica, médica y social.	Talleres realizados con menores en diferentes escuelas sobre los hábitos de vida saludables [52]

Para el logro de los objetivos propuestos en la tesis doctoral se propuso una metodología que se divide en diferentes fases.

El enfoque metodológico aplicado en la investigación fue de corte mixto cuasi experimental para la intervención en centros educativos, hospitalarios y análisis de casos, combinando técnicas cualitativas y cuantitativas.

Con respecto a la organización de este documento, la presente tesis doctoral se ha preparado siguiendo esta estructura: el Capítulo 1 presenta el diseño de la investigación. El Capítulo 2 presenta una síntesis del programa de intervención educativa desarrollada durante tres cursos académicos, dividida en sus diferentes fases. El Capítulo 3 muestra el resumen de los principales resultados obtenidos del programa de intervención relacionados con el conocimiento sobre hábitos de vida saludables (alimentación). Finalmente, en el Capítulo 4 se presentan las conclusiones junto con las posibles limitaciones de la investigación realizada, así como la propuesta de las futuras líneas de investigación relacionadas. Por último, se anexan las principales artículos derivados de esta tesis doctoral: en el Anexo 1 se expone el artículo donde se realizó una revisión del estado del arte; en el Anexo 2 se detalla el modelo de intervención educativa gamificado; en el Anexo 3 se presenta el artículo donde se habla las soluciones basadas en juegos activos que se usaron durante la intervención, así como algunos de los resultados parciales; y en el Anexo 4 se recoge el artículo donde se presentan los principales resultados de la intervención y que se exponen en esta tesis.

CAPÍTULO 1.
DISEÑO DE LA INVESTIGACIÓN

Introducción

En esta sección se describen los materiales y métodos utilizados en el proyecto. En primer lugar, se presentan los protocolos éticos relacionados a la intervención, así como la metodología cuasi experimental llevada a cabo en diferentes fases anuales. Asimismo, se presenta la muestra del estudio conformada por 46 menores de la isla de Tenerife con obesidad, divididos en un grupo control y otro experimental. Además, se presentan los instrumentos, haciendo especial énfasis en la plataforma de videojuegos activos TANGO:H, así como las variables analizadas y el procedimiento llevado a cabo durante los tres años de intervención del programa. El diseño de la investigación ha sido publicado en diferentes artículos derivados de esta tesis [41-44].

A continuación, se describe el diseño de la investigación llevada a cabo en esta tesis doctoral.

Diseño

El diseño de la investigación es de corte cuasi experimental, longitudinal y prospectivo de 3 años de duración (2014-2017).

No existieron problemas o riesgos derivados del estudio para los participantes. Los tutores legales de todos los participantes han sido informados y han firmado un consentimiento para utilizar sus datos para el estudio y para compartirlos con la comunidad científica. El tratamiento, la comunicación y la transferencia de datos personales de todos los sujetos participantes cumplen con las disposiciones de la Ley Orgánica 15/1999, de 13 de diciembre, sobre la protección de datos personales. Los protocolos utilizados en el estudio han sido aprobados por el Comité de Ética del Hospital Universitario de Canarias y el Comité de Ética de la Universidad de La Laguna, Referencia CEIBA2020-0410.

El estudio se dividió en dos fases anuales, en cada una de ellas se repitió la misma intervención en grupos diferentes de sujetos.

Cada fase de intervención anual fue diseñada para llevarse a cabo con un grupo experimental y un grupo de control, de 10 a 15 niños y niñas con edades comprendidas entre los 6 y los 12 años, todos ellos del área norte de la isla de Tenerife.

Los criterios de inclusión fueron la edad (6-12 años); índice de masa corporal (IMC) en el percentil 97 o superior; tener el permiso de los padres, madres o tutores legales para

participar en el estudio; no padecer patologías que les impidan participar en el estudio; y no haber participado en otro ensayo clínico en los últimos 12 meses.

Los criterios de exclusión fueron la participación durante los últimos 12 meses en un ensayo clínico; que los menores no presentasen deterioro cognitivo que les impidiese participar en el proyecto; y que no contasen con tecnologías de redes básicas en casa (ordenador e internet) y televisor (solo para grupo experimental). El proyecto se encargará de proporcionar el resto de las herramientas tecnológicas requeridas para la intervención en el domicilio (sensor Kinect, consola Wii y Wii balance board) y en las sesiones grupales.

En la Fase 1, la muestra se compuso de niños y niñas seleccionados en las Consultas Externas de Pediatría del Hospital Universitario de Canarias (HUC) que se encontraban en tratamiento ambulatorio para la obesidad infantil. El Grupo Experimental (G1) estaba formado por 13 menores con obesidad/sobrepeso (5 niños y 8 niñas) que participaron en el programa de intervención. El Grupo de Control (G2) estaba compuesto por 10 menores con obesidad/sobrepeso (7 niños y 3 niñas) que no participaron en el programa de intervención.

En la Fase 2, debido a que no se encontraron suficientes participantes que cumplieran los criterios de inclusión del estudio en el HUC, los participantes fueron seleccionados desde diferentes escuelas de educación pública del distrito de La Laguna. El Grupo Experimental (G3) consistió en 12 menores con obesidad/sobrepeso (5 niños y 7 niñas) que participaron en el programa de intervención. El Grupo de Control (G4) estaba compuesto por 11 menores con obesidad/sobrepeso (4 niños y 7 niñas) que no participaron en el programa de intervención.

La asignación de los participantes a los grupos experimental y de control en ambas fases se realizó en función al compromiso y disponibilidad de las familias para asistir a todas las sesiones presenciales (grupo experimental) o solo a las evaluaciones (grupo control).

Participantes

La Tabla 1 resume las principales características de los 46 menores participantes del estudio divididos en grupo experimental (25 menores) y grupo control (21 menores). El nivel educativo de las familias fue considerado como un indicador socioeconómico, estableciendo tres categorías: alto (estudios universitarios); medio (educación secundaria) y bajo (no educación o solo educación primaria).

Tabla 1. Detalle de los participantes en el estudio

Fase 1												
ID G1	Sexo	Edad	IMC*	Escuela	Nivel socio-económico familias		ID G2	Sexo	Edad	IMC*	Escuela	Nivel socio-económico familias
GE01	F	11	33,3	Pública	B		GC01	M	6	22,91	Pública	B
GE02	F	8	22,16	Pública	M		GC02	F	11	25,57	Privada	M
GE03	M	10	26,96	Pública	B		GC03	F	10	25,42	Pública	M
GE04	F	10	35,72	Pública	B		GC04	M	8	26,65	Pública	B
GE05	F	7	40,32	Pública	B		GC05	M	7	32,85	Pública	B
GE06	F	10	31,68	Privada	M		GC06	F	8	29,28	Pública	B
GE07	F	6	21,73	Pública	M		GC07	M	6	21,3	Pública	M
GE08	M	11	34,82	Pública	B		GC08	M	10	27,8	Pública	B
GE09	M	9	33	Pública	M		GC09	M	8	25,78	Pública	B
GE10	F	7	40,54	Pública	B		GC10	M	10	26,75	Pública	B
GE11	M	11	31,01	Pública	B							
GE12	M	10	27,87	Pública	M							
GE13	F	12	33,46	Pública	M							
Fase 2												
ID G3	Sexo	Edad	IMC*	Escuela	Nivel socio-económico familias		ID G4	Sexo	Edad	IMC*	Escuela	Nivel socio-económico familias
GE21	F	6	23,68	Pública	M		GC21	F	12	30,63	Pública	M
GE22	F	9	31,01	Pública	M		GC22	M	10	29,88	Pública	M
GE23	F	8	34,94	Pública	B		GC23	M	9	28,1	Pública	M
GE24	F	11	31,17	Pública	M		GC24	M	12	24,95	Pública	A
GE25	M	11	24,67	Pública	B		GC25	F	11	30,1	Pública	A
GE26	F	10	25,64	Pública	M		GC26	M	10	23,52	Pública	M
GE27	M	9	30,13	Pública	B		GC27	F	12	27,93	Pública	M
GE28	F	8	25,76	Pública	M		GC28	F	10	25,56	Pública	M
GE29	M	11	23,63	Pública	M		GC29	F	8	24,61	Pública	M
GE30	M	8	25,71	Pública	M		GC30	F	8	21,33	Pública	M
GE31	F	8	28,65	Pública	B		GC31	F	9	25,17	Pública	A
GE32	M	11	25,09	Pública	M							

* Percentil >=97 de acuerdo a la OMS [28]

ID: Código identificación de los participantes en función del grupo.

Sexo: F: Femenino / M: Masculino

Nivel socioeconómico: A: Alto, M: Medio, B: Bajo

Instrumentos

El estudio involucró el uso de diferentes instrumentos para analizar diferentes datos en cada área de estudio.

Se recogían las siguientes variables: nombre, sexo, fecha de nacimiento y edad, lugar de residencia, curso, centro educativo, medidas antropométricas (peso, altura, pliegues cutáneos, y perímetros corporales para valorar no solo en índice de masa corporal, sino para conocer también la cantidad de grasa, músculo y masa ósea), y parámetros analíticos. Para medir la composición corporal y medidas biomédicas se han utilizaron los siguientes instrumentos: pesa digital con tallímetro, lipocalibre y calibre, cinta métrica inextensible, curva de crecimiento para determinar los percentiles y los análisis de sangre se usaron para determinar valores bioquímicos (colesterol, triglicéricos, insulina, hormonas). También se registró en el momento de la toma de las medidas antropométricas: fecha y hora de la medición, ropa que lleva en el momento de la medición. La báscula y el tallímetro se comprobaron y calibraron con frecuencia, y como mínimo al principio de cada día que se realizaron las medidas.

Para analizar las emociones durante la intervención se utilizó la Emodiana [53], un instrumento que permite medir 10 emociones básicas, representadas con diferentes expresiones de un personaje asociadas a sus correspondientes etiquetas, ajustadas al lenguaje utilizado por los niños y niñas. Este instrumento se representa como una diana permitiendo medir la intensidad de cada emoción, en una escala de tipo Likert, siendo un 5 la emoción más intensa en el centro y un 1 la más débil en el exterior de la diana. Se usaba durante las sesiones de intervención grupal al inicio y al final de cada una.

Para valorar el esfuerzo que perciben los participantes al hacer ejercicio, se usó la Escala de Esfuerzo Percibido para la población Infantil (CERT - *Children Effort Rating Table*) [54], esta escala presenta un rango de categorías numéricas intuitivo (1-10) y expresiones verbales de esfuerzo ampliamente entendidas por los niños y adolescentes. Se usó al final de las sesiones de intervención grupal.

Para estudiar la conducta y personalidad de los niños y niñas se seleccionó el BASC (Sistema de evaluación de la conducta de niños y adolescentes) adaptación española del cuestionario de Reynolds y Kamphaus [55], un cuestionario multidimensional que mide numerosos aspectos del comportamiento y la personalidad. En el auto informe el niño, niña o adolescente describe sus emociones y percepciones y proporciona información sobre escalas clínicas (actitud negativa hacia el colegio, actitud negativa hacia los profesores, búsqueda de sensaciones, atipicidad, locus de control, somatización, estrés social, ansiedad, depresión y sentido de incapacidad) y escalas adaptativas (relaciones interpersonales, relaciones con los padres y madres, autoestima y confianza en sí

mismo). Permitiendo la obtención de cuatro dimensiones globales: desajuste escolar, desajuste clínico, ajuste personal y un índice general, el índice de síntomas emocionales.

Para conocer los hábitos sobre actividad física y la percepción de bienestar nos decantamos por una adaptación del cuestionario diseñado por Manuel Delgado y Pablo Tercedor en 2002 en la "Estrategia de intervención en educación para la salud desde la educación" [56]. La Adaptación del Cuestionario sobre actividad físico-deportiva y salud-bienestar es un cuestionario de 22 ítems en las que se valoran: estados de la actividad física (actividad física o deporte practicado, días y horas a la semana, horas de inactividad, etc.), disfrute con la actividad física, autopercepción de la competencia motriz y utilidad de la actividad física y el deporte, alimentación, salud y bienestar personal.

Por otra parte, para determinar la adhesión y el índice de calidad de la dieta Mediterránea, considerada cardiosaludable, se utilizó el cuestionario KIDMED [57]. Este test cuenta con 16 ítems de tipo dicotómico de respuesta afirmativa o negativa que recoge los principales indicadores de la alimentación. Las respuestas afirmativas en las preguntas que representan una connotación negativa en relación con la Dieta Mediterránea (ítems 6, 12, 14 y 16) valen -1 punto, y las respuestas afirmativas en las preguntas que representan un aspecto positivo en relación con la Dieta Mediterránea valen +1 punto. Si la respuesta es no sabe/no contesta no puntúan. Por tanto, dicho índice puede oscilar entre -4 y 12.

Finalmente, para evaluar el perfil del video jugador de los niños y niñas se escogió el test del perfil del jugador, una adaptación del cuestionario sobre uso y actitudes hacia los videojuegos de Alfageme y Sánchez [58], un cuestionario con un total de 12 preguntas que se centran en el tipo de videojuegos que juega el menor, las horas a la semana que le dedica, y los valores y creencias respecto a los videojuegos.

Como excepción, en la fase 2 se diseñó un cuestionario que titulamos Informe de Salud Infantil, donde les solicitamos a los padres y madres, los datos demográficos e información médica de sus hijos e hijas relativa a antecedentes de salud (enfermedades pasadas), problemas de salud (enfermedades presentes actualmente) y tratamiento médico que estuviera recibiendo con el fin de hacer una valoración inicial ya que dichos niños y niñas no fueron seleccionados desde el hospital como fuera el caso del año previo. Dicho informe estaba bajo la ley de protección de datos y sólo fue tratado por el personal sanitario del proyecto con fines científicos. Este documento se rellenó únicamente al inicio del estudio.

Para la recogida y registro de las variables: frecuencia cardiaca, distancia recorrida, tiempo, velocidad y gasto calórico, se seleccionaron y estudiaron como instrumentos los sensores biométricos utilizados en la intervención y los sensores de movimiento para los

ejercicios de TANGO:H [59]. Para un mayor detalle de las variables que se ha considerado en este estudio ver Anexo 2.

En las sesiones de intervención grupal se usaron los pulsómetros y acelerómetros del tipo *wearable* reloj pulsera + cinturón de la marca Decathlon (Geonaute Onmiles 600), dichos sensores de tipo comercial traen su propio *software* de análisis.

Por otra parte, se destacó la utilización de la plataforma TANGO:H en las diferentes sesiones realizadas en el proyecto. Las plataformas de videojuegos activos se describen con mayor detalle en el Anexo 3. A continuación, se describirá brevemente una de las plataformas utilizadas para realizar ejercicios físicos gamificados durante la intervención.

TANGO:H

Como se ha descrito anteriormente, PROVITAO es un programa de intervención educativa que utiliza ejercicios físicos gamificados, estimulando el movimiento corporal y una participación más activa a través de juegos digitales activos o exergames, que permiten capturar, virtualizar y reproducir los movimientos físicos del jugador para llevar a cabo los retos que se le presentan en el juego.

Por tanto, todas las sesiones realizadas fueron diseñadas desde un punto de vista lúdico, esto significa que después de cada contenido teórico se realizaba un juego activo que lo reforzaba, utilizando en particular un videojuego activo o exergame llamado TANGO:H.

TANGO:H es una plataforma creada mediante un convenio de colaboración entre el Instituto Tecnológico y de Energías Renovables (ITER) y el grupo de Investigación Interacción, Tecnología y Educación (i- TED) del Departamento de Ingeniería de Sistemas y Automática y Arquitectura y Tecnología de Computadores de la Universidad de La Laguna. TANGO:H permite al usuario interactuar con la aplicación sin necesidad de un medio intermedio físico, a través de gestos utilizando su propio cuerpo.

El sistema proporciona al usuario la capacidad de jugar tanto en solitario como en un modo multijugador de forma secuencial, colaborativa o competitiva (Figura 1, 2, 3).

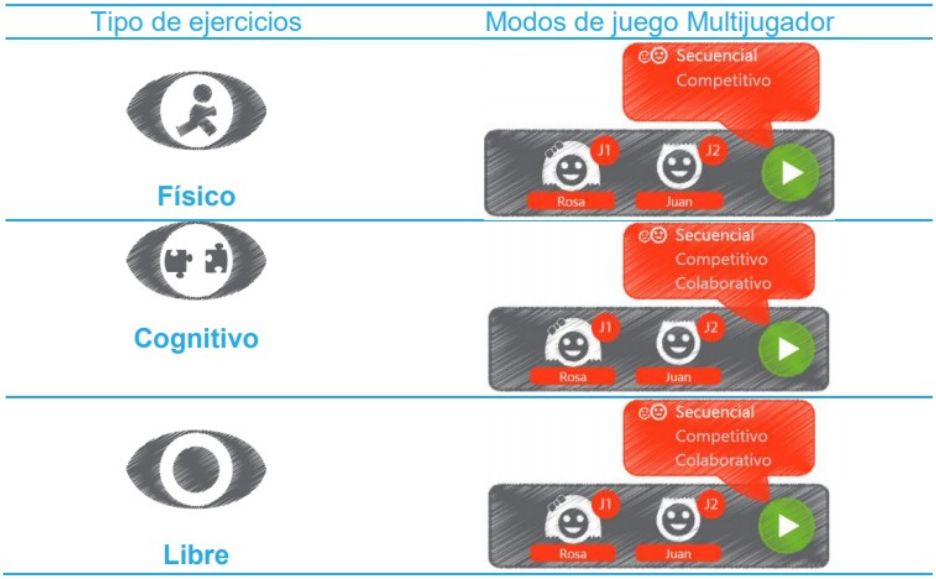

Figura 1. Tipos de ejercicios y modos de juego de TANGO:H.

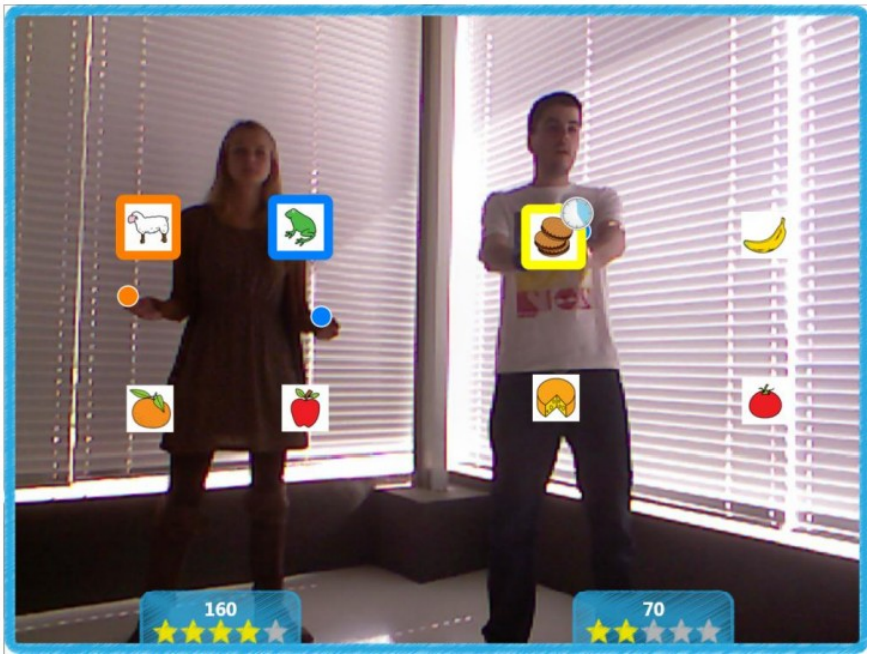

Figura 2. Ejemplo del modo competitivo de juego: Dos jugadores compiten simultáneamente para tener mayor puntuación en un ejercicio.

Figura 3. Ejemplo del modo colaborativo de juego: Dos jugadores colaboran simultáneamente para alcanzar los objetivos en un ejercicio.

También existe un modo de juego inteligente, mediante el uso del sistema recomendador, que sugiere ejercicios en función de las habilidades del usuario.

Asimismo, TANGO:H proporciona al usuario un sistema gamificado, que estimula al usuario a mejorar su evolución en el juego mediante el uso de un sistema de premios, los cuales obtendrá mediante el canjeo de puntos. Este sistema se utiliza para aumentar la motivación en la realización de los ejercicios físicos planteados a través de retos en el juego. Tanto los ejercicios como el sistema de recompensas (premios) pueden ser creados y modificados a través de una aplicación denominada TANGO:H Designer (Figura 4). Esto permite que al profesorado o especialistas diseñar ejercicios personalizados que se ajusten a sus necesidades y objetivos específicos.

Figura 4. TANGO:H Designer.

De esta forma, a través de TANGO:H Designer se permite la creación de diferentes tipos de ejercicios: físicos, cognitivos e híbridos o libres. A su vez, los ejercicios cognitivos pueden ser de emparejamiento, ordenamiento y clasificación. Cada uno de los tipos de ejercicios tiene diferentes funcionalidades de interacción en la interfaz de usuario. Un ejercicio consta de un conjunto de pasos y estos, a su vez, se organizan en un conjunto de fases. Las fases se componen de un conjunto de objetivos con diferentes articulaciones del esqueleto del cuerpo humano asociadas a ellos, que serán los puntos de contacto. Un ejercicio estará conformado por tanto en un conjunto de pasos, fases, objetivos y articulaciones asociadas. Además, TANGO:H Designer utiliza archivos multimedia para diseñar ejercicios, como imágenes o audios, los cuales pueden ser libres, ofreciendo la flexibilidad de creación adaptada a la necesidad del profesorado o especialista.

La interfaz de edición (Figura 4) de TANGO:H Designer es donde el usuario define los parámetros del ejercicio. Esta interfaz consta de los siguientes elementos:

- Barra de menú: Ejecuta las acciones sobre el archivo del ejercicio y la configuración del editor.
- Panel de ejercicio: Visualiza el esquema de un ejercicio, permitiendo navegar por sus componentes y realizar acciones sobre cada uno de sus elementos.
- Panel de destino: vea y edite las propiedades del destino seleccionado.

- Panel de objetivos disponibles: contiene los objetivos que se pueden utilizar para crear un ejercicio.
- Panel de diseño: Componente donde se diseña el ejercicio, que le permite arrastrar objetivos a este panel.

En el programa de intervención se han diseñado un conjunto de actividades para la enseñanza-aprendizaje de hábitos de vida saludables utilizando TANGO:H Designer. Dichas actividades se encuentran disponibles en la página web del proyecto PROVITAO (http://provitao.webs.ull.es/).

Procedimiento

El procedimiento para este estudio fue el siguiente:

Primero, se solicitaron los permisos correspondientes y los formularios de consentimiento informado. En la Fase 1, se solicitó la aprobación de la investigación al Comité de Ética de Hospital Universitario de Canarias, y en la Fase 2, también se solicitaron autorizaciones de la Dirección Territorial de Educación del Gobierno de las Islas Canarias y, posteriormente, de la Administración en cada centro participante.

A continuación, los profesionales de medicina del estudio realizaron la búsqueda de posibles participantes. Una vez que se seleccionó la muestra, se envió una carta informativa a los padres, madres o tutores legales en la que se detallaron las principales características del estudio a realizar, asegurando el anonimato de los datos y los fines científicos del mismo. Durante una reunión presencial con las familias, se aclararon sus dudas y se les solicitó su participación en el estudio ya fuera en el grupo experimental o control. La muestra del estudio se confirmó una vez que los padres, madres o tutores que decidieron participar firmaron el consentimiento informado.

Finalmente, el estudio se realizó para coincidir con el año escolar académico correspondiente (de septiembre a junio) para cada fase anual. Las sesiones de trabajo se dividieron en tres etapas trimestrales: intervención, creación del proyecto vocacional y desarrollo de dicho proyecto (Figura 5). Las evaluaciones realizadas con los instrumentos descritos en la sección anterior se realizaron antes, durante y al final de cada una de las fases anuales.

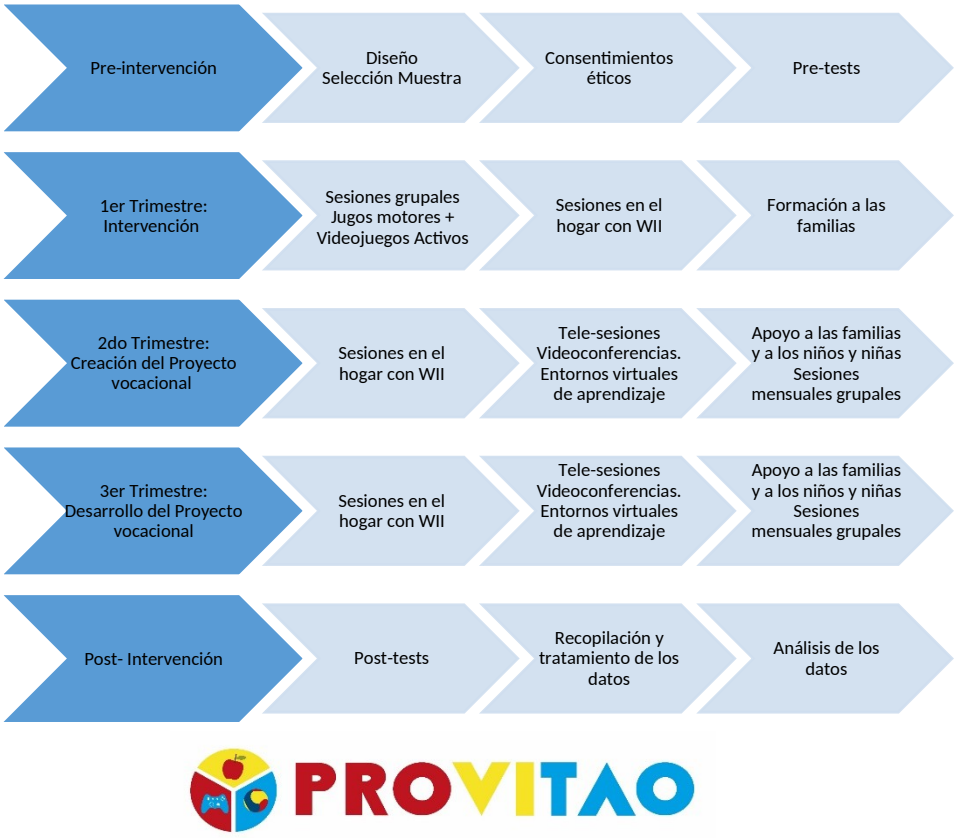

Figura 5. Etapas e instrumentos utilizados en cada fase anual.

Primera etapa: la intervención

La intervención consistió en una sesión grupal semanal de dos horas de duración de forma presencial (un total de 12 sesiones) (Figura 6). En estas sesiones se trabajaron actividades formativas de hábitos saludables y educación sanitaria sobre obesidad (60 minutos); se practicaron juegos motores tradicionales y se realizaron en parejas actividades en TANGO:H con contenidos en hábitos saludables (60 minutos).

Todas las sesiones fueron diseñadas desde un punto de vista lúdico, esto significa que después de cada contenido teórico se realizaba un juego que lo reforzaba (utilizando juegos motores y el videojuego activo TANGO:H), de este modo cada sesión adjuntaba un juego diseñado específicamente para dicho contenido. Esto se complementó con 2 sesiones de actividad física semanal en su domicilio de 30 minutos cada una con un videojuego comercial (Wii Fit Plus).

También trabajamos con los padres, madres y/o tutores de los menores, estos recibieron una sesión educativa de 120 minutos de duración, donde se trataron tres temas: los hábitos de vida saludables, la obesidad como una enfermedad, y las falsas creencias sobre los videojuegos. Se tuvo en cuenta la diversidad de la procedencia geográfica de las familias (distintas comunidades autónomas españolas, distintos países: Venezuela, etc.) para educar en hábitos nutricionales.

Además, para favorecer una buena relación y comunicación entre el equipo y las familias, y servir de apoyo y motivación para influir de forma positiva en los cambios de hábitos, se usaron herramientas TIC como servicios de mensajería instantánea (WhatsApp), las redes sociales (Facebook) o las Google apps para mantener esta relación.

a) Formación inicial en sesiones grupales

b) Juego motor en sesiones grupales

c) Actividades nutricionales en TANGO:H

d) Formación con las familias usando Classdojo

Figura 6. Diferentes momentos y estrategias utilizadas en la intervención educativa.

Segunda etapa: Creación del proyecto vocacional.

Esta etapa implicó la creación de un proyecto vocacional destinado a identificar actividades saludables que los participantes pudieran desear en su entorno. Esta actividad fue supervisada a través de una sesión de videoconferencia semanal y el uso de la plataforma virtual Moodle. Paralelamente, se continuó desarrollando el programa de actividades con Wii Fit Plus en el domicilio con dos sesiones semanales de 30 minutos cada una.

La periodicidad de las sesiones grupales presenciales se hizo mensual. Estas sesiones duraron dos horas y se centraron en reforzar las actividades realizadas durante la semana. También se realizaron mensualmente varias actividades de orientación con los padres y madres para apoyar el desarrollo del proyecto vocacional de sus hijos, así como para responder preguntas sobre el uso de las diferentes herramientas tecnológicas (videoconferencia con Google Meet y plataforma Moodle).

Tercera etapa: Desarrollo del proyecto vocacional.

Esta última etapa requirió que cada participante desarrollará su propio proyecto vocacional centrado en actividades saludables y brindó apoyo a los niños y niñas al comenzar sus nuevas actividades. Con este fin, se ofreció atención individual, domiciliaria y continua, apoyada por las TIC (videoconferencias y la plataforma Moodle, y Classdojo para el seguimiento). Además, se mantuvieron las dos sesiones semanales de actividad física en el hogar con Wii Fit Plus, al igual que la asesoría para padres y madres sobre el desarrollo del proyecto vocacional.

Durante este trimestre, y en la Fase 2 el equipo del proyecto se implicó con los centros educativos públicos que participaron en el estudio impartiendo charlas y talleres sobre hábitos de estilo de vida saludables a estudiantes de 3º a 6º grado de Primaria, mostrándoles cómo usar TANGO:H y otras herramientas tecnológicas, tales como Kahoot [60], para favorecer y potenciar el aprendizaje.

En cada fase del estudio, se recopilaron datos para un análisis más detallado antes, durante y al final de la intervención.

Conclusiones

En este capítulo se ha presentado el diseño de la investigación llevada a cabo durante la tesis doctoral. Se han descrito los materiales, método y procedimiento desarrollado, así como las características de los participantes del estudio. Asimismo, se han presentado los diversos instrumentos utilizados para medir diferentes aspectos de la intervención, tales como la EMODIANA, KIDMED, BASC, entre otros cuestionarios e instrumentos validados.

La intervención educativa estuvo apoyada por diversos recursos tecnológicos tales como entornos virtuales de aprendizaje (Moodle, Classdojo), videoconferencias (Google Meet) y plataformas de videojuegos activos propios (TANGO:H) y comerciales (Wii Fit Plus).

El diseño del programa de intervención llevado a cabo con el grupo experimental tuvo dos fases anuales, coincidentes con el curso escolar, en donde se replicaron 3 etapas: intervención grupal presencial con los menores, creación del proyecto vocacional y desarrollo del proyecto vocacional.

CAPÍTULO 2.
PROGRAMA DE INTERVENCIÓN EDUCATIVA BASADA EN VIDEOJUEGOS ACTIVOS Y GAMIFICACIÓN

Introducción

En este capítulo se presentará el programa formativo diseñado y aplicado en esta investigación, basado en juegos motores y uso de videojuegos activos que incorporan contenidos sobre hábitos saludables para la prevención de la obesidad infantil. Se presentan los temas y objetivos tratados sobre hábitos de vida saludables en las sesiones grupales que se desarrollaron en el primer trimestre. Los juegos motores fueron integrados con los objetivos que se trabajaban en el resto del programa de actividades formativas. El programa formativo llevado a cabo en este trabajo ha sido publicado en [41,42,52].

A continuación, se presentan las diferentes actividades educativas diseñadas y desarrolladas a lo largo de las sesiones con los menores del grupo experimental y sus familias.

Intervención educativa

Primer trimestre

Durante el primer trimestre de la intervención, para los niños y niñas participantes se desarrolló el programa educativo, con un total de 12 sesiones. Todas las sesiones formativas se acompañaban de contenido teórico que posteriormente se reforzaba con juegos, usando juegos motores y el videojuego activo TANGO:H como repaso de cada sesión. De este modo cada sesión adjuntaba un juego motor diseñado explícitamente para dicho contenido y se evaluaba su impacto emocional con la EMODIANA antes y después de la sesión (Figura 7).

Para las distintas actividades que se trabajaron con los niños y niñas se usaron métodos expositivos y participativos, mediante la dinámica de grupos, el uso de debates y juego de roles (*role-playing*).

Figura 7. Diferentes momentos de la intervención educativa diseñada.

A continuación, se muestran los temas tratados en las sesiones y los objetivos de estas (Tabla 2).

Tabla 2. Temas y objetivos por sesión en la intervención grupal del primer trimestre.

Sesión	Tema	Objetivo
1	Presentación	Saber en qué consiste el estudio y conocer a sus compañeros
2	Los hábitos de vida saludables	Aprender diferentes hábitos de vida saludable
3	Explicación del concepto de Índice de Masa Corporal (IMC) incluyendo la fórmula, los valores normativos y su relación con la salud	Aprender qué es el índice de masa corporal (IMC), cuáles son los valores normativos y su relación con la salud
4	Importancia de los hábitos de vida saludable	Que los niños y niñas conozcan las consecuencias a largo plazo de una mala alimentación y explicar la importancia de la higiene postural
5	Exposición sobre la cantidad y la frecuencia de ingesta de agua	Conocer la importancia de beber agua (cantidad y frecuencia), y saber cómo son de saludables el resto de las bebidas
6	Elucidación de la Pirámide de la Alimentación, alimentos que la componen y frecuencia de consumo de estos	Conocer la pirámide de la alimentación (Figura 8)
7	Profundización en los diferentes componentes de los alimentos, qué alimentos los	Aprender qué son los hidratos de carbono (azúcares), qué alimentos los contienen, con qué frecuencia han de consumirse, cuáles son los

	contienen y con qué frecuencia deben consumirse: Hidratos de carbono (azúcares) y Proteínas	simples y los complejos y qué los diferencian. Aprender qué son las proteínas, qué alimentos las contienen, cuáles son de origen animal y cuáles de vegetal, y con qué frecuencia han de consumirse
8	Profundización en los diferentes componentes de los alimentos, qué alimentos los contienen y con qué frecuencia deben consumirse: Lípidos y Vitaminas, Minerales y oligoelementos	Aprender qué son los lípidos (grasas de origen animal y vegetal), qué alimentos los contienen y con qué frecuencia han de consumirse. Aprender qué son las vitaminas, los minerales y los oligoelementos, qué alimentos las contienen y con qué frecuencia han de consumirse. Refuerzo de los conocimientos adquiridos.
9	Refuerzo de los conocimientos adquiridos	Reafirmar sus conocimientos de la pirámide de la alimentación y sobre la importancia de beber agua
10	Argumentación e identificación sobre la influencia de los estados emocionales en la conducta de la ingesta alimenticia y maneras de evitar la ingesta sin control	Aprender a identificar los estados emocionales que pueden desencadenar una ingesta sin control y conocer formas para evitarlo
11	Exposición de la Pirámide de la Actividad Física. Introducción al concepto de consumo de calorías y gasto calórico. Beneficios de la actividad física en términos de salud. Presentación y práctica de deportes. La pretensión es ampliar el conocimiento de deportes al que puedan acceder. Explicación y práctica de los deportes tradicionales canarios	Aprender la pirámide de la actividad física, qué es el gasto calórico, cuáles son los efectos del ejercicio físico, y conocer deportes menos populares (Figura 9) Conocer y practicar algunos deportes tradicionales canarios, menos populares, con el fin de mostrar a los menores deportes no tan conocidos, pero quizás más atractivos
12	Reforzar los conocimientos adquiridos sobre los hábitos de vida saludable. Introducción a la “Regla de los 5”	Esta última sesión se diseñó como una Gincana, titulada "En busca de la Pirámide saludable" (Figura 10), donde siguiendo la temática pirata de gamificación instaurada al inicio del programa formativo, nuestros navegantes realizaban un viaje imaginario desde el norte de Turquía, pasando por Grecia, Italia, Francia, la costa valenciana española, Marruecos hasta llegar a las Islas Canarias reforzaban y repasaban los conocimientos adquiridos sobre los hábitos de vida saludable y aprendieron la Regla de los 5. (5 comidas al día, 5 piezas de frutas y verduras diariamente, 5 gramos de sal cada día, 5.000 pasos al día, 5 vasos de agua a diario) como resumen de unos hábitos de vida saludables

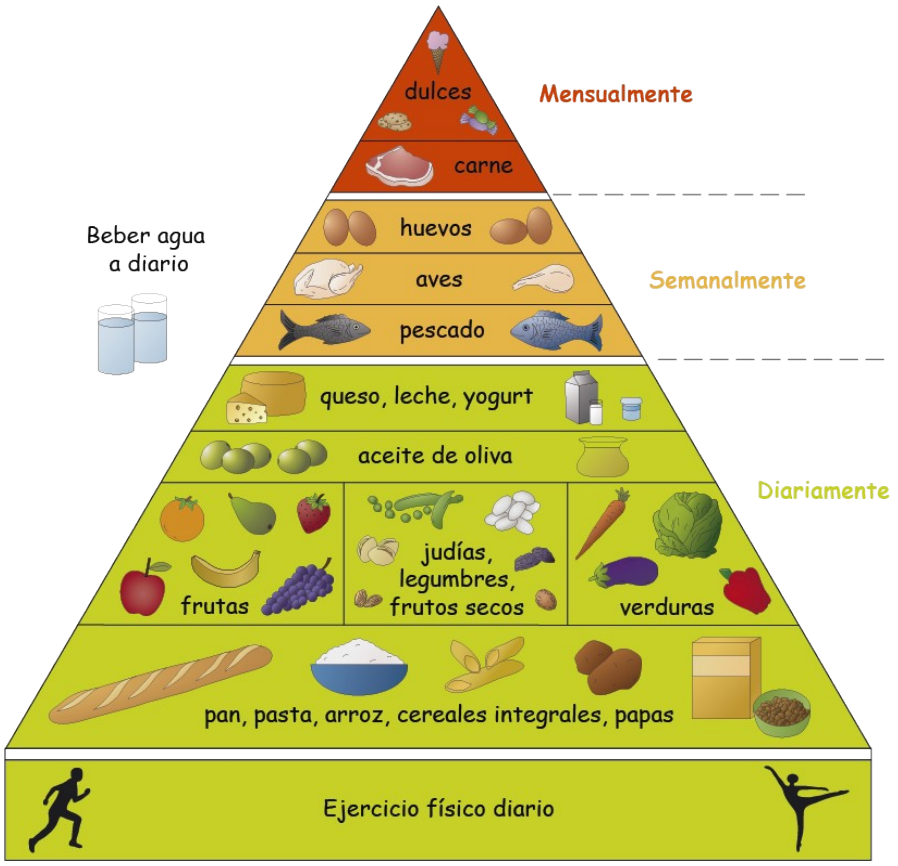

Figura 8. Pirámide de alimentación utilizada en la formación.

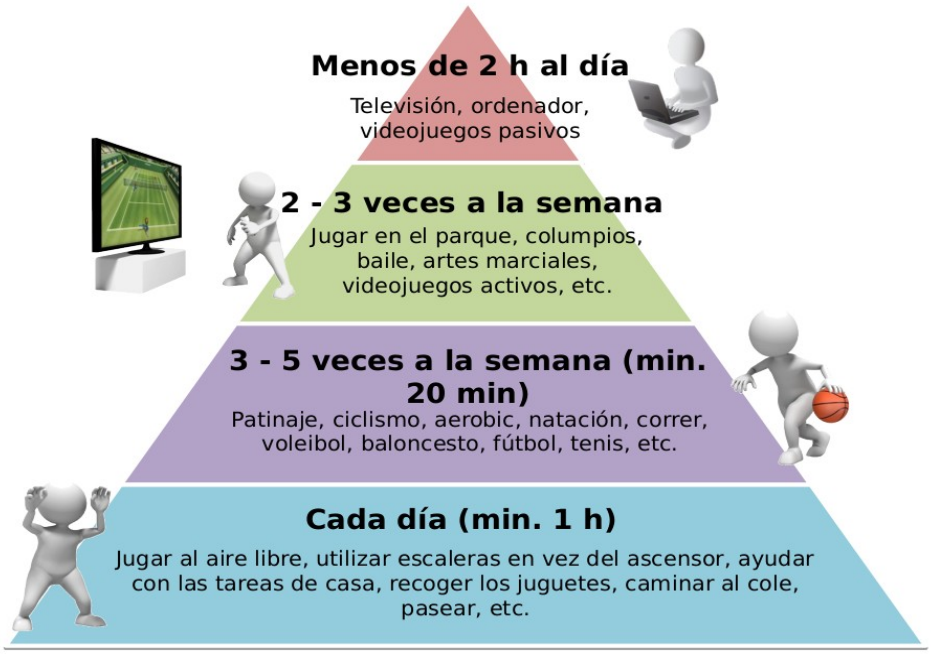

Figura 9. Pirámide de la actividad física utilizada en la formación.

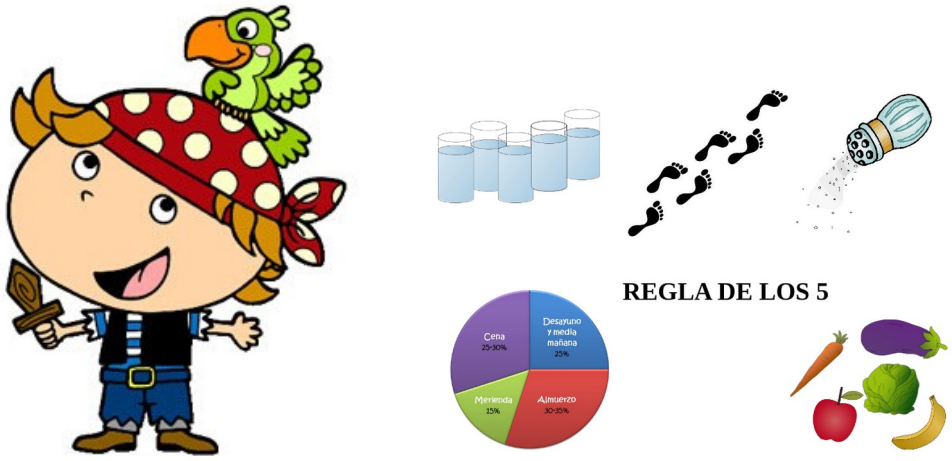

Figura 10. Gincana sobre la regla de los 5 utilizada en la sesión final grupal.

Para el desarrollo de las sesiones, se crearon y adaptaron diferentes tipos de ejercicios formativos (físicos y cognitivos y libres) en TANGO:H Designer para trabajar sobre hábitos de vida saludables en modo individual, colaborativo y competitivo. Además, se agregó un módulo de gamificación al TANGO:H Designer para poder asignar y crear premios y regalos, ejercicios con niveles de dificultad y restricciones de tiempos (Figura 11).

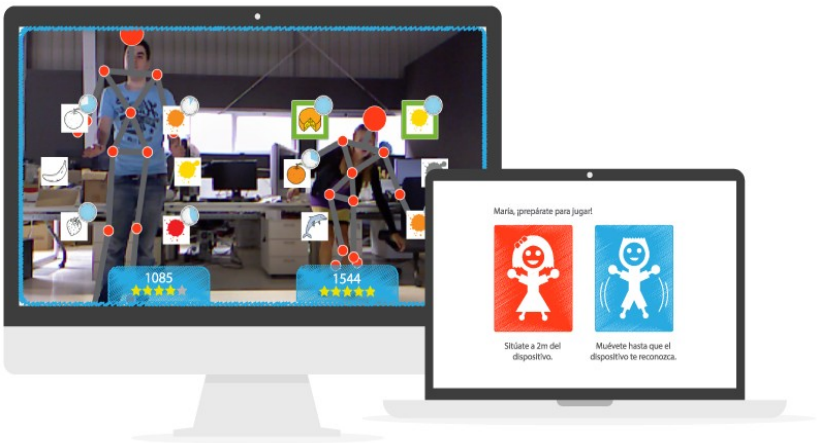

Figura 11. Juegos creados en TANGO:H para el programa de intervención educativa.

Durante esta fase, también se solicitó la realización de dos sesiones semanales de ejercicio físico en casa, utilizando la Wii Balance Board con el videojuego Wii Fit Plus, favoreciendo la realización de la actividad física en el contexto familiar. Para ello, se seleccionaron y planificaron las sesiones con la Wii para trabajar diferentes áreas corporales con cada sesión (Figura 12).

Además de la retroalimentación inmediata que ofrecen las actividades (puntuación en TANGO:H, Wii; conocimiento de las ganancias de puntos en las demás actividades presenciales), sus puntuaciones se trasladaron a un ranking general, que se hacía público al grupo en las sesiones presenciales para gamificar todas las actividades realizadas en la intervención.

Por otra parte, se recomendaron juegos serios móviles y otras actividades en internet para promocionar hábitos de vida saludables para realizar en el domicilio, tales como: Diana come sano, Activilandia, Héroes saludables, La venganza de Cool-E, entre otras.

El lugar donde se llevaron a cabo las sesiones fueron las instalaciones deportivas del Colegio Aneja, en La Laguna (Figura 13). Las sesiones grupales se desarrollaron por la tarde de 17 a 19 horas.

Figura 12. Algunos juegos seleccionados en la plataforma Wii Fit Plus para las sesiones en el hogar.

Figura 13. Ejemplo de sesión grupal desarrollada en las instalaciones deportivas.

Para los padres, madres y/o tutores se estableció una sola sesión educativa de 120 minutos de duración, donde se trataron tres temas: los hábitos de vida saludables en la alimentación y la actividad física, la obesidad como una enfermedad, y las falsas creencias sobre los videojuegos.

La sesión se estructuró en dos momentos principales, primero la explicación teórica, y segundo el desarrollo de actividades formativas.

Los contenidos abordados en dicha sesión fueron:

- Generalidades sobre hábitos de vida saludables.
- Explicación del concepto de Índice de Masa Corporal incluyendo la fórmula, los valores normativos y su relación con la salud.
- Exposición sobre la cantidad y la frecuencia de ingesta de agua.
- Explicación de la Pirámide de la Alimentación, alimentos que la componen y frecuencia de consumo de estos.
- Profundización en los diferentes componentes de los alimentos, qué alimentos los contienen y con qué frecuencia deben consumirse: Hidratos de carbono (azúcares), Proteínas, Vitaminas, Minerales y oligoelementos, y Lípidos.
- Esquematización de los grupos de alimentos adecuados para cada comida.
- Concepto de consumo y gasto de kilocalorías.
- Argumentación e identificación sobre la influencia de los estados emocionales en la conducta de la ingesta alimenticia y maneras evitar la ingesta sin control.
- Exposición de la Pirámide de la Actividad Física.

- Beneficios de la actividad física en términos de salud.
- Presentación sobre los beneficios de los videojuegos activos y aclaración de las falsas creencias sobre los mismos.
- Introducción a la “Regla de los 5” (5 comidas al día, 5 piezas de frutas y verduras diariamente, 5 gramos de sal cada día, 5.000 pasos al día, 5 vasos de agua a diario) como resumen de unos hábitos de vida saludables.

Los objetivos específicos de la sesión fueron:

- Aprender conceptos generales sobre hábitos de vida saludables.
- Entender el concepto de Índice de Masa Corporal (IMC) incluyendo la fórmula, los valores normativos y su relación con la salud.
- Conocer la cantidad y la frecuencia adecuada de ingesta de agua.
- Aprender cómo se estructura la Pirámide de la Alimentación, es decir, saber los alimentos que la componen y la frecuencia de consumo de los mismos.
- Profundizar en los diferentes componentes de los alimentos, qué alimentos los contienen y con qué frecuencia deben consumirse.
- Conocer los grupos de alimentos que deben estar presentes en las comidas y las cenas.
- Entender el concepto de consumo y gasto de kilocalorías.
- Ser consciente de la influencia de los estados emocionales en la conducta de la ingesta alimenticia y conocer maneras de evitar la ingesta sin control.
- Conocer la Pirámide de la Actividad Física y los beneficios en términos de salud.
- Ser consciente de los beneficios de los videojuegos activos y de las falsas creencias sobre los mismos.
- Saber la “Regla de los 5”.

Luego, realizaron dos actividades de formación para las cuales se dividió a los padres y madres en diferentes equipos.

- Actividad 1. “Frases verdaderas y falsas”: Se entregó a los padres y madres un folio con 20 frases, las cuales debían decidir, por grupos, si eran verdaderas o falsas.
- Actividad 2. “TANGO:H”: Los padres y madres probaron el videojuego TANGO:H realizando la actividad de la pirámide de la alimentación. En dicho juego, el jugador debe emparejar los diferentes alimentos que le aparecen a la izquierda con la posición de la pirámide alimenticia que corresponda.

Segundo y tercer trimestre

Durante el segundo y tercer trimestre, la intervención fue individual y domiciliaria, apoyadas en tecnologías y se centró en la creación por los propios menores de un proyecto vocacional en relación con el descubrimiento de actividades saludables que pudieran gustarles en su entorno (cambio de hábitos hacia otros más saludables). El desarrollo de esta fase consistió en programar una actividad física (segundo trimestre) que debían realizar autónomamente (tercer trimestre). Se trabajaron aspectos como la resistencia al cambio frente a la apertura a la experiencia y la percepción de autoeficacia y el descubrimiento de los recursos del entorno próximo para implementar conductas saludables. Esta actividad se tutorizó a través de una sesión de videoconferencia semanal, acompañada de sesiones en la plataforma Moodle donde el equipo de trabajo guió, apoyó y dinamizó el cambio de conducta de los menores, en colaboración con sus padres y madres.

Las actividades con los niños y niñas incluyeron debatir sobre vídeos y podcasts relacionados con el cambio o la resistencia al mismo, dinámicas de promoción de autoestima dentro del grupo, dramatizaciones/juegos de roles, descubrir su entorno usando aplicaciones informáticas y narrativas. La gamificación de esta fase se realizó otorgando puntuaciones según el cumplimiento de las actividades pautadas y la participación en las mismas (por ejemplo, se otorgaban 10 puntos si realizaban una actividad y 5 puntos si participaban en el foro) y entregando al finalizar cada trimestre un diploma con los diferentes roles de la narrativa empleada (piratas) (Figura 14).

Figura 14. Diplomas entregados el final del primer trimestre. Todos los niños y niñas llegaron a la categoría de "Capitán" y se destacó a los 3 mejores participantes con la categoría de "Yonko". Asimismo, se otorgó un Diploma al finalizar la intervención.

La búsqueda de actividades saludables organizadas por los ayuntamientos y en el entorno de los menores no resultó favorable, ya que, salvo deportes, existe una carencia de oferta pública y gratuita de actividades físicas y saludables durante todo el año adecuada a los intereses de los niños y niñas. Esto supuso una dificultad para el desarrollo y ejecución del proyecto vocacional saludable que pudiera permanecer cuando el equipo de investigación retirara la intervención directa, tal y como estaba planeado en esta fase. Por ello, se incluyeron encuentros mensuales para reforzar el componente social y compromiso con el proyecto y sus objetivos.

Durante el tercer trimestre, las sesiones mensuales grupales con los niños y niñas del grupo experimental en donde se abordaron habilidades cognitivas y sociales, enfocadas a la resolución de problemas con los iguales, dada la elevada frecuencia en que estos se relacionan con la obesidad infantil (Figura 15).

Figura 15. Sesión presencial dinamizada con temática pirata en el tercer trimestre.

Para los padres y madres, se realizaron actividades formativas y de orientación para de carácter mensual, dichas citas coincidían con las reuniones mensuales de los niños y niñas participantes. Esta actividad tenía como finalidad dar apoyo al desarrollo de proyecto vocacional de los menores, así como resolver dudas en cuanto al manejo de las diferentes herramientas tecnológicas (videoconferencia, plataforma Moodle, Classdojo). Esto llevó a que desde el propio equipo investigador se contactará con los ayuntamientos y asociaciones de la zona donde vivían los menores para conocer los recursos y actividades saludables disponibles cuando informaron los padres y madres sobre las dificultades encontradas o a realizar un taller con los padres y madres sobre el acoso escolar o bullying que sufrían algunos de ellos en su entorno (Figura 16).

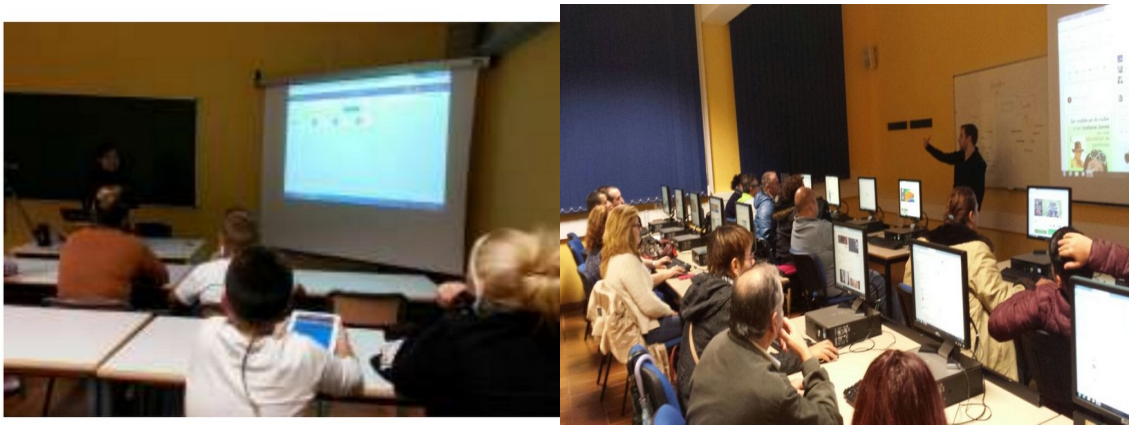

Figura 16. Formación con las familias utilizando Classdojo, Moodle y otras herramientas.

Las sesiones de esta fase se desarrollaron en la Escuela de Ingeniería y Tecnología de la Universidad de La Laguna en horario de tarde de 17 a 19 horas según disponibilidad de las familias.

En la fase 2, se les entregó a los niños y niñas, las actividades en una libreta con el fin de facilitar el acceso a las actividades al informar algunos padres y madres de problemas de

conexión (por ejemplo, no tener ordenador y ser difícil realizar las tareas desde el móvil) (Figura 17).

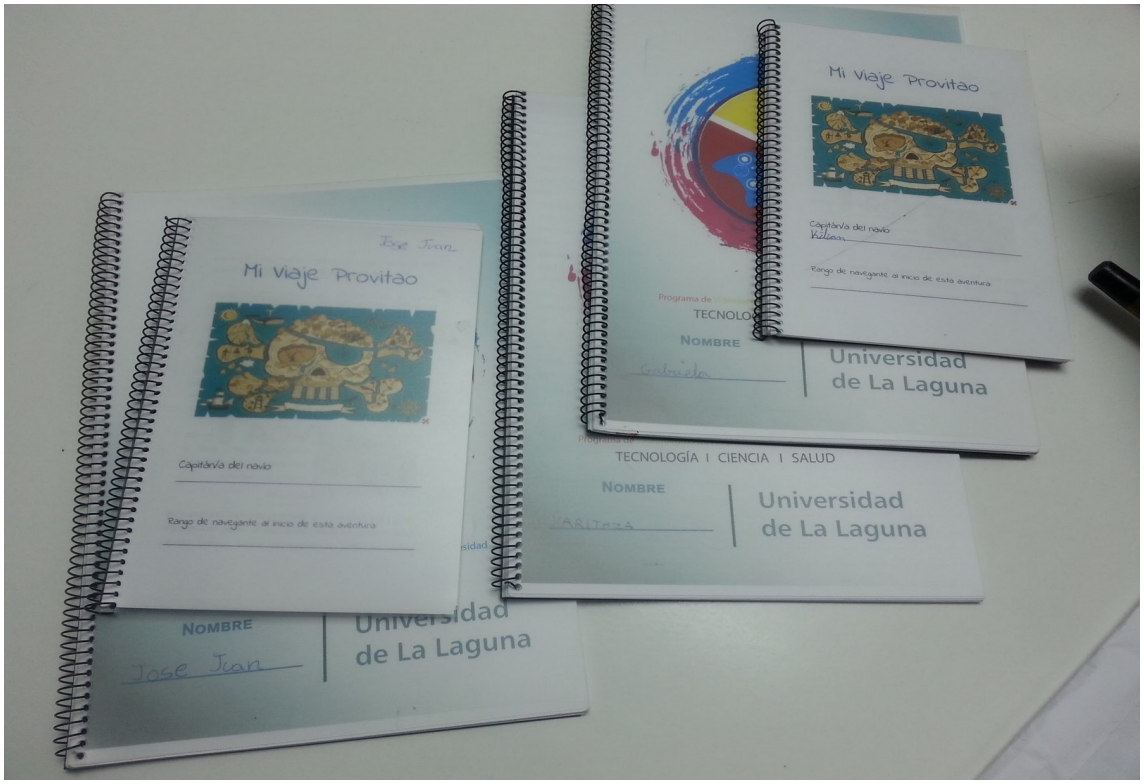

Figura 17. Cuaderno de bitácora para el seguimiento de las actividades desarrolladas.

Talleres en colegios

Centrados en el tema de la divulgación y promoción sobre los hábitos de vida saludable y la importancia de la prevención de la obesidad infantil se realizaron talleres formativos educativos e interactivos con el alumnado y el profesorado en los diferentes centros educativos que participaron en el proyecto. A continuación, se describe la experiencia llevada a cabo.

Figura 18. Ejemplo de sesión desarrollada en los colegios participantes en el estudio.

Los colegios donde se realizaron los talleres fueron los siguientes: CEIP Las Mercedes, CEIP Aguere, CEIP Aneja, CEIP San Rosa de Lima, y CEIP La Verdellada pertenecientes a San Cristóbal de La Laguna, Tenerife, España. Las actividades se realizaron para los cursos de 3º a 6º de primaria (niños y niñas de 8 a 12 años). Participaron durante tres meses un total de 581 estudiantes y los docentes responsables de cada clase (16 profesores) de los cinco colegios implicados. El rango de edad de los profesores era de 38 a 59 años, aunque el 75% eran mayores de 50 años (edad media=51,62). La mayoría de los profesores que participaron en el estudio eran mujeres (81,25%).

Las actividades realizadas en los colegios, dirigidas al alumnado de tercero a sexto de primaria y a los profesores responsables, se estructuraron de la siguiente manera:

- Horas lectivas y 45 minutos.
- Actividades teórico-prácticas gamificadas: incluyeron una breve presentación sobre el tema centrada en la alimentación saludable y juegos para mejorar los hábitos de vida saludables de forma gamificada utilizando la herramienta Kahoot de forma grupal (4-5 estudiantes por tableta digital) y continuaron con la realización de juegos motores y videojuegos activos utilizando TANGO:H de forma individual.

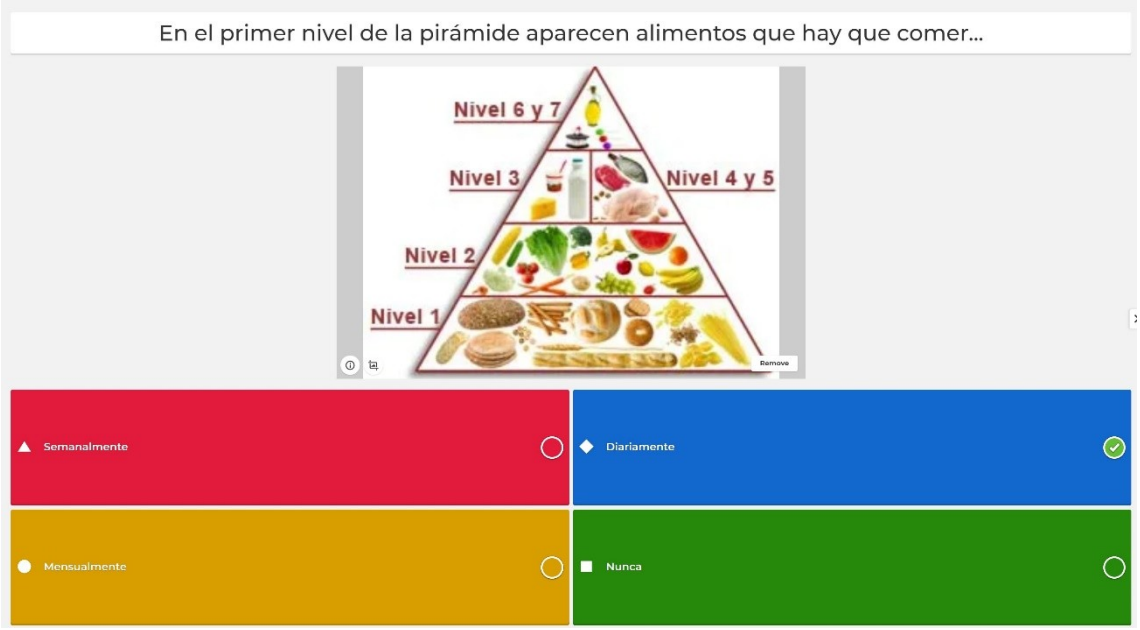

Figura 19. Uso de la herramienta de gamificación Kahoot como actividad grupal en las escuelas.

En total se pasaron 17 Kahoots relacionados con la alimentación saludable. Teniendo en cuenta los reportes de los cuestionarios gamificados que se pasaron, el conocimiento sobre la alimentación saludable en los colegios es de un 51%. Los niños y niñas tuvieron dificultades en las preguntas sobre la pirámide de alimentación, en la frecuencia de comer determinados alimentos como el aceite de oliva, o dificultades para distinguir los tipos de carnes (roja, blanca).

Luego de la realización de los Kahoots grupales y analizar los conocimientos y mitos sobre la alimentación se pasó a la realización de juegos activos, que tenían ejercicios físicos con contenidos relacionados con la alimentación saludable. Como videojuego activo utilizamos TANGO:H.

La satisfacción global con los talleres se midió mediante una escala de Likert (1=Muy insuficiente/inadecuado; 5=Muy bueno/Muy adecuado), y podemos decir que en el caso de la intervención global fue muy alta (4,69), así como con el uso del videojuego activo TANGO:H (4,75). Otras variables medidas relativas a la satisfacción con la intervención fueron: tiempo (4,69), duración de la sesión (4,44), uso de Kahoot (4,67), contenidos educativos (4,63), objetivos del programa (4,63). También se midieron variables relacionadas con la dinamización, como los conocimientos de los dinamizadores (4,88), las habilidades de comunicación (4,63), su capacidad para responder a las preguntas (4,67) y su capacidad para crear interés (4,75).

Figura 20. Uso del videojuego activo TANGO:H en las escuelas.

Conclusiones

En este capítulo se ha presentado el programa de intervención educativa diseñado, que se basa en un programa de aprendizaje basado en juegos motores, videojuegos activos y gamificación.

Se han descrito además los temas tratados en las sesiones sobre hábitos de vida saludables, organizados en por cada etapa del trimestre, tanto para los niños y niñas como para las familias.

Se destacaron las herramientas tecnológicas utilizadas para dar soporte a la formación desarrollada, tales como TANGO:H, Moodle, Classdojo, entre otras herramientas. Asimismo, se han utilizado herramientas analógicas, como el cuaderno de bitácora, que fue un material creado para que los menores pudieran ir registrando sus actividades y avances en el proyecto vocacional.

También se describió la intervención desarrollada en diferentes escuelas de Tenerife, donde participaron 581 menores y el profesorado a su cargo, mostrando una alta satisfacción con el programa desarrollado.

CAPÍTULO 3.
RESULTADOS

Introducción

En este capítulo se presentan algunos de los resultados obtenidos del estudio realizado en esta tesis doctoral, que incluyen el conocimiento sobre nutrición a lo largo del estudio por parte de los menores, la adherencia a la dieta mediterránea y el estudio sobre un caso único de una menor con obesidad y diabetes.

Se presentan resultados según el grupo control y experimental, para mostrar el efecto del programa de intervención educativa descrito en el anterior capítulo.

Asimismo, se presenta el caso único de forma de ejemplo de diferentes medidas tomadas a lo largo del estudio.

Los resultados de la investigación fueron publicados en diferentes publicaciones científicas [42-51].

Debido a la extensión del proyecto de investigación, esta Tesis va a presentar los principales resultados relacionados con el aprendizaje sobre nutrición, la adherencia a la dieta mediterránea y el caso único de obesidad y diabetes. Posteriormente se expone un resumen de los otros resultados obtenidos del proyecto.

Conocimiento sobre nutrición a lo largo del estudio

En esta sección, se analizan las respuestas de los participantes que involucran su conocimiento sobre nutrición saludable. En todos los casos, las puntuaciones más altas indican mejores hábitos, conocimiento y satisfacción. Todas las variables involucradas en estos análisis exhiben una distribución normal, según la prueba de Kolmogorov-Smirnov. La comparación de las medias de los dos grupos en la línea de base indica que ambos presentaron puntuaciones similares al inicio del estudio en los cuatro índices estudiados (Tabla 3).

Tabla 3. Media y grupo (desviaciones estándar) y estadísticas de la diferencia de las medias de las puntuaciones en los cuestionarios de los participantes en la línea de base.

	Control N= 20	Experimental N= 25	F(1,43)	p	η2p	P	
Nutrición	27,00 (3.64)	26,40 (2,66)	0,41	0,52	0,01	0,10	

Nota: Ajuste de Bonferroni

Para cada indicador se realiza el análisis de medidas repetidas, con grupo como factor inter-sujetos y un factor intra-sujetos con tres niveles que hemos denominado "Seguimiento". Cada nivel viene definido por una fase de la intervención: la línea base (medidas tomadas antes de iniciar la intervención), el seguimiento inmediato (evaluación realizada al finalizar la fase de intervención presencial), el seguimiento a largo plazo (evaluación llevada a cabo tras finalizar la intervención con los menores y retirar los seguimientos). Cuando no se cumple la esfericidad de las matrices de varianza-covarianza se realiza la corrección épsilon por el método de Greenhouse-Geisser. En el caso de existir efectos principales del factor intrasujetos, se realizan los análisis a posteriori con ajuste de Bonferroni, asimismo, si en el análisis de los efectos principales no se cumple el criterio de homogeneidad de las varianzas, se realiza la prueba robusta de Welch. La Tabla 4 presenta las medias y desviaciones estándar de los índices de los cuestionarios informados por los menores en las evaluaciones de seguimiento.

Tabla 4. Medias y desviaciones estándar de los índices de los cuestionarios informados por los dos grupos de menores en las evaluaciones de seguimiento.

	Inmediata		**A largo plazo**	
	Control N= 16	Experimental N= 17	Control N= 16	Experimental N= 15
Nutrición	27,00 (2,88)	28,71 (2,62)	29,56 (2,50)	30,87 (2,95)

Nota: Ajuste de Bonferroni

La interacción entre el factor Seguimiento y Grupo no resulta significativa ($F(2, 50) = 2{,}582$; $p = {,}086$; $\eta^2p = {,}094$; $P = {,}492$), tampoco existe efecto significativo de Grupo ($F(1{,}25) = 0{,}503$; $p = {,}485$; $\eta^2p = {,}020$; $P = {,}105$). En cambio, existe efecto significativo del factor Seguimiento ($F(2, 50) = 28{,}647$; $p = {,}000$; $\eta^2p = {,}532$; $P \geq 0{,}999$), al atender a los análisis por pares con el ajuste de Bonferroni, encontramos las puntuaciones en el seguimiento a largo plazo son significativamente diferentes a las de la línea base ($t(23) = 7{,}002$; $p \leq {,}001$; d= 1,2) y a las del seguimientos inmediato ($t(23) = 6{,}234$; $p \leq {,}001$; d=

0,99). Analizando la evolución de las medias (ver figura 21) considerando conjuntamente a los dos grupos, en ambos casos las medias mayores en conocimiento se dan en el largo plazo.

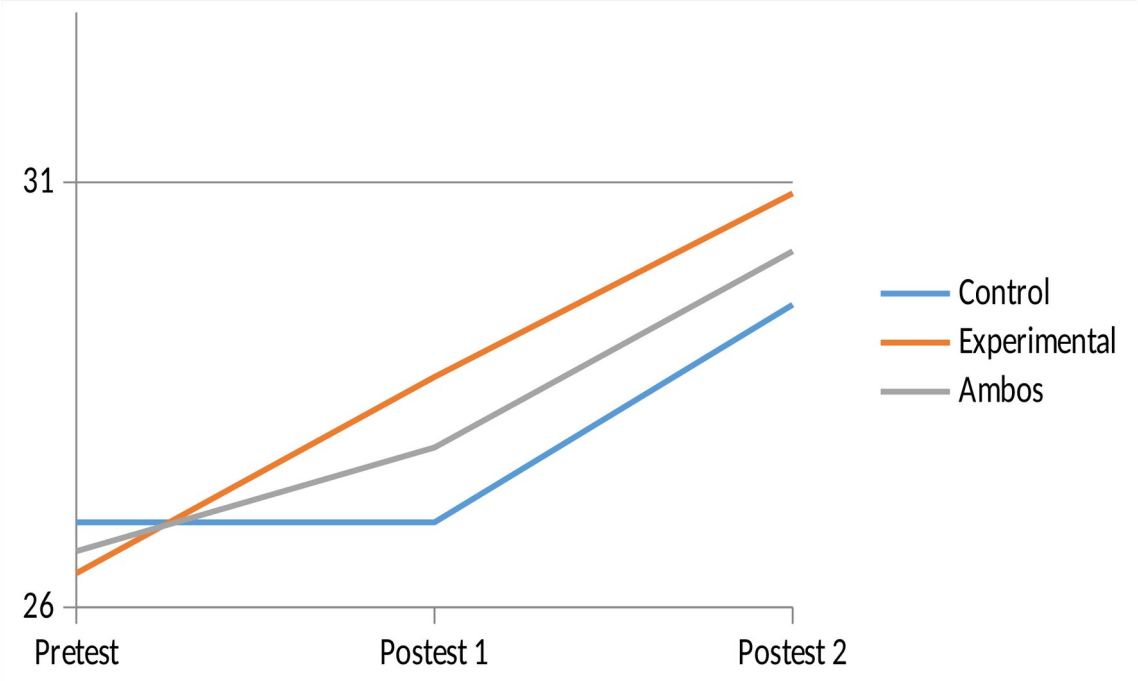

Figura 21. Conocimiento sobre nutrición a lo largo del estudio

La observación de la gráfica de representación de las medias indica que, a pesar de que la interacción entre el factor de Seguimiento y Grupo no sea significativa, pueda existir interacción entre la línea base y el seguimiento inmediato, es decir, el realizado justo después de la fase de intervención presencial. Por ello, se analizará esta fase de forma independiente. En este caso, la matriz de varianzas-covarianzas no presenta un patrón de esfericidad, por lo que se realizará la corrección Épsilon mediante el método de Greenhouse-Geisser. La interacción entre el factor Seguimiento inmediato y Grupo es significativa (F(1,00, 31,00) = 6,911; p =,013; η^2p = ,182; P = ,721), asimismo es significativo el efecto principal del factor Seguimiento inmediato (F(1,00, 31,00) = 6,911; p =,013; η^2p = ,182; P = ,721), pero no el de Grupo (F(1,31) = 0,215; p = ,646; η^2p = ,007; P = ,073). Como se observa en la figura 3, cuando promediamos las puntuaciones de los dos grupos, las medias en el seguimiento superan a las de la línea base; en cambio, la interacción observada y la revisión de las medias indica que las puntuaciones de cada grupo describen una evolución diferente entre la línea base y el seguimiento inmediato.

Adherencia a la dieta mediterránea

En esta sección se analiza las respuestas de los niños y niñas en el cuestionario sobre la calidad de la dieta mediterránea (KIDMED), analizando los datos del cuestionario preliminar y cuestionario posterior a corto plazo (después de la intervención presencial grupal). Como muestran los datos, al principio ambos grupos tenían un índice KIDMED promedio de 7 (adherencia promedio). Sin embargo, después de la intervención, el grupo experimental mostró una leve mejoría en este índice, mientras que en el grupo de control disminuyó. Las diferencias en el índice KIDMED no son significativas. Por lo tanto, decidimos analizar cada elemento del cuestionario KIDMED. Estas tablas muestran diferencias significativas en la ingesta de vegetales (una o más) y el consumo de pescado, pasta y cereales. También es significativa la cantidad de niños y niñas que han dejado de comer pasteles industriales para el desayuno.

Con respecto al impacto del programa en los hábitos alimenticios, como muestra la Tabla 5, en el grupo experimental, el índice KIDMED muestra una leve mejoría que no es significativa, mientras que el grupo de control ve un empeoramiento en su índice KIDMED que sí es significativo.

Tabla 5. Índice KIDMED para diferentes tiempos y grupos.

Índice KIDMED	**Grupo Experimental Pre Min=5,00 / Max=11,00**	**Grupo Experimental Post Min=5,00 / Max=10,00**	**Grupo Control Pre Min=4,00 / Max=11,00**	**Grupo Control Post Min=5,00 / Max=10,00**
Media	7,67	7,75	7,11	6,78

En la Tabla 6 podemos ver representados en porcentajes los elementos según el grupo al que pertenecen y el momento en que todos los participantes fueron evaluados. Al analizar todos los elementos que conforman la prueba KIDMED según el grupo al que pertenecían, se hizo evidente que había mejoras en el grupo experimental tales como en el consumo de verduras, pasta o cereales para el desayuno, y que todos los participantes dejaron de comer pasteles industriales para el desayuno.

En contraste, el grupo de control dejó de comer verduras regularmente y también mostró peores indicadores relacionados con la panadería industrial y los dulces. Luego, se realizó la prueba "t" para muestras relacionadas, lo que nos permitió confirmar si había diferencias significativas entre la prueba previa y la posterior de la prueba, tanto en el grupo experimental como en el grupo control. En ambos casos, debemos aceptar que la medida en la población tanto en el grupo experimental (0,72) como en el grupo

de control (0,563) es la misma, y no se encontraron diferencias significativas cuando los valores fueron superiores a 0,5. Posteriormente, se realizó la prueba "t" para muestras independientes, relacionando primero la prueba preliminar en los grupos experimental y de control. Esto no reveló diferencias significativas en el cuestionario entre los grupos experimental y control (0.54).

Así, comenzamos con una muestra con medidas homogéneas en relación con la calidad de la dieta mediterránea, pero después de la intervención, encontramos diferencias significativas en los post-tests de los grupos experimental y de control (0,23). Entonces, podemos afirmar que los niños y niñas que participaron en el grupo experimental lograron mejorar la calidad de su dieta.

Tabla 6. Resultados por ítem de la prueba KIDMED.

KIDMED	Grupo Experimental Pre	Grupo Experimental Post	Grupo Control Pre	Grupo Control Post
Toma una fruta o un zumo natural todos los días	66,6	66,6	77,7	66,6
Toma una 2ª pieza de fruta todos los días	25,0	0,0	33,3	33,3
Toma verduras frescas o cocinadas regularmente una vez al día	91,6	**100,0**	77,7	**55,5**
Toma verduras frescas o cocinadas de forma regular más de una vez al día	41,6	25,0	11,1	11,1
Consume pescado con regularidad (por lo menos 2-3 veces a la semana)	66,6	**83,3**	77,7	**66,6**
Acude una vez o más a la semana a un centro de comida rápida (*fast food*) tipo hamburguesería	0,00	0,0	0,0	0,0
Le gustan las legumbres y las toma más de 1 vez a la semana	91,6	83,3	77,7	**66,6**
Toma pasta o arroz casi a diario (5 días o más a la semana)	25,0	**50,0**	33,3	33,3
Desayuna un cereal o derivado (pan, etc.)	83,3	**91,6**	77,7	77,7
Toma frutos secos con regularidad (al menos 2-3 veces a la semana)	16,6	16,6	33,3	**55,5**
Se utiliza aceite de oliva en casa	91,6	91,6	100,0	100,0
No desayuna	0,0	0,0	0,0	**11,1**
Desayuna un lácteo (yogurt, leche, etc.)	100,0	100,0	88,8	88,8
Desayuna bollería industrial, galletas o pastelitos	8,3	**0,0**	22,2	**11,1**
Toma 2 yogures y/o 40 g queso cada día	75,0	66,6	44,4	55,5
Toma golosinas y/o caramelos varias veces al día	0,0	0,0	0,0	**11,1**

Caso único de obesidad-diabetes

Para ejemplificar las diferentes actividades realizadas y su impacto en la salud se presenta un estudio de caso único de una menor que participó en el grupo experimental.

Paciente mujer de 11 años de edad que entrar a formar parte del estudio remitida desde las Consulta Externas de Pediatría del Hospital Universitario de Canarias con diagnóstico de Obesidad y Resistencia a la insulina (prediabetes tipo II), en tratamiento farmacológico con Metformina 850mg.

Antecedentes familiares:

- Madre y padre ambos con sobrepeso. La madre sufre de obesidad y padece Diabetes tipo II. El padre es asmático, fumador, padece psoriasis.
- Abuela materna: Diabetes tipo II, asma, cáncer de útero y Lupus.
- Abuelo materno: HTA, Diabetes tipo I, Nefropatía, y cardiopatía.
- Abuela paterna: HTA.
- Abuelo paterno: Cáncer de pulmón.

Antecedentes personales:

Se trata de una niña asmática que precisa tratamiento y realiza seguimiento en el Servicio de Neumología del Hospital Universitario de Canarias (HUC) desde su nacimiento por problemas respiratorios, motivo principal que genera una continua demanda asistencial durante gran parte de su infancia por asma bronquial, catarro de vías altas y laringitis en múltiples ocasiones.

Respecto a la obesidad, dicha patología se detectada por primera vez en la consulta de Atención Primaria de su Pediatra en la revisión de los 3 años, esta elevación del peso por encima del Percentil 97 se mantiene en todos los controles de salud hasta el momento de la evaluación en este proyecto, manteniendo percentiles normales con respecto a su talla. Los primeros datos que se disponen en la Historia clínica electrónica al respecto son en la revisión de los 3 años donde su peso es de 21,800kg (percentil mayor de 97) y su talla de 94,5cm (percentil 25-50). No es hasta la revisión de los 4 años donde saltan las alarmas, y se le diagnostica Obesidad II, en dicha visita la menor pesa 29g (percentil >> 97), mide 103cm (percentil 50-75), y su índice de masa corporal (IMC) es de 27,3; su madre asegura que “come de todo y variado”. En ese momento se pauta un control estricto de la dieta (evitando alimentos grasos, fritos y azucares refinados, garantizar una dieta balanceada educando en el uso de frutas frescas, verduras, ensaladas, carnes asadas o la plancha, etc.), practicar de forma regular deporte y control de peso y talla en 3 meses. Sin embargo, la niña no acude a dicho control.

En años posteriores se retoman los controles de peso y talla y se insiste desde la consulta de enfermería y del pediatra en las medidas a tomar para mejorar hábitos de vida y ayudar a controlar el aumento de peso, a pesar de esto, la mayoría de estos controles son puntuales en el tiempo y no muestran ser efectivos. Tras la revisión de los 7 años, y durante un pequeño periodo de tiempo (entre enero-junio 2011) se realizan visitas y controles periódicos que parecen conseguir una mejora en los hábitos alimenticios y en el control del peso (reducción de 1,6kg en 2 meses), pero estos controles se vuelven a interrumpir y no es hasta la revisión de los 9 años (junio 2013).

Talla: 140 - Pc: 50,75. Peso: 64 - Pc: 100) donde se remite a la niña desde la consulta de pediatría de su Centro de Salud a la consulta de Endocrinología del HUC para control y evolución de Obesidad III (mórbida), "con intento de control desde hace unos años sin respuesta". En septiembre de 2013, se retoman los controles de peso y tensión arterial por orden del HUC que se realizan durante 2 meses, y al poco inicia tratamiento con Metformina 850mg (febrero 2014). Tratamiento que ha precisado durante todo el estudio según pauta médica.

Entra a formar parte del Grupo Experimental de PROVITAO en octubre de 2014 realizándose controles antropométricos y analíticos pre y post intervención, el de seguimiento a los 6 meses y la última de control al año de inicio de la intervención. A continuación, se muestran algunas de las medidas tomadas en dichos controles (Tabla 7).

Tabla 7. Medidas tomadas en la exploración

	Pre-intervención	**Post-intervención (3 meses)**	**Seguimiento (6 meses)**	**Anual**
Edad	10	11	11	12
Peso (kg)	71,6	72	72,3	78,3
Talla (cm)	1,47	1,48	1,52	1,54
IMC	33,13	32,52	31,29	32,68
Perímetro cintura (cm)	104,5	100,5	97	101,5

Como se puede observar, tanto el peso, el perímetro abdominal y el IMC mejoraron en el control post-intervención y en el seguimiento de los 6 meses, logrando un mayor descenso en todas las cifras en el control realizado a los 6 meses, sin embargo, en el control que se realizó al finalizar ese año, donde transcurrieron 6 meses en los que no se llegó a realizar ninguna intervención se produjo un aumento en las cifras de IMC y perímetro abdominal muy próximos a los valores registrados al inicio del estudio (Tabla 8).

Tabla 8. Valores analíticos y niveles de referencia para una niña de 11 años.

	Pre-test	Post-test (6 meses)	Post-test (al año)
Glucosa basal Menor a 100 mg/dl	93	84	93
Colesterol total Menor a 170 mg/dl	148	152	149
HDL Mayor a 45 mg/dl	37	46	46
LDL Menor a 110 mg/dl	92	92	92
Triglicéridos Menor de 90 mg/dl	94	69	52
TSH basal Menor de 4,5µUI/ml	2,1900	2,2700	-
Insulina basal	25,6	33,7	-

Antes de comenzar, se va a explicar el motivo de las diferencias entre las analíticas. Disponemos de la analítica completa pre-intervención y la de seguimiento a los 6 meses (tiempo transcurrido 9 meses). La analítica post-intervención no se realizó debido a que la niña se sometió a otras analíticas por patologías agudas, decidiendo el padre y la madre que era innecesario realizar otra extracción de sangre en ese periodo. La analítica que se debía realizar al año está incompleta porque la endocrina consideró que no era necesario realiza nuevamente un control de insulina basal.

También debemos recordar antes de realizar la interpretación de estos valores que la menor estaba en tratamiento con Metformina 850mg 1 vez al día (en el desayuno) varios meses antes del inicio del estudio. Dicho fármaco actúa directamente sobre la glucosa reduciendo los niveles plasmático postprandial y basal por 3 mecanismos: reduce la producción hepática de glucosa, incrementa la sensibilidad a la insulina en el músculo y la captación de la glucosa periférica (importante cuando se está realizando actividad física) y retrasa la absorción intestinal de glucosa (disminuye la probabilidad de producir hipoglucemia). Lo que significa que en todas las analíticas encontramos niveles normales de glucosa basal y de la insulina basal.

En relación con el colesterol y triglicéridos, encontramos una mejora de los niveles de HDL o llamado colesterol bueno y triglicéridos entre la analítica pre-intervención y la de seguimiento, esto se puede deber a la realización de actividad física durante la

intervención y posteriormente con el proyecto vocacional (la niña se apuntó a clases de Zumba) y a la mejora en los hábitos alimenticios que se explicarán mejor más adelante.

Por último, se solicitó la TSH en los análisis porque se ha propuesto que la TSH aumenta en los pacientes obesos como parte de un proceso adaptativo que busca restablecer el equilibrio del balance energético a través del aumento del gasto en reposo. Los niveles de las hormonas tiroideas varían según la técnica de medición utilizada, la edad y el desarrollo puberal y se relacionan al IMC, la obesidad central, y la insulina plasmática. No encontramos en este caso una alteración en los niveles de TSH.

Sobre la valoración emocional de las actividades grupales presenciales, la paciente acude al 100% de las sesiones presenciales, informando siempre de emociones positivas, específicamente Alegría, a la entrada. En el inicio justificada en la mayoría de los casos la emoción por cuestiones externas a la actividad. A la salida, se mantiene siempre la selección de la misma emoción incrementándose, por norma general, la intensidad y pasando a justificarse por motivos relacionados con la actividad. Ello es indicativo de un efecto motivador de la actividad física, el entorno social desarrollado y las estrategias de gamificación (Figura 22). Por otra parte, no percibe la actividad desarrollada como intensa (Figura 23), cuando la actividad realizada ha sido en algunos casos intensa-moderada (Figuras 24-25, Tablas 9-10).

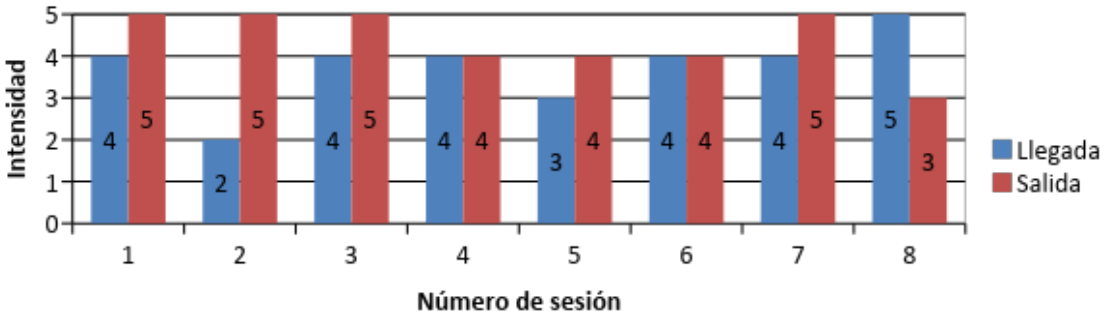

Figura 22. Intensidad de la emoción "alegría" informada al inicio y finalización de cada sesión presencial.
Nota. La escala de intensidad es la siguiente: 1 muy poco, 2 poco, 3 normal, 4 bastante5 mucho

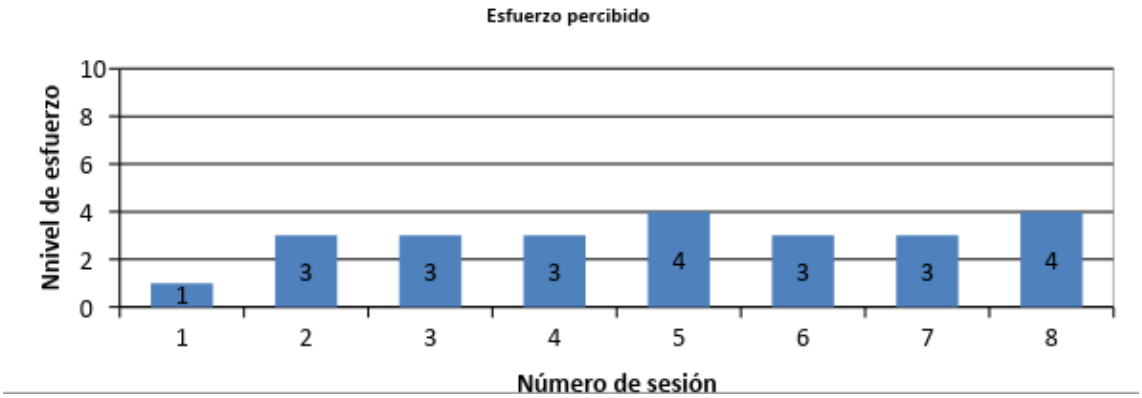

Figura 23. Esfuerzo percibido en cada sesión presencial (juego motor)
Nota. La escala es la siguiente: 1 Muy, muy fácil, 2 Muy fácil, 3 Fácil, 4 Sintiendo un poco de esfuerzo, 5 Empezando a ser pesado, 6 Siendo bastante pesado, 7 Pesado, 8 Muy pesado, 9 Muy, muy pesado, 10 Tan duro que tengo que parar.

Tabla 9. Frecuencia cardíaca media, máxima y mínima recogida por los sensores biométricos para el caso.

Sesión/ Frecuencia Cardíaca	**s1**	**s2**	**s3**	**s4**	**s5**	**s6**	**s7**
Media	136	150	138	135	129	117	106
Max	197	197	182	174	167	156	157
Min	72	95	97	63	90	85	62

Frecuencia Caso		**Estándar**
FcMax	205,2	215
FcReserva	124,2	155
FcReposo	81	60

70% Fc de trabajo según Karvonen = (Fc máxima-Fc reposo)·0,7 + Fc reposo	
167,94	FC de entrenamiento según Karvonen
161,64	Caso de estudio

Tabla 10. Frecuencia cardíaca recomendada, máxima y mínima recogida por los sensores biométricos para el caso.

Actividad física recomendada		MIN Caso	MAX Caso
Intensidad muy ligera: 50-60%, útil para trabajos de recuperación, calentamiento y vuelta a la calma.	143,1	132,6	147,12
Intensidad ligera: 60-70%, zona para el trabajo base de la condición física, muy recomendable para personas que se inician en el deporte y quieren comenzar a construir una buena forma física. También utilizado en los inicios de temporada de deportistas para comenzar a asentar una base de trabajo.	155,52	147,12	161,64
Intensidad moderada: 70-80%, intervalo en el que ya se persigue un objetivo de mejora en rendimiento y se trabaja la eficiencia del corazón (utilización de menos energía para la realización de un esfuerzo). Recomendado para ciclos de entrenamientos preparatorios a pruebas de media-larga duración donde se establece una base aeróbica importante.	167,94	161,64	176,16
Intensidad dura:80-90%, este ya es un escalón donde la fatiga aparece de manera manifiesta. El objetivo es ganar rendimiento y poder trabajar a alta intensidad a lo largo del tiempo. No se recomienda para programas donde se busque mejora de la condición física básica, para eso están los escalones anteriores. Este es un intervalo más para entrenamiento específico y anaeróbico que persigue rendimiento en el deporte.	180,36	176,16	190,68
Intensidad máxima: 90-100%, es el máximo esfuerzo que pueden tolerar nuestros órganos y músculos, se trata de un entrenamiento anaeróbico que debido a su dureza solo se puede aplicar en breves periodos de tiempo (menos de 5 minutos). solo es recomendable para entrenamientos específicos de deportistas que busquen rendimiento.	192,78	190,68	205,2
Nota: FcMax (chicas) =226 - edad y en chicos 220-edad			

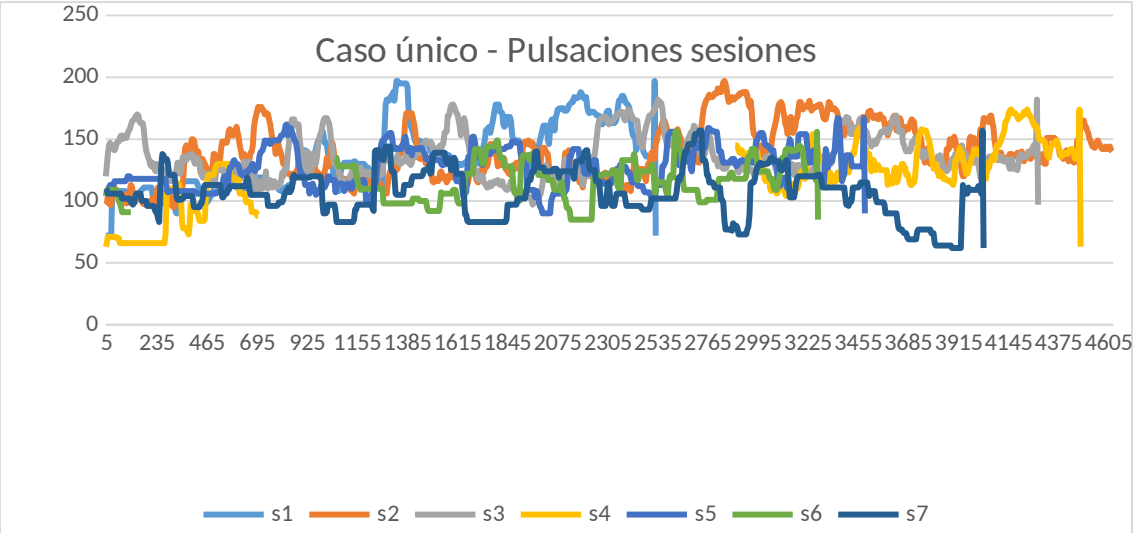

Figura 24. Pulsaciones de la paciente durante las sesiones grupales de actividad física.
Nota: Fc máxima detectada: 205,2

Además, se han calculado índices de no solapamiento de datos, técnica habitualmente aplicada para comprobar la eficacia de tratamiento en casos individuales (por ejemplo, en psicología). Hemos optado por esta técnica porque no requieren contar con muchas medidas en la línea base no en los seguimientos, a pesar de ello, al contar con una única medida de cada indicador en la línea base, hay que considerar con cautela los siguientes datos, por no poder detectar la posible presencia de una tendencia en la misma, pero resultan orientativos para entender los cambios que se han producido. Se ha utilizado el método de no solapamiento de todos los pares (NAP), a partir de la realización de las curvas de ROC, para ello, se consideran de forma conjunta los tres seguimientos, como periodos de información sobre la eficacia de la totalidad de la intervención. Presentamos los tamaños de efecto para la evolución de los índices valorados mediante los cuestionarios, con la categoría propuesta por sus autores, de acuerdo con la valoración: 0-65% efecto débil; 66-92% efecto medio; 93-100% efecto grande, considerándose de 90% al 100% un tratamiento muy efectivo (Tabla 11).

Cuando observamos la adherencia a la dieta mediterránea, las puntuaciones siempre indican que es deseable mejorar los hábitos alimenticios.

Tabla 11. Índice de tamaño de efecto

		NAP	Interpretación convencional
Auto informe	Estados de actividad física	16,7%	Efecto débil
	Autopercepción competencia motriz y de utilidad de AFoD	66,67%	Efecto medio
	Alimentación	100%	Efecto grande
	Salud y bienestar personal	100%	Efecto grande
Padres y Madres	Hábitos saludables	100%	Efecto grande
	Hábitos alimenticios	100%	Efecto grande
	Conocimientos alimentación	50%	Efecto débil
	Tiempo libre	33,33%	Efecto débil
	Actitud hacia videojuegos	100%	Efecto grande
	KIDMED	66,67%	Efecto medio

Otros resultados

Por otra parte, dentro del proyecto de investigación PROVITAO se han analizado otras variables y medidas tomadas a lo largos de la intervención y que se detallan brevemente a continuación con la intención de dar una visión global de todo el programa.

- En cuanto a los hábitos informados por los menores. Se analizaron las respuestas en los cuestionarios sobre hábitos relacionadas con la actividad física realizada en el día a día, la autopercepción de su competencia motriz (CM), su opinión sobre la utilidad de la Actividad Física o Deporte (AFoD) y su percepción sobre su salud y bienestar.

  Los resultados no muestran una mejora significativa estadísticamente entre el grupo control y el experimental en las conductas referidas a la actividad física, su CM o su opinión sobre la utilidad de las AFoD, así como con la salud y el bienestar percibidos. Esto sugiere que no se ha logrado un incremento significativo en la actividad física en su vida cotidiana, esto se podría justificar como vimos en el desarrollo de su proyecto vocacional que implicase actividad física, durante la búsqueda de recursos, encontramos que en las zonas de residencia de algunos participantes no existían recursos accesibles y asequibles para los menores que además resultasen atrayentes para ellos. En algunos casos sí que existían instalaciones de uso público que permitían el desempeño de actividades (parque, avenidas con aparatos destinados a la actividad física, canchas de juego), pero implica que los niños y niñas tengan la motivación de realizar estas actividades y este colectivo destaca por estar poco motivado para la realización de ejercicio físico.

- En cuanto a los cuestionarios de padres y madres. Se analizaron las respuestas organizadas en cinco índices según su contenido. En cuatro de ellos las puntuaciones más altas indican mejores hábitos, mejor actitud o más conocimientos, según proceda, se trata de los índices: hábitos alimenticios de los menores; conocimientos de los padres y madres sobre alimentación; actitud de los padres y madres hacia los videojuegos; y adhesión a la dieta mediterránea de sus hijos/as medida mediante el cuestionario KIDMED. En el caso del índice, hábitos saludables y hábitos de tiempo libre de su hijo o hija, las puntuaciones mayores indican peores hábitos desde el punto de vista de la promoción de la salud.

  De acuerdo con la información aportada por los padres y madres, los dos grupos de participantes presentaban al inicio del estudio perfiles similares.

  Informan de una mejora de los hábitos saludables durante la intervención, pero que se pierden en los hábitos de alimentación en el largo plazo (quizás debido al olvido o falta de formación continua o falta de motivación hacia conductas saludables), podría haber influido en estos cambios, los periodos vacacionales previos al seguimiento a largo plazo, que pueden alterar las rutinas cotidianas.

  Existe una mejora en los hábitos de tiempo libre de los menores del grupo experimental frente al grupo control, aunque no alcanza una significación estadística.

  Respecto a la actitud hacia los videojuegos de los padres y madres encontramos una mejor actitud del grupo experimental frente al control durante la intervención probablemente uno de los beneficios de las actividades desarrolladas durante la fase de intervención con los niños y niñas. En este sentido, habríamos logrado transmitir a los padres y madres que los videojuegos pueden ser una herramienta lúdica que permite poner en práctica, educar y/o reforzar los buenos hábitos. Sin embargo, esta mejora se pierde a largo plazo en ambos grupos, y al menos en el grupo experimental se puede justificar en la vuelta al uso meramente lúdico de los videojuegos.

- En cuanto a las medidas antropométricas, y las analíticas no se encontraron diferencias significativas entre el grupo control y experimental ni entre los diferentes momentos. Ambos grupos, control y experimental, disminuyen el IMC después de la intervención y aumentan en el seguimiento. Por tanto, no podemos concluir que la disminución sea producto de la intervención realizada.

- En el caso de la evaluación conductual, donde se aplicó el BASC en su modalidad de auto informe. Atendiendo a las medias y medianas grupales, estas se sitúan por norma general en las puntuaciones de “normalidad” tanto en las escalas

clínicas como en las adaptativas. En cambio, si atendemos a las extensas desviaciones típicas y los máximos y mínimos en la mayoría de estas, se puede ver que están representadas puntuaciones indicativas de escaso ajuste. Esto se debe en gran medida a la presencia de puntuaciones en los rangos de riesgo y/o significación clínica de varios participantes de ambos grupos en los diferentes momentos de evaluación.

Centrándonos en los cambios a lo largo del tiempo de estudio encontramos que en el grupo control las actitudes hacia el colegio mejoran a medida que varían a lo largo del estudio que coincide con el desarrollo del curso escolar; a pesar de ello las medidas de tendencia central no identifican una actitud general negativa hacia el colegio o su utilidad. No se producen cambios significativos en ningún otro indicador o escala en el grupo control. Se dan más cambios en el grupo experimental. Por ejemplo, disminuyen a lo largo de la intervención la presencia de pensamientos, conductas o pensamientos inusuales, además en el grupo experimental se va desarrollando la sensación de responsabilidad y control sobre cuestiones relacionadas con su vida. El estrés social, es decir, las sensaciones negativas asociadas a las interacciones sociales van modificándose a lo largo de las fases evaluadas y aunque la tendencia central se mantiene, las medias van en disminución. Algo similar ocurre en el índice de depresión que disminuye la variabilidad de las puntuaciones con tendencias centrales.

- En cuanto a la intervención grupal basada en juegos, los resultados del análisis emocional que se realizaba a los participantes a la entrada y a la salida de las sesiones presenciales brindan un indicador de la motivación con la que acudían a la intervención, pero nos interesa especialmente por el carácter informativo sobre el impacto emocional de la misma. Así, para valorar el efecto emocional de la gamificación, las dinámicas de juego llevas a cabo y la formación.

  Los niños y niñas acudían por norma general a las sesiones sintiendo emociones positivas que se mantenían al finalizar las mismas, con escasa representación de emociones negativas o neutras tanto a la entrada como a la salida de las sesiones. La intervención muestra una tendencia a favorecer las emociones positivas y en base a las justificaciones realizadas vemos que estas se relacionan con los elementos de la actividad realizada (juegos, participantes, compañeros, aprendizaje), además de hacer referencia a motivos personales, destacando las verbalizaciones de divertirse y pasarlo bien. Estos resultados reafirman el valor motivador de las sesiones presenciales, especialmente del juego motor y los juegos de formación, que logran establecer expectativas positivas de una sesión a la siguiente.

- Respecto a la actividad física desarrollada durante las intervenciones presenciales a través de juegos motores, se analizó el esfuerzo percibido por los niños y niñas por medio de la aplicación de una escala de auto informe. Cada participante, de forma individual, indicaba al final de la sesión cómo le había resultado la actividad física realizada, seleccionando la etiqueta que mejor lo definiese de entre una escala con 10 niveles que van desde "Muy, muy fácil" hasta "Tan duro que tengo que parar".

  De acuerdo a la información aportada, los juegos motores realizados fueron percibidos de intensidad media y/o baja, en su mayoría (88,9%) dentro de las categorías de fácil a muy fácil (Figura 25).

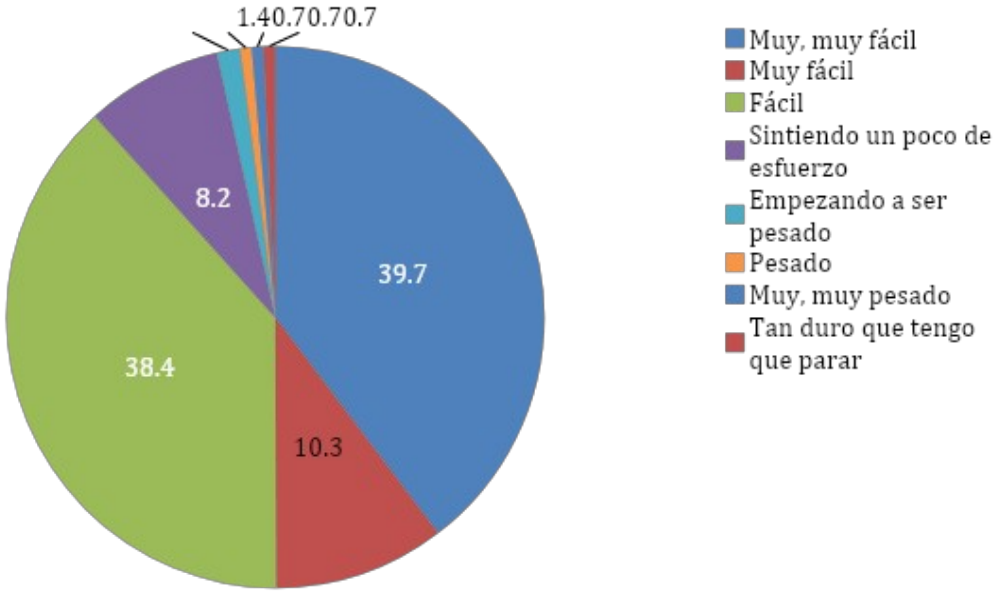

Figura 25. Porcentajes de los niveles de esfuerzo valorados a lo largo de todas las sesiones de intervención.
Nota. Las etiquetas "Siendo bastante pesado" y "Muy pesado" no fueron seleccionadas y no aparecen en el gráfico por claridad expositiva.

Sin embargo, los datos recogidos por los sensores demuestran que la actividad realizada en algunos casos fue moderada a intensa, llegando a picos cercanos a las 200ppm. en algunos casos. Por lo que, aunque las actividades demandaban un esfuerzo medio, para algunos menores supuso una actividad física intensa y algunos de ellos así lo manifestaron en sus percepciones (8,2% un poco de esfuerzo y 3,4% esfuerzo de mayor intensidad). Dicha observación también fue realizada por parte del equipo profesional indicando que algunos de los niños y niñas realmente mostraban evidencias de estar realizando una actividad física "intensa" y de estar disfrutando de la actividad, y consideraban aun así que la actividad desarrollada había sido fácil (en alguno de sus

grados). Además de las diferencias individuales, que pueden variar el impacto de una misma actividad para diferentes participantes; la motivación y el adecuado ajuste de las habilidades requeridas para el desempeño de los juegos motores, pueden ser factores determinantes para que el esfuerzo físico que haya podido realizarse no afecte negativamente a la percepción de eficacia y por tanto de sencillez de la actividad física realizada.

Conclusiones

En este capítulo se ha procedido a presentar los principales resultados del programa de intervención relacionados con la adquisición de hábitos de alimentación saludables a largo a plazo, encontrando que haber participado en el grupo experimental parece suponer un beneficio, pues los conocimientos adquiridos por el grupo experimental tras la intervención presencial se mantienen en el largo plazo, siendo una diferencia significativa.

Se ha presentado también el estudio de un caso único, una paciente mujer de 11 años de edad con diagnóstico de obesidad y resistencia a la insulina (prediabetes de tipo II) para ilustrar las actividades y evaluaciones de la intervención sobre los participantes.

También se ha procedido a presentar un breve resumen de otros resultados del proyecto de intervención enmarcado dentro de PROVITAO.

CAPÍTULO 4.
CONCLUSIONES

A lo largo de las fases del estudio, se observa una mejora significativa en el conocimiento de ambos grupos sobre alimentación saludable, alcanzando niveles más altos a largo plazo que en las dos evaluaciones anteriores. Por un lado, esta tendencia común puede estar reflejando los beneficios de la educación formal, familiar y de salud, que estaba disponible para ambos grupos en la comunidad y cuyo acceso fue promovido por el Proyecto. Al centrarnos solo en los momentos anteriores e inmediatamente posteriores a la intervención cara a cara, encontramos una tendencia diferente en las puntuaciones de ambos grupos. Al observar los medios, vemos que el conocimiento del grupo experimental sobre alimentación saludable es superior al de referencia, mientras que el del grupo de control permanece estable. A partir de ese momento, el conocimiento de los dos grupos aumenta con un perfil similar, evolucionando en paralelo. Haber participado en el grupo experimental parece ser un beneficio, ya que la brecha en el conocimiento adquirido por el grupo experimental después de la intervención presencial sigue presente a largo plazo. Asimismo, se observó una mejora significativa en la adherencia a la Dieta Mediterránea (MD) del grupo experimental en comparación con el grupo control. Además, observamos que el grupo de control empeoró en algunos artículos en comparación con el grupo experimental. Este resultado es importante porque el MD es tradicionalmente un modelo de alimentación cardiosaludable que se caracteriza por un alto consumo de verduras, legumbres, frutas, y cereales usando principalmente el aceite de oliva en para cocinar o aliñar los alimentos. Es probablemente uno de los modelos dietéticos más saludables que existen actualmente. Numerosos estudios epidemiológicos destacan los efectos beneficiosos de este tipo de dieta para combatir las enfermedades cardiovasculares, la diabetes, ciertos tumores y otras patologías asociadas. En este sentido, la DM se relaciona con una mayor esperanza de vida y una menor incidencia de enfermedades crónico-degenerativas, lo que evidencia que un pequeño aumento en la tasa de adherencia a la DM conduce a una reducción significativa en el riesgo de mortalidad y en la incidencia de estas enfermedades.

Este estudio, sin embargo, presenta una serie de limitaciones. Se debe tener en cuenta que se tuvo una muestra de 46 participantes durante las dos fases; sin embargo, el retiro de los participantes del estudio a lo largo de los meses significó la pérdida de datos, sin que se pudiera incluir a nuevos participantes. Además, los participantes provenían de diferentes contextos socioeconómicos, por lo que se tuvo que adaptar las recomendaciones sobre hábitos alimenticios y actividades físicas a las posibilidades económicas de cada familia. En la Fase 1, los participantes asistían a escuelas privadas y públicas, por lo que no había homogeneidad en las opciones educativas. Finalmente, los niños y niñas tenían diferentes intereses de ocio y capacidad de atención, por lo que tuvimos que trabajar rápidamente para crear un círculo de confianza entre los participantes.

Por otra parte, se ha presentado el estudio de un caso único, una paciente mujer de 11 años de edad remitida desde las consultas externas de Pediatría del HUC con diagnóstico de obesidad y resistencia a la insulina (prediabetes de tipo II). La paciente entró a formar parte del GE en la primera fase de PROVITAO. Por tanto, se le realizaron los controles antropométricos y analíticos pre y post intervención, el de seguimiento a los 6 meses y la última de control al año de inicio de la intervención. Tanto el peso, perímetro abdominal y el IMC mejoraron el en control post-intervención y en el seguimiento a los 6 meses. Los valores sufrieron un aumento cuando no se realizó ninguna intervención presencial. Las analíticas refieren valores normales de glucosa basal y de insulina basal al estar la paciente en tratamiento con Metformina 850mg diaria. En relación con el colesterol y triglicéridos encontramos una mejora en los niveles de HDL al finalizar la intervención, cuestión que creemos se debe a la realización de actividad física durante la misma. También se ve una mejora a largo plazo, ya que la paciente desarrolló un proyecto vocacional relacionado con actividad física moderada (zumba), y desarrolló hábitos alimenticios más saludables. No se encontraron alteraciones en los niveles TSH.

Las sesiones presenciales grupales la motivaron y elevaron el bienestar emocional manifestando alegría con una intensidad alta-muy alta. Esto puede deberse al efecto motivador de la actividad física basada en juegos motores y videojuegos activos, el entorno social y la gamificación. Destacamos que, aunque la actividad física desarrollada ha sido moderada e intensa en algunos casos, como se puede observar a través de los datos recogidos por los sensores biométricos, la paciente la percibe como de baja intensidad, al estar inmersa en los juegos desarrollados.

Además, se ha comprobado la eficacia del tratamiento en casos individuales, viendo que, en la alimentación, salud y bienestar personal, actitud hacia los videojuegos, ha tenido un efecto grande (100%), en la autopercepción de la competencia motriz y adhesión a la dieta mediterránea un efecto medio (66,67%) y un efecto débil en los estados de actividad física (16,7%) y tiempo libre (33,3%).

Se cree que es necesaria una mayor concienciación y movilización de la sociedad sobre los problemas derivados del sedentarismo, el sobrepeso y la obesidad infantil. También consideramos que es necesario que a corto plazo se plantee introducir en el currículo educativo de los menores un espacio para la educación en hábitos de vida saludables. Y que este tipo de educación no quede al azar y al interés del docente de formar a sus alumnos y alumnas en este tema. El hecho de que la educación en hábitos de vida saludable forme parte del currículo aseguraría a largo la adquisición de conductas saludables y la prevención de las enfermedades no transmisibles relacionadas con los malos hábitos, repercutiendo en una mejora de la salud para toda la sociedad.

Como además se necesitan diferentes estrategias para lograr un cambio real en los hábitos de vida de los menores, consideramos que en los centros educativos sería

posible replicar este tipo de intervención combinando diferentes herramientas de gamificación y videojuegos activos que motiven a los alumnos a adquirir conocimientos y practicar actividades físicas saludables, ya que se trata de un programa que educa y motiva el cambio de conducta desde edades tempranas utilizando la dinámica de los juegos, tan cercana a los niños y niñas.

El interés del programa de intervención educativa presentado no pretende promover la interacción con videojuegos activos o exergames para sus fines, sin embargo, con la motivación adecuada, pueden despertar la conciencia del alumnado sobre el problema de salud en cuestión, por tanto, la interacción con los exergames puede ser una herramienta eficaz para generar un entorno motivador que puede traducirse en cambios efectivos en los estilos de vida de las personas que interactúan con él, como ya se ha podido ver.

Aunque las limitaciones del estudio en cuanto al tamaño y falta de homogeneidad muestral, así como la complejidad añadida de las diferencias de contexto (escolar, familiar y socioeconómico) hicieron que los resultados del estudio no sean extrapolables al resto de la población, siendo necesario el análisis por casos, podemos concluir que la intervención ha demostrado ser eficaz para motivar a los menores a mejorar sus hábitos a estilos de vida más saludables, promoviendo relaciones sociales satisfactorias y aumentando la percepción de control sobre la propia vida, es decir, favoreciendo su salud integral.

Finalmente, aunque no fue el objetivo de este documento describir todo el programa de intervención general y todos sus resultados, se destacan sus puntos fuertes:

El proyecto PROVITAO ha desarrollado un programa educativo gamificado para hábitos saludables, basado en videojuegos activos y juegos de motor. Ha creado y validado un marco de referencia para la intervención, el monitoreo y la evaluación emocional, biomédica, interactiva, social, psicológica y educativa, basada en juegos, aplicada al tratamiento de la obesidad infantil y a la prevención de complicaciones asociadas. También ha producido varios productos tecnológicos (exergames, juegos serios, aplicaciones web, bibliotecas sensoriales, *wearables*, etc.).

El programa desarrollado consiste en un plan de actividades específicamente diseñado sobre hábitos saludables con juegos motores, videojuegos comerciales (Wii Fit Plus y aplicaciones) y juegos desarrollados internamente como TANGO:H, que se pueden presentar en el hogar y en grupo. Sesiones cara a cara.

PROVITAO se aplicó a un total de 46 niños y niñas con obesidad infantil y a sus cuidadores durante el año escolar, en dos fases.

El grupo de investigación ha participado en diversas actividades a nivel local (charlas en escuelas, conferencias, talleres, etc.) para promover hábitos saludables.

Este estudio se llevó a cabo durante tres años, de 2014 a 2017, gracias al trabajo conjunto realizado por un equipo multidisciplinario de profesionales en las áreas de Educación Física, Psicología, Pedagogía, Ciencias de la Salud y Ciencias de la Computación que diseñaron, supervisaron, ejecutaron y estudiaron el programa propuesto en este trabajo.

A pesar del alcance limitado de este estudio, tiene un gran potencial para obtener conocimiento sobre la población infantil con obesidad porque:

- Se desarrolla en una de las comunidades autónomas con las mayores tasas de obesidad en España y en Europa.
- Proporciona información sobre los hábitos saludables de una población intercultural.
- En implica un grupo de edad donde los hábitos de vida saludables pueden promoverse más fácilmente.
- Educa y crea conciencia en la entidad responsable de los hábitos alimenticios y la actividad física de los niños y niñas, y en la familia.
- Es uno de los primeros programas en utilizar herramientas de gamificación centradas en el aprendizaje educativo no formal que involucra la obesidad y el estilo de vida y su evaluación a largo plazo.
- Han participado diversas entidades, tales como: el Servicio Canario de Salud (Hospital Universitario de Canarias, Servicio de Pediatría, Servicio de Psiquiatría Infantil, Centros de atención primaria), el Departamento de Ingeniería del Instituto de Tecnologías y Energías Renovables, la Dirección General de Salud Pública a través del Servicio de Promoción de la Salud, la Consejería de Educación del Gobierno de Canarias a través de la Dirección Territorial y los diferentes colegios que participaron en el proyecto: CEIP Santa Rosa de Lima, CEIP Las Mercedes, CEIP La Verdellada, CEIP Aguere, CEIP La Aneja y CEIP Samoga.
- El proyecto ha dado lugar a diferentes colaboraciones internacionales con grupos de investigación de EE. UU., Brasil, México, Colombia, Ecuador, Canadá y Portugal, así como con otros grupos nacionales de videojuegos, salud y educación.
- Ha permitido la colaboración con el programa PACES (*Partnerships for Active Children in Elementary Schools*) un Programa Americano para la promoción de la actividad física en las escuelas pionero en la temática.

Además, como trabajo futuro, se pueden establecer las siguientes líneas principales de esta tesis doctoral:

- Ampliar la muestra y desarrollar el programa de intervención en todo el archipiélago canario, así como en otros lugares, más allá del territorio autonómico.
- Validar por parte de los profesionales sanitarios de la eficacia del programa en el tratamiento a largo plazo de la obesidad infantil, especialmente en lo que se refiere al mantenimiento de conductas saludables.
- Diseñar y desarrollar nuevas sesiones educativas basadas en videojuegos activos y otras herramientas tecnológicas gamificadas.
- Extender e introducir la formación de hábitos de vida saludables en los colegios de forma transversal.
- Desarrollar nuevas herramientas para la creación de actividades gamificadas que fomenten los hábitos de vida saludable en los menores en todas las áreas.
- Crear un programa de formación para las familias, dado que los menores dependen de las decisiones de sus padres, madres o tutores, y sus hábitos se desprenden de los que mantengan en su familia.
- Crear programas para los ayuntamientos sobre hábitos de vida saludable.
- Sensibilizar a través de los resultados obtenidos sobre la importancia del juego motor y la actividad física, relacionada con los videojuegos activos y las tecnologías.
- Contextualizado a la pandemia derivada del COVID-19 [61-64] y sabiendo cómo ha afectado a la actividad física y a la salud mental de la población, sería interesante estudiar si este tipo de videojuegos activos pueden ayudar a mantener una actividad física saludable y, al mismo tiempo, ayudar a la salud mental de las personas.

CONTRIBUCIONES ACADÉMICAS DE LA TESIS DOCTORAL

Las contribuciones de esta tesis se publicaron previamente en las siguientes conferencias revisadas por pares y en revistas indexadas que se enumeran a continuación:

Revistas

1. González-González, C.S.; Gómez del Río, N.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2021). Active game-based solutions for the treatment of childhood obesity. Sensors 2021, 21(4), 1266 **(JCR, Q1)**.
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ESTANCIA INTERNACIONAL DURANTE LA TESIS DOCTORAL

Universidad
Nacional
de San Juan

La doctoranda realizó una estancia predoctoral de investigación en la Universidad Nacional de San Juan (Argentina) desde el 01-09-2019 al 01-12-2019, participando en las líneas de investigación relacionadas con tecnología educativa, la gamificación y los videojuegos en educación. En particularmente se ha trabajado investigando sobre el modelado de usuarios y sistemas de recomendación en videojuegos.

AYUDAS RECIBIDAS PARA EL DESARROLLO DE LA TESIS DOCTORAL

Para el desarrollo de esta tesis doctoral se ha contado con el apoyo (financiación por proyectos, becas de estudios, utilización de infraestructuras y/o materiales, realización de estudios y/o procedimientos médicos, y participación) de las siguientes instituciones:

- Financiado por la Fundación CajaCanarias, en el marco del Programa de Ayudas para proyectos de Investigación Sanitaria. Referencia: OBE05. Duración: 1/01/2014-30/06/2017.

- Beca destinada a cursar estudios universitarios de grado y posgrado (Concurso General de Becas) del Cabildo de Tenerife durante los cursos académicos 2018-2019 y 2019-2020.

- Servicio Canario de Salud. Dirección General de Salud Pública. Servicio de Promoción de la Salud, por su participación en actividades formativas, materiales educativos de los programas desarrollados por el servicio (Círculos de vida saludables, Proyecto Delta, Programa PIPO, Programa Aladino, Proyecto Action Health).

- Servicio de Pediatría del Hospital Universitario de Canarias y Servicio de Psiquiatría infanto-juvenil del Hospital Universitario de Canarias, por la participación activa para la selección de casos, realizaciones de las pruebas médicas necesarias en el estudio y seguimiento.

- Facultad de Ciencias de la Salud. Sección de Medicina. Campus de Ofra. Universidad de La Laguna, por ofrecer sus instalaciones para la realización de pruebas médicas.

- Facultad de Ciencias. Sección de Matemáticas. Campus de Anchieta. Área de Ingeniería Informática y de Sistemas. Universidad de La Laguna, por ofrecer sus instalaciones para la realización de talleres y actividades formativas para los padres, madres, tutores, niños y niñas integrantes del estudio.

- Consejería de Educación del Gobierno de Canarias. Dirección Territorial, por su ayuda en la selección de centros educativos participantes en la segunda fase del proyecto.

- Centros educativos públicos del municipio de La Laguna: CEIP Prácticas Aneja E.U.P., CEIP Las Mercedes, CEIP Aguere, CEIP Santa Rosa de Lima, CEIP La Verdellada, y también al CEIP Samoga perteneciente al municipio de El Sauzal, por su participación activa en el estudio, selección de casos y realización de actividades formativas con el equipo investigador.

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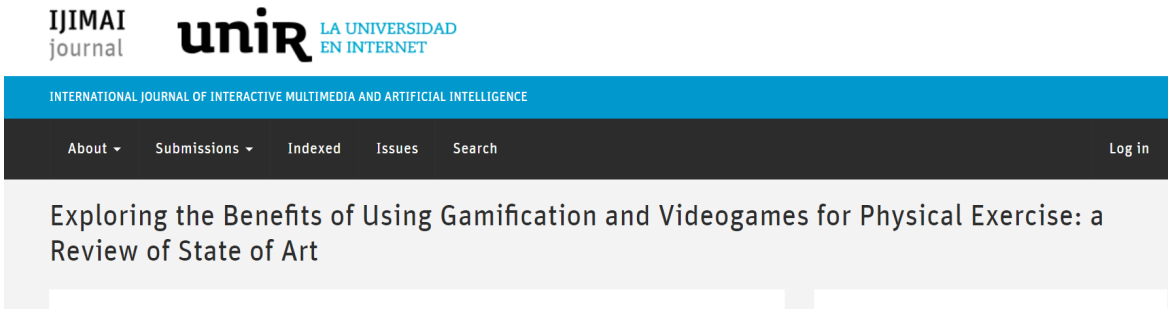
ANEXOS

Anexo 1.
Artículo 1



Resumen

Existe una falta de motivación en los niños, niñas y adolescentes para hacer ejercicio físico y, al mismo tiempo, una epidemia de obesidad en todo el mundo. La gamificación y los videojuegos activos pueden ser utilizados para aumentar la motivación de los jóvenes, promoviendo hábitos saludables.

En este trabajo se exploran diferentes estudios sobre videojuegos activos, eSports y gamificación aplicados al ejercicio físico y a la promoción de la salud.

Los principales hallazgos incluyen efectos positivos en la reducción del peso corporal y en la promoción para continuar realizando ejercicio físico. También contribuye a aumentar la motivación en niños, niñas y adolescentes para la práctica de ejercicio. La personalización de la experiencia del usuario y las tecnologías emergentes (big data, *wearables*, tecnologías inteligentes, etc.) se presentan como oportunidades prometedoras para mantener el compromiso en el programa basado en el juego y la gamificación del ejercicio físico.

Exploring the Benefits of Using Gamification and Videogames for Physical Exercise: a Review of State of Art

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Received 9 January 2018 | Accepted 20 March 2018 | Published 29 March 2018

Abstract

There is a lack of motivation in children and adolescents to do physical exercise and at the same time a worldwide obesity epidemic. Gamification and active videogames can be used to increase the motivation of young people, promoting healthy habits. In this work we explore different studies on active videogames, eSports and gamification applied to physical exercise and health promotion. Main findings include positive effects in a reduction in body weight and in the promotion to continue performing of physical exercise. It also contributes to increase the motivation in children and adolescents to practice exercise. The personalization of user experience and emerging technologies (big data, wearables, smart technologies, etc.) are presented as promising opportunities to keep the engagement in game-based program and gamification of physical exercise.

Keywords

Physical Exercise, Gamification, Active Videogames, Literature Review, State of The Art.

DOI: 10.9781/ijimai.2018.03.005

I. Introduction

In the school or outside, physical exercise (PE) is considered a positive element and widely as a fun, engaging and social activity. Inside schools, there is a curricular formal PE, named Physical Education, which main goals is to develop motor skills, knowledge and healthy behaviors. Outside schools, PE can have many non-formal ways: fitness, sports, dancing, etc. But, many times, the PE lessons in school are the main PE that young people and children have [1]. Physical and active games can attract children and young people to have a regular PE and in this way, to promote healthy habits and wellbeing.

PE can be gamified or transformed into an active game if we consider that any process that satisfies the following premises can be gamified: "the activity can be learned; the user actions can be measured, and the feedbacks are timely delivered to the user" [2].

In the creation of active games, as in other types, designers must take into account fundamental elements. These game elements can be classified in many diverse ways, for example, as:

- Mechanic, story, aesthetics, and technology [3].
- Interfaces, rules, entity manipulations and goals [4].
- Mechanics, dynamics and aesthetics [5].
- Mechanics and dynamics [6].
- Dynamics, mechanics and components [7], organized in a pyramid structure, according if the element is conceptual or tactical.

Although, the most common elements associated to gamification are points, badges and leader-boards (PBL), there are diverse frameworks to design or gamify systems with a variety of elements related to the intrinsic and extrinsic motivation of user [8, 9]. These elements allow the design of personalized gamified experiences according to the user preferences.

In this paper we perform a literature review to extract the elements of games and gamification used for PE and their effectiveness.

II. Studies About Games and Gamification for PE

In the literature we can find several studies about games and PE related with the energy expenditure in educational programs carried out in schools combined with children's leisure time [10]. Main findings include that these kind of physical educative programs in schools increase the motivation of children and adolescents to continue performing physical exercise [11]. But, not all physical activity

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Please cite this article in press as:
C. S. González-González, N. Gómez del Río, V. Navarro-Adelantado. Exploring the Benefits of Using Gamification and Videogames for Physical Exercise: a Review of State of Art, International Journal of Interactive Multimedia and Artificial Intelligence, (2018), http://dx.doi.org/10.9781/ijimai.2018.03.005

impacts in the reduction of body weight, because it depends on the frequency, duration and intensity of the activity [12]. For example, in the study carried out in [13] related to the dancing game, it was found that the cardiorespiratory answer was comparable to an aerobic dance of medium to high intensity [13].

TABLE I. Gamification, Games And Physical Exercise

Reference	Research	Major Findings
[10],[11], [12]	Physical activity and energy expenditure through educational intervention programs	Positive effects in a reduction in body weight and in the promotion of physical exercise.
[14], [15], [16]	Motivation	Increasing the motivation in children and adolescents to practice exercise.
[12], [13], [14], [17], [18], [19], [20],[21], [22]	Energy expenditure with active games	Energy expenditure of an active game is significantly higher than that derived from other sedentary activities or non-active videogames. Children burned the same amount of calories when they walked moderately and three times more than while resting (moderate intensity).
[23],[24], [25],[26], [27],[28]	Interactive technologies to promote healthy habits in children	Gaming platforms, playgrounds and technologies, with gestural and body movement as an interactive element, promotes physical activity. Also, mobile devices and wearables promotes outdoor physical activity.
[29],[30], [31],[32]	Design of active games (collaboration, social aspects, structural elements, etc.)	Patterns for design collaborative games and structural framework based on the fundamentals of motor play to guide the design and evaluation of active videogames.

Regarding the motivation to PE, some studies conclude that is better to encourage children participating in team rather than in individual sports [14]. Also, in other study on a group of overweight children and adolescents using an exergame (Dance Dance Revolution of Konami) as a routine physical activity, found that the game was not enough to motivate them to participate. Then, to increase participation researchers encouraged cooperative play, increased the musical variety and included a competitive mode in the activities [15]. Besides, a dancing videogame used in children´s homes was evaluated while they were playing weekly in group. Results showed that the motivation and participation increased due to the group sessions [16].

Moreover, the use of active videogames has positive effects promoting an active lifestyle. A study compared the energy expenditure (EE) required by a sedentary game and two active videogames, finding that the non-active game increased 22% the EE, in contrast to active games, that increased 108% in the case of torso's movements and 172% in the case of dancing. The same study found that non-obese children had lower EE when playing the dancing video game than obese children [17]. Other studies about EE with active games found that the EE was significantly higher in these kind of games than with conventional videogame [18], [19]. Similar findings of other study showed an increase over the base line of between 120% and 140% in the EE and the energy consumed playing active games, similar when the participant did other PE (walk, jogging, swimming) [20]. Besides, in other study the calories consumed at rest, while watching television and while walking was measured in children and compared with the calories burned when playing active videogames. The results revealed that children burned the same amount of calories when they walked moderately and three times more than while resting [21].

Although positive effects were found in several studies on the EE with active videogames, PE and sports cannot be replaced. As we mentioned above, EE depends on the intensity, duration and frequency of the activity and only a few active videogames allow performing PE with moderate intensity [22].

Several studies describe the effective use of technologies with children in the promotion of healthy habits [23]. Some gaming platforms includes body movement as an interactive element that can be used for PE [24]. Also, outdoor PE are favored by smartphones supporting different sensors tracking biometrics and allowing augmented reality activities [25]. Other technology is the Playware based on the use of sensors, actuators, hardware and software for playgrounds [26]. In Playgrounds, some game elements like social interaction, simplicity, challenge, goals, and feedback should be considered [27]. Playgrounds can be used to spatial cognitive development, considering multiple perspectives, zooming in and out, distances, experiencing movement or finding visual cues [28].

Other game elements that should be considered in the design of educative videogames in general and for active videogames in particular are collaboration and social aspects [29]. A set of theoretical elements for the design of educational videogames were proposed [30] and for monitoring and evaluating educational videogames [31]. A framework based on the fundamentals of motor play to guide the design and evaluation of active videogames have been developed [29]. Other study, analyzed the effectiveness of commercial active platform (Nintendo Wii) and an active platform designed following principles of educational, collaborative and active videogames [32]. In Table I is summarized the major findings of the literature review analyzed regarding gamification, games and physical exercise.

III. eSports and Physical Exercise

Electronic sports (eSports), videogames competitions (digital sports, exergaming, cybersport, etc.) are gaining popularity around the world [33]. Perhaps, the name eSports is based on the transference of the classic classification of "sports" for electronic games that were based on a sport. Despite the eSports are officially accepted as sport in about 60 countries [34], still there is no consensus in a common definition of eSports [33]. Some authors define "eSport" as "an umbrella term used to describe organized, sanctioned video game competitions, most often in the context of video game tournaments" [34]. Other authors define" eSports" as an "area of sport activities in which people develop and train mental or physical abilities in the use of information and communication technologies" [35]. Thus, the term "eSports" sometimes is used as a direct synonymous of digital "sport", but they are not the same. Maybe this confusion is because there are concepts, like 'sport gaming,' 'virtual sports,' and 'exergaming', that are being used to describe the digitalization of playful activities in different ways [35].

The eSports are considered as a "sedentary activity" (or with a low level of physical activity) to be considered an "sport" [36]. And, in the philosophy of sport literature there seems to be 'a solid point of agreement in that the physical skill is a necessary component of all sports [37]. But among the eSports there are games which require physical skill and games which do not [38]. Some authors claims that eSports "require the learning and performance of motor skills and that embodiment within a virtual environment may be considered playful or even athletic" [39]. So, some eSports can be utilized for the development of motor skills, but maybe or not be implies physical exercise [40], as we can observe in examples of eSports with official competition leagues like Counter Strike, WOW (World of Warcraft), League of Legends or FIFA [40].

Although, certain types of eSports cannot be left out of the category of sports, there is not a common criterion about to including eSports into educational contexts [41]. The authors argue that although some eSports can be considered games because it implies the learning of motor skills [39], however, do not concluded that these skills should be taught in physical education programs. They argue that the embodied interaction and visibility of movement behavior can useful to learn about the movement and physical education [39].

IV. Related Projects for Physical Exercise

There are several research projects related to gamification, education and PE. In Table II we related some of the last relevant European Projects. Among the Spanish related projects, we note the project "Play the Game: gamification and healthy habits in physical education". Hernando et al (2015) [42] have studied the impact of the gamification as learning strategy in PE subject at school. The study has been designed as a didactic unit named "Play the game" where students of three secondary schools has to achieve a healthy cardiac frequency in their physical activity through different challenges, levels, points, leaderboards and badges. Therefore, Play the game has innovative elements, such as personalization, cooperation, emotions, technologies and a combination of formal and informal contexts. The results of Play the game show the potential of gamification as an emergent learning strategy in PE because increase the motivation and promote the healthy habits in the students.

Other relevant project on gamification in PE is "ExpandeEF" or Expanded Physical Education, work developed by Lucía Quintero (2017) [43]. ExpandeEF was applied during one academic course with students of the second year in a high school of Tenerife (Canary Islands, Spain). Quintero (2017) used not only gamification strategies to design the experience, but emergent didactic methodologies such as mobile learning, flipped classroom or service-learning was applied (Fig. 1).

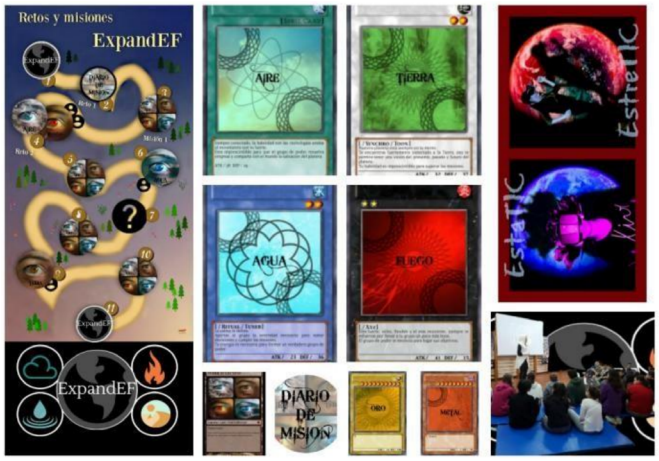

Fig. 1. ExpandeEF project. Source: http://bit.ly/2FNItIx

TABLE II. European Projects for PE

	Description
PEGASO	Uses wearable technologies and games to encourage healthy lifestyles amongst teenagers [20] shows a case study on the use of Gamification strategies and wearable lifestyle technologies for personal health management, in the framework of the European Project PEGASO. This author describes the results of two-year project exploring the potential of various lifestyle tracking and health monitoring equipment and the impact on the health parameters and well-being. The data captured and visualized by the mobile applications linked to these lifestyle technologies illustrates how gamification and enabling technologies have evolved in support of pervasive personal health management. URL: http://www.pegaso4f4.eu/
DOREMI	The main goal of DOREMI project is the "active ageing" based on three keys: healthy eating, active lifestyle and social interaction. The decline of cognitive ability is strongly related to lifestyle, as well as social engagement, cognitive stimulation, nutrition and physical activity. DOREMI is focused on social inclusion with the help of cognitive games and the development of a social and gamified environment. URL: http://www.doremi-fp7.eu/project
BEACONING	The project is named "Breaking Educational Barriers with Contextualized, Pervasive and Gameful Learnin". The 'anytime anywhere' learning concept is developing through pervasive, context-aware and gamified techniques and technologies, framed under the Problem-Based Learning approach. The project will create a platform as ubiquitous solution based on context aware systems, procedural content generation, pedagogy-driven gamification, learning analytics and cloud technology. URL: http://beaconing.eu/
ProsocialLearn	The project "Gamification of Prosocial Learning for Increased Youth Inclusion and Academic Achievement" is founded on the hypothesis that children at risk of social exclusion, lacking empathy and showing high levels of aggressive or anti-social behaviors, should benefit from digital games tailored to teach prosocial skills (the ability to identify the benefits of cooperation, recognize the emotions and needs of others and express trustworthiness) that can help them achieve academically, appreciate team work and recognize the value of understanding other people's needs. The gamification of prosocial learning will be driven by a set of well-defined prosocial learning objectives that are designed for the development of specific prosocial skills, in terms of prosocial theory, gameplay and game mechanics. Moreover, ProsocialLearn will create a new ecosystem through a new market for digital games, designed to support learning and development of prosocial skills, and offering games developers scientifically proven prosocial game elements for development digital games. An application programming interface (API), ProsocialAPI, will allow developers to integrate functions into games including visual sensing, identification of prosocial signals from in-game actions, personalized adaptation of game elements, player profiles, game mechanics and expressive virtual characters, and support for data collection with protection of personal data. URL: http://prosociallearn.eu/
LEGEND	The main goal of this project is to create an ecosystem of tools and apps to key agents of the sport sector. As Google does with its platform but with the sport as the soul, the core of LEGEND platform is Search but then it provides with dozens of tools. With this tool, public (local government, Universities or Schools) and private (sport facilities, individuals, federations, associations, etc.) managers from all around the world can send real time alerts, manage the classifications in an easy way, generate automatic calendars, publish the rules and news, define roles as referees or team managers and many more features to come. Also they have developed mobile apps for following the league but also the users can organize their friendly matches, comment on them before and after the match, check the results of their friends and to share them in other social networks. So, to motivate people to report the results, the project added an algorithm to calculate their skill level of every sport and also added gamification technics to the app so users can get badges depending on their results. Finally, users can track and check all their stats and historical results. URL: https://ec.europa.eu/easme/en/sme/5462/legend-sport-goes-viral

Also, several related projects have been developed by our research group, such as:

- VIDEM (Developing healthy habits and physical education through active educational games for hospitalized children and adolescents) funded by the Ministry of Science and Innovation, Ref. EDU 2010-10010, had the main goal of developing healthy habits through motor games and active video games in hospital classrooms. Among the objectives of the project, there are: a) Designing a model of educational intervention through physical exercise and ICT. The exercise is the transversal educational strategy, related attitudes and communicative values for integration of minors; b) Evaluating the influence of physical activity with learning games and motor play in learning healthy habits. Besides, training interventions and effectiveness of game models and tools applied are valued. In this context, it has been made and validated an integrated educational program formed by motor games and active videogames for the development of healthy lifestyles at a primary school [32]. URL: http://videm.es/
- SALUD-in (Platform for Interactive Virtual Rehabilitation with Physical Social Games for Health and Techniques of Natural Interaction) Ref PROID20100218, funded by the Canarian Agency for Research, Innovation and Information Society. This interactive platform, aimed at hospitalized children, allow the virtual-based rehabilitation based on physical social games for health and natural interaction techniques. It is based on multiplayer games, with games designed for physical and cognitive rehabilitation, a motion capture system and biomedical data based on a low cost system (Kinect sensor and wearables devices). In this project TANGO:H (Tangible Goals platform) was created (Fig. 2). TANGO:H is a platform for hospitalized children with functional diversity developed by the Technological and Renewable Energy Institute (ITER) and the Interaction, Technology and Education Research Group (i-TED)) of the University of La Laguna. Further it comprises a clinical management system and remote monitoring of rehabilitation exercises and medical records of patients. URL: http://saludin.es/

Fig. 2. TANGO:H allow the design of personalized physical games in individual and collaborative modes. URL: http://tangoh.iter.es

- PROVITAO (Active videogames program for Outpatient Treatment of Obesity). The PROVITAO Ref OBE05 project, funded by the CajaCanarias Foundation (2014-2017), aims to support the treatment of obesity at early ages, contributing to improving the state health patients and preventing future disorders in adulthood [44]. It has a model of educational intervention designed for education in healthy habits, with an exercise program, motor games and commercial and own active video games, created in the research group, such as TANGO:H. The whole program is "gamified", in order to motivate and to achieve the engagement of children during the intervention in schools and home (one school year) (Fig. 3). URL: http://provitao.webs.ull.es

Fig. 3. Children using TANGO:H in the school under the PROVITAO project.

Finally, some example of the last gamified platforms or active games to develop healthy habits and can be used in PE are:

- SuperBetter: This platform increases resilience - the ability to stay strong, motivated and optimistic even in the face of difficult obstacles, making more capable of getting through any tough situation. URL: https://www.superbetter.com/
- Zombies, Run!: is a mobile game for running in which players has to run away from zombies. Then, while players run, stories are narrated, random sprinting to avoid zombies are launched. Players can collect items and be punctuated in personal music playlists. URL: https://zombiesrungame.com/
- Fitocracy: In this app, users work on exercise goals in group/ community, and, also, can have a personal coach to keep motivated in fitness and nutrition. URL: https://www.fitocracy.com/
- VirZoom: this technology combines Virtual Reality (FR) and Fitness Technology. VirZOOM is a static bicycle connected to VR games. For example, the user can live different virtual experiences: power a horse in a race, a tank in battle, a fire-breathing dragon through mountains. URL: http://virzoom.com/

V. Trends in Gamification and Games For PE

A. Personalization

People have different ways to get fun. So, the research has identified different player types and motivations to play. Bartle (1996) [45] identified four player types: killer, achiever, socializer, and explorer. Regarding the motivations, Lazzaro (2004) [46] detected four motivational factors for playing games: hard fun, easy fun, altered state and people factor, and Yee (2006) [47] identified three main motivation components: achievement, social and immersion. So, the student model must represent the way people play, and the types of players. The personalization of game elements in the system [48] should take into account the forms of adaptation proposed by Kobsa et al. (1999) [49]: to user data, to usage data and to environment data. Besides, a typology of engaged behaviors to determine if a player is engaged or not has been proposed by Bouvier et al. (2013) [50]. Some research can help to understand the influence of environment data. For example, Cheng (2011) [51] tried to find the good moments to play at work.

Therefore, in gamification it is important to know how to motivate a particular and different person at the right moment using different types

of motivations [52]. Thus, it is possible uses gamification strategies based on intrinsic motivation (inherent in the person, taken for its own sake or interest, for example, status, power, access to certain skills, or to contribute to a common good) or in extrinsic motivation (outside the person, made for reward or feedback). Social strategies can be used to, for example to compete, to collaborate or to compare achievements. In social games, there are collective mechanical equipment (projects, group scores, etc.) and other mechanical applied to the individual (motivation, positive reinforcement, etc.) [53].

Adaptation and personalization are concepts closely related and similar, which have a mutual goal: to offer a closer user experience by offering content close to the user, personalized to your interests and looking for increasing fidelity and satisfaction [53]. To perform this adaptation / personalization, the basic elements are: to define the user profile, to define the content and functionality that you want to adapt, and to define the interface elements that allow this adaptation / personalization. Personalization allows the adaptation of system through different techniques, such as content filtering or rule-based filtering, to infer the user's needs and preferences [54]. For personalization / adaptation of a gamified system, we must think about what are the features that make the system fun and if the system can work with or without these gamified features. We must also think about how these features relate to gamified different user profiles. Moreover, we must also consider whether the system can work independently to gamification without affecting the core functionality, which in our case is learning. For example, a leaderboard can be activated for the most competitive users, while not for others like introspective or special needs users. For the adaptation / personalization experience, the gamification engine must decide when and how specific and general features will be activated, taking into account: a) the student model (consisting of the user profile or static information and user history or dynamic information, and b) contextual information.

The static part of the student model or profile contains data such as age, gender, administrative information, learning style, type of player and preferences. Identifying the type and player preferences will increase the student motivation. The dynamics of the model student or history contains information of student interaction with the learning system and the state of their learning. However, a gamified system must also incorporate the trace of student interaction with the system for activation or deactivation of the functionality of gamification to increase the degree of engagement. Moreover, contextual information is essential in a gamification engine. The students can perform the activities from school, work or in their free time, in the classroom with their peers and with the teacher, or remotely. Student can also do the activities from a tablet, a mobile device, a laptop or desktop computer. All these contextual characteristics affect the gamified experience and the gamification engine must be able to adapt the features to different contexts. For example, if the activity is carried out in the classroom with teacher assistance, the chat cannot be very useful.

According to Gadiyar (2014) [55] "many gamification initiatives use points, badges and leaderboards as a way to motivate and incent participants to alter their behavior and use analytics to measure and monitor users' actions and social components to increase the user motivation", but, most of them fail to keep the user involved over the long term. The proposed solution for this problem is the personalization of the entire gamification process.

Gamification techniques should try to understand users, their personality, feelings, behaviors and actions. Big data [56], behavioral insights and elements of psychology can be used in gamification to provide a better end-user experience. Thus, in a gamification experience, every feedback, message or response should relate to user characteristics and situation properly. Typical gamification approaches, includes PBL, Levels, Feedback, Reward and Recognition techniques. The social gamification includes social media, communities, Web 2.0 elements, and big data analytics. Next generation of gamification systems, includes the elements for a personalized and contextual experience, such as: behavior-based frameworks, mental models, neuroscience and big data analytics.

B. Technology for Gamification and Games for PE

Technology plays a central role in the lives of today's children and young people. So, the use of new technologies, apps and devices into schools, could offer more engaging physical activities and healthier lives to students. Technology should be the core of engagement strategies in PE.

Lister et al (2014) [57] establish that apps "represent a promising opportunity for getting people active and have received considerable attention but this has been at the expense of in-depth analysis of effectiveness" and if the applications are not developed properly, "they will end up in a common technology cycle of hype with the users' feelings of failure and frustration on technology". To promote positive and active user experience in apps, many apps uses gamification, but they only use the most convenient game elements and did not use the full potential of gamification to create a success gaming experience. So, Lister et al (2014) [57] have conducted an analysis of 132 most popular apps in markets and seems to agree with this criticism. Moreover, the authors studied if the apps addressed correctly the motivational components to produce a behavior. They found the apps ignore the individual ability to perform the behavior, being this the main issue to achieve long-term behavioral change. So, digital rewards like badges or points may not produce a long-term behavioral change. We believe that apps have potential in physical education, but the design of these apps needs put attention in to achieve a sustained change in behavior.

According to a report on active life style in young people, it is found that "today's children and adolescents live sedentary lives full of computers, video games and television" [58]. But, certain technology (i.e. wearables, smartphones) that can encourage children to perform outdoor exercise. In this sense, some organizations like Youth Sports Trust, highlighting "the need to include wearable technology and gamification in physical education classes in schools" [59]. Furthermore, they said "in order to get children active from a young age, a more holistic approach to PE is needed, one which integrates technology and the delivery of a seamless, intuitive and digitally enhanced form of physical activity" [58]. Therefore, smart textiles can be introduced in the schools, as PE uniforms, and can take an important role in PE. For example, there are biosignal-monitoring underlayers produced by Athos, which read muscle effort, heart and breathing rates, analyses this information and push recommendations through mobile devices [58].

But tracked data on the activities and statistical information cannot be enough to transform this data into knowledge, skills, attitudes and behaviors [59], motivating and enhancing physical activity. Coaching support in physical activity can be an important key of success in PE. Moreover, school PE teachers will need skills and resources to offer a diverse set of PE activities focused on health, fitness and emotional wellbeing, and supported by technologies. Digital literacy should start at early ages and PE teachers must be put attention at this area. To use effectively technologies teachers requires a specific knowledge, but most primary school teachers tend to be generalists. And, to integrate the technology with the PE in a transparent and intuitive way it is needed to have a holistic approach.

VI. Conclusions

In this paper we presented a review about different studies on games and gamification applied to physical exercise, specially focused on the

promotion healthy habits. We also present a review about the concept of "eSport" and its relationship with physical exercise and some considerations to be include in physical education programs. We found that many studies on active games or gamified physical exercise has been focused on energy expenditure and motivation.

Although, we found several studies and related project about how to use interactive technologies to promote healthy habits, most of games and gamified programs fail to keep the user involved over the long term. So, we believe that providing a more personalized experience can solve the problem of the engagement in long term. Personalization and emerging technologies (big data, wearables, smart technologies, etc.) based games and gamification for physical activity promising opportunity for getting people active.

Finally, we note that active videogames and gamification can be used in educational programs to increase the motivation of children and adolescents in physical exercise. In this sense, the nursing profession can play a fundamental role in health education. So, the educational programs to promote physical exercise and healthy habits should be designed and developed from the Primary Health Attention Centers and, also, in schools. And, the introduction of gamification into these educational programs (i.e. PROVITAO), can improve the quality of life of children who suffer from childhood obesity thanks to the acquisition of healthy habits.

Acknowledgment

This work has been supported partially by Fundación Caja Canarias, Project PROVITAO OBE05.

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Anexo 2.
Artículo 2

sensors

Open Access Article

Health Promotion for Childhood Obesity: An Approach Based on Self-Tracking of Data

by Nazaret Gómez-del-Río [1], Carina S. González-González [2,*], Pedro A. Toledo-Delgado [2], Vanesa Muñoz-Cruz [2] and Francisco García-Peñalvo [1]

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Sensors **2020**, *20*(13), 3778; https://doi.org/10.3390/s20133778

Received: 12 June 2020 / Revised: 25 June 2020 / Accepted: 3 July 2020 / Published: 6 July 2020

Resumen

En la actualidad, la obesidad y el sobrepeso son una epidemia sanitaria mundial. Las intervenciones tradicionales para promover hábitos saludables no parecen ser eficaces, sin embargo, las soluciones tecnológicas emergentes basadas en *wearables* y dispositivos móviles pueden ser útiles para promover hábitos saludables. Estas aplicaciones generan una cantidad considerable de datos de actividad rastreada.

Por lo tanto, nuestro enfoque se basa en el modelo del yo cuantificado para recomendar actividades saludables. La gamificación también puede utilizarse como mecanismo para mejorar la atención personalizada, aumentando la motivación del usuario.

En este artículo se presentan las cinco principales contribuciones de este trabajo.

En primer lugar, se analizan las prácticas de cuantificación del yo en la recogida y exploración de datos personales sobre sus actividades vitales.

En segundo lugar, proponemos y describimos un modelo de EQ de niños y niñas con obesidad. El propósito es explorar el posible cambio de comportamiento en los niños y niñas con hábitos mejores y más saludables.

En tercer lugar, también se describen las fuentes de datos primarias para el modelo de EQ. Estas fuentes incluyen *wearables*, teléfonos móviles, apps, registros de actividad y análisis de sentimientos.

En cuarto lugar, se incluye un modelo UX de la aplicación PROVITAO. Este aspecto es crítico para nuestro propósito de mejorar la adherencia al programa de intervención. El modelo considera siete componentes: aspectos objetivos y subjetivos del sistema, experiencia del usuario, interacción, perfil del usuario, características contextuales y gamificación.

En quinto lugar, un sistema de recomendación de actividades para promover hábitos saludables en niños y niñas obesos. También incluye los módulos de filtrado de acciones, activación de recomendaciones y elección de acciones.

Además, este artículo también incluye la validación de los modelos propuestos, y se describen las validaciones del modelo QS y de las intervenciones gamificadas.

Por último, se presentan los resultados de un programa gamificado aplicado durante tres años en menores con obesidad y el proceso de evaluación del modelo *quantified-self* con expertos. Los resultados del proyecto no han mostrado una mejora significativa inmediata o general en medidas como la composición de la masa corporal de los participantes o el porcentaje de grasa corporal. Sin embargo, hay pruebas de un impacto positivo en los hábitos y salud de los participantes, que podría conducir a un efecto positivo a largo plazo. Estos cambios incluyen un mejor conocimiento sobre la alimentación saludable, una mejora del comportamiento y un mayor sentido de la responsabilidad, un control sobre cuestiones como el estrés social y la depresión, una tendencia a favorecer las emociones positivas después de la intervención y una mejora en los hábitos de tiempo libre.

sensors

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Health Promotion for Childhood Obesity: An Approach Based on Self-Tracking of Data

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Received: 12 June 2020; Accepted: 3 July 2020; Published: 6 July 2020

Abstract: At present, obesity and overweight are a global health epidemic. Traditional interventions for promoting healthy habits do not appear to be effective. However, emerging technological solutions based on wearables and mobile devices can be useful in promoting healthy habits. These applications generate a considerable amount of tracked activity data. Consequently, our approach is based on the quantified-self model for recommending healthy activities. Gamification can also be used as a mechanism to enhance personalization, increasing user motivation. This paper describes the quantified-self model and its data sources, the activity recommender system, and the PROVITAO App user experience model. Furthermore, it presents the results of a gamified program applied for three years in children with obesity and the process of evaluating the quantified-self model with experts. Positive outcomes were obtained in children's medical parameters and health habits.

Keywords: child obesity; physical activity; user model; recommender system; UX; QS

1. Introduction

Obesity is regarded one of the most problematic illnesses in developed countries [1]. Its consequences for life expectancy and quality of life are severe. Obesity is not merely an aesthetic problem, but represents a real social health problem, with significant short-, medium-, and long-term consequences. These impacts are not only physical, but also emotional and social, and directly affect the well-being of the population. Consequences occur at the individual, health, and economic levels. Thus, it has been postulated in a number of countries that obesity may represent an unsustainable burden on the health system. The problem of obesity is even more severe when it affects children.

Childhood obesity is the most prevalent chronic disease in developed and developing countries. The incidence of overweight and obesity among children has increased dramatically in recent decades. One of the most critical risks of childhood obesity is that being overweight in early childhood increases the risk of obesity later [2]. A rise in the likelihood of diseases [3] and obesity-related health risks has also been documented, including an increase in the incidence of type-2 diabetes among young people in recent years [4].

The problem of poor patient adherence can be a pervasive threat to health. The current approach to treating obesity often focuses primarily on weight loss. Self-motivation is essential for adhering to change; however, it can be challenging for individuals to adhere to a routine of exercise and physical activity despite knowledge that lifestyle change is the most effective method for long-term weight

management. The use of wearable health monitors and predictive analytics techniques provides the basis for an excellent healthcare system [5].

In children, the reasons for not adhering to healthy routines involve problems related to adapting schedules, refusing to perform the treatment, and dissatisfaction with the results, among others [6]. Lack of adherence may lead to various problems related to the patient's capacity to change their habits and to commit to the treatment. Furthermore, there is a gap in the literature regarding the effects of gamification in the long term [7]. As a result, we developed an educative gamified program, named PROVITAO, to promote healthy habits using motor play and exergames [8]. This gamified educational program enhances patient learning in a fun way using gamification techniques and aids in weight loss maintenance using games. Consistent with the available bibliography, observations of the program, in which children met with their peers and professionals, showed a strong attachment was made to the proposed activities during the programmed interventions, followed by a quick decay in interest to continue the activities on their own during the months following the program sessions.

A solution to the problem of adherence may be provided by technology. In recent years, the number of mobile apps available to facilitate therapeutic adherence has increased. Park et al. [9] carried out a study of the efficacy of mobile phone interventions and demonstrated that personalized feedback has positive effects on medication adherence. Other studies have also been carried out to evaluate the effectiveness of technological means to increase adherence to treatment [10–12], although it should be noted that some applications only remind the patient to take medication. In contrast, other applications have more content, such as educational interventions or rehabilitation exercises [13,14].

The popularization of devices that make it possible to continually measure different variables related to a person's activities has led to the appearance of what has been termed the Quantified Self (QS) [15].

According to the Quantified Self Institute, the term "quantified self" embodies self-knowledge through self-tracking. Some common points of QS are data collection, the display of these data, and the cross-referencing of these data to discover possible correlations [16]. Measures about the self can be organic, bodily, behavioral, or environmental [17]. These data can be recorded daily (heart rate, respiration, hours slept) or even more frequently (blood pressure or weight, for example). Other data that can enrich the QS user model can be related to short-term and long-term information, such as the attitudes, behaviors, effects, and cognitive functions of users [18,19]. QS can involve the graphical presentation of the information and a response loop of reflection and self-analysis [17]. Recent studies have shown that behavior and physical exercises with activity supervision raise activity to reduce overweight or obesity [20]. However, high attrition rates after a number of months have also been reported [21,22]. Moreover, the implementation of self-tracking for health has also received criticism [23].

PROVITAO is a project, a technology ecosystem, and an intervention program for the promotion of healthy habits in children with obesity. Its scope is broader than the contribution made to this paper [7]. The PROVITAO App is one of the technologies of the mentioned ecosystem. The app is a closely related implementation of what is proposed in this paper. Although discussion of the development of the app is not an objective of this paper, herein the user experience model developed for the app is analyzed.

We propose a QS multidimensional model for children aged 6 to 12 years old to promote healthy habits by self-tracking of their daily activities. Several research problems emerge from this issue, namely:

- RQ1. What is an appropriate multidimensional QS model for promoting healthy habits in children?
- RQ2. How might a recommender system complement the QS model to help the user select the appropriate actions and the time to do them?
- RQ3. How can the User eXperience (UX) of using a QS approach for children be improved?
- RQ4. How does a gamified technology-based intervention impact the health of children?

Therefore, the main contributions of this paper are five-fold.

First, quantified-self practices in collecting and exploring personal data about their life activities are analyzed [24].

Second, we propose and describe a QS model of children with obesity. The purpose is to explore the potential change of behavior in children with better and healthier habits. Experts have previously validated the model in the context of the PROVITAO Project.

Third, the primary data sources for the QS model are also described. These sources include wearables, mobile phones, apps, activity logs, and sentiment analysis.

Additionally, a UX model of the PROVITAO App is included. This aspect is critical for our purpose to improve adherence to the intervention program. The model considers seven components: objective and subjective system aspects, user experience, interaction, user profile, contextual characteristics, and gamification.

Finally, an activity recommender system (ARS) is central to the use of the information in the models, and is activated during the interaction of the user with the system. It also includes the modules of action filtering, recommendation trigger, and action chooser.

Moreover, this paper also includes validation of the proposed models, and validations of the QS model and the gamified interventions are described.

The paper is organized as follows. In Section 2, we analyze the state of the art and related research on QS and its health applications. Then, in Section 3, we describe the technological solution we designed for this project, focusing on the QS model and the activity recommender system to promote healthy habits in obese children. Finally, we present the validation results in Section 4 and the conclusions in Section 5.

2. State of the Art

Wolf and Kelly defined the term quantified-self in 2007 which, according to Swan [25], can be defined as "any individual engaged in the self-tracking of any kind of biological, physical, behavioral, or environmental information, as a proactive stance toward obtaining information and acting on it." This author also provided several examples of different quantified self-data, such as:

- Physical activities (distance, steps, calories, repetitions, etc.)
- Diet (calories consumed, satiety, fat, etc.)
- Psychological states (happiness, anxiety, depression, etc.)
- Mental and cognitive states (patience, creativity, reaction, memory, etc.)
- Environmental variables (location, noise, weather, etc.)
- Situational variables (context, time, date, etc.)
- Social variables (influence, charisma, status, etc.).

Swan (10) defined quantified self-tracking as the collection of information (physical, biological, environmental, or behavioral) that can be measured by an individual. The technologies should make it easy to use and access this information, and the data should be accurate and suitable for analysis. In addition, machine learning techniques should be employed to extract useful information [26].

There are several varieties of QS projects. In the sections that follow, we focus on those related to health.

2.1. Quantified Self for Health

QS is increasingly being used for healthcare with new methodologies and biometric data analysis [27]. In this environment, QS application has many advantages: self-healing, self-discipline, self-improvement, self-knowledge, etc. The main advantages are the positive effect of preventive medicine and enabling the patient and doctor to see updated information in real-time [28,29]. QS has been applied to health in several practices, including personal informatics. There are several health

tracking devices, including accelerometers, pedometers, smartwatches, wrist-worn devices, wearables biosensors, clothing and wearable textiles, and smartphone applications [30–34].

Shin and Biocca proposed a study of the design and evaluation of technologies and QS applications to identify different means to encourage healthy user behavior [35]. Their results showed that confirmation and gratification (for example, satisfaction with technology use and enjoyment) and confirmed the importance of usability in the promotion of healthy user behavior. In their research, they observed that health feedback was more efficient when shown in text and comparative form, and that comparative feedback motivated users more than non-comparative feedback. Shin previously presented a study of a quantified-self user experience that employed wearable devices for health monitoring, which highlighted the importance of comparative feedback and of taking the characteristics and differences of users into account when designing strategies for improving healthcare by using self-monitoring or self-tracking devices [36].

Régnier and Chauvel conducted an interview study of the influences of various factors (social, cultural, and economic) on the use of self-tracking and fitness applications [37]. Their results demonstrated that users from lower milieus used fewer digital devices and participated less in social media (due to the cost of the devices, etc.), and therefore benefited less from a healthy lifestyle. However, the study results showed that, in terms of healthy behaviors, digital self-quantification devices are less important than their use.

Nevertheless, not all health tracking information involves automatic sensing derived from devices or biosensors. Sometimes other user information is needed, such as food consumption or physical activities undertaken, moods, and emotions. For this, apps and web platforms exist to support the collection of health data from users and provide insights via visualization [38]. Quantified-self measurements can be observational [39] or experimental [40]. In either case, it is necessary to identify specific user profiles and objectives of the application to design customized systems that adapt to and motivate the user depending on their goal [41].

Williamson [38] analyzed the digitized future of physical education, in particular, "how health tracking technologies promote new 'bio-pedagogies' of organic optimization based on data-led and algorithmically-mediated understandings of the body." The author suggested the need for a greater focus on "how algorithmic systems are becoming embedded in emerging physical education technologies and pedagogical practices."

Didžiokaitė conducted a study of the use of the MyFitnessPal app for dieting to improve fitness or sports performance, in which participants primarily used the technology with limited goals and little discipline because the objective of the majority of the users was to lower calorie intake immediately [42].

2.2. Wearables for Childen and Digital Biopedagogical Platforms

Various wearable trackers for children exist, providing a means for parents to track their child's activity. These include AngelSense, Trax Family, Hereo, My buddy Tag, The Gator, Weenect, Ambertalert, Flashme Sidney; in addition, Omate x Nanoblock, Lineable Junior, and Kiddo are under development. The following are designed especially for fitness purposes: Garmin Vivofit Jr. 2, Fitbit Zip, Unicef Kid Power Band, Nabi Compete, X-Doria Kidfit, and Fitbit Alta HR.

In terms of health, in the educational field, the emerging area of portable physical activity monitors that combine tracking and biosensing capabilities with built-in algorithms to calculate and estimate health and fitness levels is being promoted to schools [43]. Many health monitoring applications for children are designed to encourage healthy lifestyles, diet planning, and physical activity. The popular features of applications related to children's health include the concept of caring for virtual creatures and satisfying their dietary and physical exercise needs, often combined with various gaming and competition elements and online social networking platforms [44]. In the future, physical education pedagogies may appear in schools with the use of health monitoring technologies; for example, digital technologies, pedometers, and aptitude tests are already used in tests to monitor and control physical education [45].

From the perspective of global citizenship and responsibility, the Quantified Self Institute manages a vital research project, "Wearable Technologies for Active Living," to develop activity monitors for children and a data platform to analyze and present the results. Its portable sensor device "makes children and parents aware of their physical activity." In addition, the analysis of data obtained by users from the platform that accompanies the activity monitors is intended to be used in scientific research in which obesity awareness, behavior, and prevention play an essential role. As an academic research program, the Quantified Self Institute provides evidence of how children's activity and physical fitness have become significant scientific enterprises.

Regarding gamified fitness, health monitoring is not only focused on metrics; it can also be fun and entertaining. Competitive and avatar-based health devices, applications, and platforms, such as Sqord represent the gamification of digital health among children. Gamification is the result of device and platform designers who persuade and guide their users towards correct behaviors using the psychology of game design. Designers have thus become medical influencers by using persuasive computer techniques [46,47]. The gamification of self-tracking can also allow for better surveillance [48].

2.3. Quantified Self and User Modeling

QS tools and devices for tracking and collecting data of healthy people open new opportunities for modeling users. The variety of data that can be collected automatically is wide: physiological states (for example, blood pressure), cognitive states (for example, stress), behaviors (for example, movements or an average number of hours of sleep), spatial context (for example, places visited), and social context (for example, people met or interacted with) [49].

This large amount of data collected from users' daily actions and behaviors is not limited to the user's web activity, as is typically the case in traditional user models [49].

The data obtained on user behavior can be used to create user models in the short, medium, and long term (18). For instance, Sarzotti et al. [49] proposed an Enhanced User Model (EUM) with short- and long-term data on four types of information:

- Attitudes: feelings, states of mind, and desires for a particular item, event, or tendency;
- Behaviors: activities that happen at a precise moment in time (like tasks or actions), or habits (series of repetitive acts);
- Emotions: moods (emotive trends over a prolonged period); emotions (over a short interval);
- Mental states: cognitive functions (for instance, memory, attention) regarding an instant and cognitive skills associated with their performance over time, such as an increase or decrease of memory health or spatial orientation.

Therefore, in this paper, we describe a QS proposal for creating a short-, medium-, and long-term user model that focuses not only on cognitive functions, attitudes, behaviors, and emotions, but also on physical and healthy performance activities.

3. Study on Enhancing Healthy Habits in Children

The PROVITAO Project

The recently developed PROVITAO project is a crucial precedent for the QS proposal described in this paper. Relevant details of the project are described here before the QS model is then detailed. The PROVITAO project aims to assist in the treatment of obesity in children, improve health, and prevent disorders in adulthood, as described in [7].

The methodology applied in the project was a quasi-experimental, longitudinal, and prospective three-year study. It consisted of two phases, with each phase having a control group (children with obesity who do not participate in the intervention program) and an experimental group (children with obesity participating in the intervention program). This program was carried out in its first year at the University Hospital of the Canary Islands (HUC), located in the province of Santa Cruz de Tenerife,

Autonomous Community of the Canary Islands, Spain. The target population was children diagnosed with obesity/diabetes type II seen in the pediatric outpatient clinics of the HUC. In the second year, the study was carried out in the public schools of the District of La Laguna, Tenerife, Spain. The target population was the students enrolled in these participating centers who suffered from obesity.

The sample comprised 45 children aged between 6 and 12 years (25 girls and 20 boys). This sample was selected using an inclusion criterion of a diagnosis of childhood obesity (Body Mass Index (BMI) > Percentile (PC)95; unit of measurement kg/m^2), and, divided into experimental and control groups. The inclusion and exclusion criteria for the sample selection were as follows:

- Inclusion criteria:
    * Children aged between 6 and 12 years with obesity, using as the criterion a BMI higher than PC95.
    * Children attending HUC's pediatric outpatient clinics (Phase 1).
    * Students enrolled in the public school participating in this project (Phase 2)
- Exclusion criteria:
    * Children who did not have the necessary networking technologies at home (computer and Internet) and television (experimental group only). The project provided the remainder of the technological tools required for the intervention at home (Kinect sensor, Wii console, and Wii balance board) and in the group sessions.
    * Children whose parents did not wish to participate in the project.
    * Children with cognitive impairment preventing them from participating in the project.
    * Participation during the preceding 12 months in a clinical trial.

The sample selection method was as follows. In Phase 1, children who attended the hospital's pediatric consultation for the first time and met the inclusion and exclusion criteria were chosen. They were invited to participate at the consultation, and the objective of the study was briefly explained to them. If they agreed to participate, the doctor provided the research team with the first data collected at the medical consultation, namely, confirmation of an obesity diagnosis in the child and contact details. In addition, parents were given an information document about the project and a small questionnaire used to identify the technology networks used in the home. Later, in an information meeting with the research team, informed consent was given to participate in the control or experimental group, and any doubts about the research were clarified. In Phase 2, the physical education teachers of each school were asked to record the weight, height, age, and sex of the students in the 3rd, 4th, 5th, and 6th grades of primary education, providing the research team with the anonymized data (the school assigned each child a number and only the school had the correspondence between the number and the identification of the child). Those children enrolled in that school, who met the criterion of Body Mass Index (BMI) higher than PC95, and whose ages were between 6 and 12 years, were chosen.

Subsequently, the school was informed that the children had been selected based on their BMI, and invited to a meeting where the objective of the study was briefly explained, and they were given an information document and a document on which to indicate informed consent.

The conduct of this work followed the ethical guidelines and principles for medical research involving human subjects, as set out in the Declaration of Helsinki adopted at the World Medical Association (WMA) Assembly in 1964, and in the latest update in 2004. Therefore, the knowledge and approval of the students' parents or guardians were ensured. In addition, the research was approved by the ethical committee of the Hospital Universitario de Canarias (approval code: CEIBA2020-0410).

We developed different serious games and apps for educational intervention to promote healthy living (some of the created resources are available at the website of the project [8]). One of these educational gamified tools and games was TANGO: H, using Kinect, which allowed the creation of different types of physical and cognitive exercises (43). Low-cost sensors (heart rate monitor

and accelerometer) were used. In particular, we opted for a pulse and accelerometer wearable type wristwatch and belt from the brand Decathlon (Geonaute Onmiles 600). This type of commercial sensor provides its own analysis software. To study the potential of commercial sensors controlled by the provided software, a sensor integration library was designed and implemented to create interfaces and biometric signal records, allowing access to the data from commercial sensors. Finally, we created the PROVITAO App for smartphones and tablets, and a portal to gamify the activities performed by the children, with weekly missions that earned points, prizes, etc. The intervention was carried out in several phases (See Table 1, Figures 1 and 2).

Table 1. Description of the phases and goals of PROVITAO.

Phase	Goal
1: Pre-Intervention Phase	• Permit application • Fieldwork Preparation • Cross-sectional simple sample study - Environment risk/protective factors - Unhealthy habits, level of knowledge - Obesity/overweight prevalence • Target Population • Definition data
2: Intervention	Intervention. 1st Quarter • Gamified Process • Group Sessions – Physical Activities + Tango: H • Home Sessions – Wii Fit Plus (Session designs) – Mobile Apps • Parent training activities • Children Educational Program Intervention. 2nd Quarter • Home Sessions – ICT Tools – Wii Fit Plus • Vocational Project • Contact with municipalities • Orientation activities for parents and children Intervention. 3rd Quarter • Execution of the vocational Project – ICT supported intervention – Videoconferencing – Tutored activities • B-learning support and advice for parents and children
3: Post-Intervention Phase	• Evaluate the influence of educational intervention. • Technological tools effectiveness validation. • Metric reevaluation after intervention phases.

Figure 1. A patient of phase 1 of PROVITAO playing with TANGO: H and using the Geonaute Onmiles 600.

Figure 2. Children in phase 2 of PROVITAO using the provided applications.

We defined a QS user model and other models to interact with the user due to the large and varied data sources used in this project (biometrics, anthropometric, interaction logs, tests, medical reports, etc.). Thus, in the following section, we describe the proposed models and data sources developed for the PROVITAO project.

4. Multidimensional QS Model for Promoting Healthy Habits

The main objectives of this paper are to describe a QS model, its data sources, a new architecture for an activity recommender system, and a UX module, all intended to enhance the adherence of children

with obesity to a healthy lifestyle after an intervention stage. To accomplish our goals, the architecture includes the following components:

- Data sources (DS): We propose gathering data from multiple sources of information, including wearable sensors, mobile sensors, applications, digital activity records, and sentiment analysis applied to written communications.
- QS user model (QSUM): We define a QS user model that is continuously updated using the information mentioned above. The QS user model includes variables grouped into several aspects, such as attitudes, behaviors, emotions, and cognitive functions.
- Activity recommender system (ARS): Given the QS user model and the contextual information gathered about the user, a recommendation can be selected at any time from a predefined set of actions. To build the recommendation system, advanced data mining and machine learning techniques are applied [50]. The actions include engaging in a particular sport, participating in an active game, learning and reinforcing knowledge about healthy habits, and motivation enhancement tasks.
- UX Module (UXM): We propose a design for motivation enhancement tasks, although this design is itself an open research problem. It has been shown that adults who have access to data collected during their physical exercise sessions improve their performance and adherence. Consequently, we propose a means to present progress data to children to maximize their response. Due to the large and varied sources of data used in this project (biometric and anthropometric data, interaction logs, tests, medical reports, etc.), we define a QS user model and other models to interact with the user.

4.1. Data Sources

Data relevant to this study can be provided by multiple sources, including wearables, mobile phones, apps, activity logs, and sentiment analysis. Figure 3 shows the different data sources and systems, and the means of pre-processing and processing the data to make it relevant to the user.

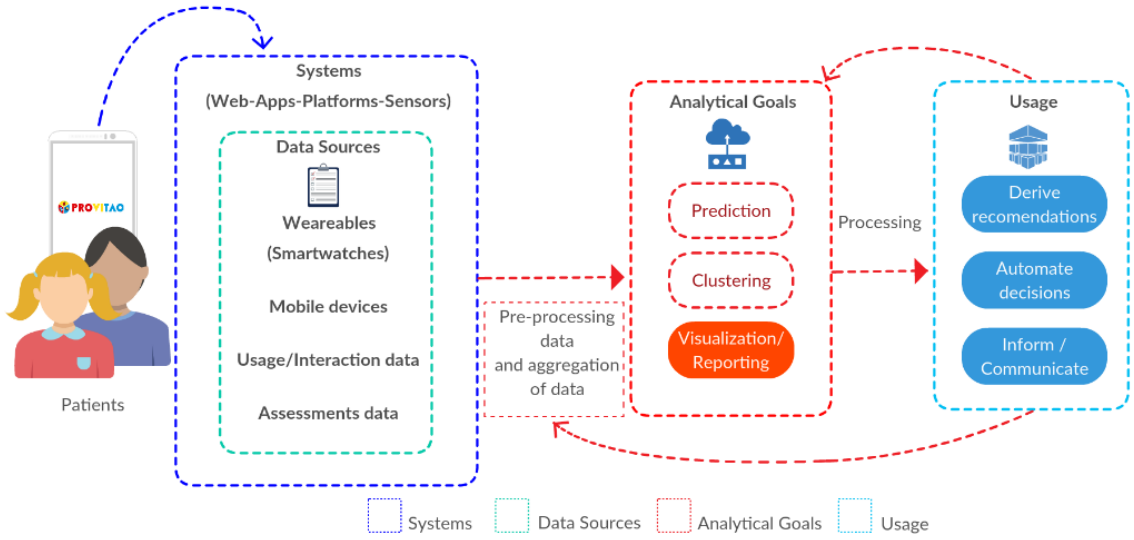

Figure 3. Main elements for making QS PROVITAO data relevant.

PROVITAO manages diverse data from different aspects related to a patient with obesity. Table 2 shows the data grouped into different categories, such as player profile, emotions, behaviors, UX, social, diet, medical reports, anthropometric data, healthy lifestyle habits, and other relevant data.

Table 2. Type of measurements, data, and times when they are collected.

Type of Measurement	Data	When
Medical reports	Diagnosis Treatment Level of compliance Tests Observations	Periodical
Blood tests	Systolic blood pressure, Diastolic blood pressure, Erythrocytes Leukocytes, Hematocrit, Hemoglobin, Platelets, Glucose Cholesterol, Triglycerides, Iron, Ferritin, B12 vitamin, Folic acid, Creatinine, etc.	Pre-/Mid-/Post-Intervention
Anthropometric data°	Age, weight, height, BMI, subscapular folds, triceps folds, biceps folds, pectoral folds, axillary folds, supraspinal folds, abdominal folds, thigh folds, leg folds, humeral diameter, wrist diameter, femur diameter, waist diameter, hip diameter, contracted arm diameter, relaxed arm diameter, leg perimeter, thigh perimeter	Pre-/Mid-/Post-Intervention
Biometric data from sensors	Pulsometer (Heart Rate) Accelerometer (Steps, Speed, Distance, Pace, etc.)	During session intervention/Diary
Geolocalization data	Patient's physical location Timepoint Patient's location history	Diary
Emotional data	Intervention (EMODIANA): -Input emotion (Positive, Negative, Neutral) -Exit emotion (Positive, Negative, Neutral) -Justification (Person, Structure, Context, Person-Structure, Person-Context, Structure-Context, Person-Structure-Context) Mood (sentiment analysis)	Per session (entrance and exit) Diary
Behavioral data (BASC)	Negative attitude toward school Negative attitude toward teachers Atypicality Control locus Social stress Anxiety Depression Sense of disability Relationships Relationship with parents Self-esteem Self-confidence Clinical mismatch School mismatch Personal adjustment	Pre-/Mid-/Post-Intervention
Diet data (KIDMED)	Adherence to Mediterranean Diet: Types of foods, Frequency, and Quantity	Pre-/Mid-/Post-Intervention
Data on healthy physical habits	States of physical activity Self-perception of motor competence and the usefulness of physical activity or sports Health and personal well-being	Pre-/Mid-/Post-Intervention
Social data	Level of interaction in collaborative activities/games Role in the group (gamification) Social status (gamification)	During session intervention
UX data	UX satisfaction (TANGO: H) Emotional variables Fun Toolkit Metrics (Apps)	During session intervention Home/Diary

Table 2. *Cont.*

Type of Measurement	Data	When
Player Profile (HEXAD)	Philanthropic Achiever Socializer Free spirit Player Disruptor	Beginning of the intervention
Socio-economic data	City, District Internet access and connected devices School (Private–Public)	Beginning of the intervention
Situational data	Context Situation Privacy concerns Time of day Day of week	During intervention

Activities	- Active video game platforms:
	  - *TANGO: H:* Type of Exercise, Level, Punctuation
	  - *Wii Fit Plus:* Type of game (i.e., aerobics, balance, toning, yoga, exercise plus), Type of exercise (i.e., hula hoop, bike ride, land on white, tightrope, warrior, tree, Zazen, etc.), Level, Punctuation, KM, Weather, Meters
	- Motor games: Type of motor games, Level of intensity, Perceived effort
	- Health mobile apps/PROVITAO App: The name of the game, the level reached, Punctuation
	- Educational activities in PROVITAO Platforms: Moodle Forum, Moodle tasks, Video conference (group), Social networks
	- Other physical activities: Type of activity (Sports, Dancing, Running, Walking, Training, Playing, ...), time spent on it
		Sessions designed for the group (weekly)
		Sessions designed for the home (weekly)
		Sessions designed for the group (weekly)
		Recommended activities to perform at home (weekly)

User Preferences	Favorite foods/drinks Favorite activities/games Favorite places	During intervention
Personal characteristics	Age Sex Educational level Attitudes and motivation	At the beginning of the intervention
Environmental data	Family environment School environment	At the beginning of the intervention

4.2. QS User Model (QSUM)

Our goal is to build a user model based on QS to be applied to obese children and to explore the potential for changing behavior toward healthier habits in the medium and long term. We also aim to enhance the QS through gamification. This user model contains information on attitudes, behaviors, emotions, learning, and health, and is supplemented with data collected from activities carried out in the real world using biometric devices, and data related to the user experience and gamification (Figure 4).

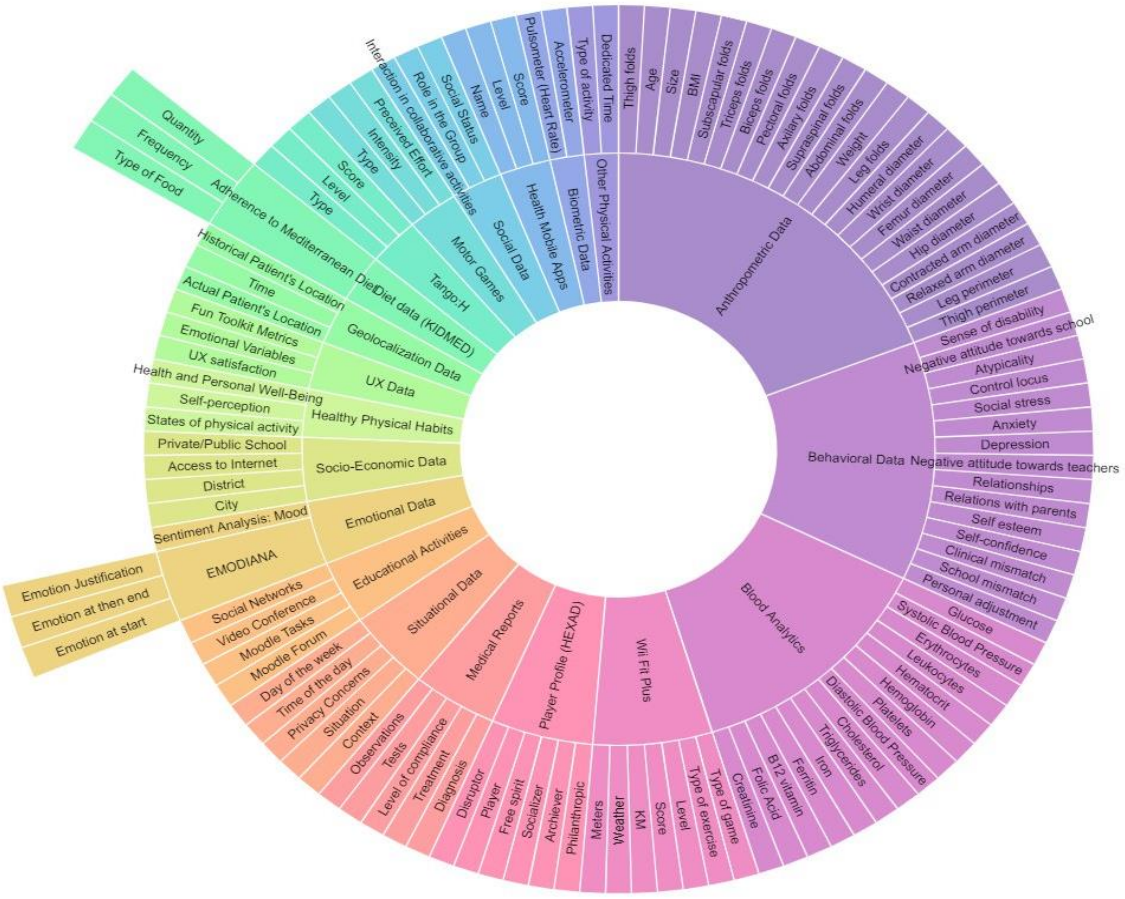

Figure 4. Data and aspects considered in the QS PROVITAO user model.

Thus, Figure 4 presents the different instruments, types of measurements, and data that we considered for the QS User Model.

Data regarding users came from medical reports (diagnosis, treatment, level of compliance, tests, and observations). These data were measured periodically.

Other types of measurement were provided by blood tests (systolic blood pressure, diastolic blood pressure, erythrocytes, leukocytes, hematocrit, hemoglobin, platelets, glucose, cholesterol, triglycerides, iron, ferritin, B12 vitamin, folic acid, creatinine, etc.). These measurements were taken at different moments of the intervention (pre-/mid-/post-).

Regarding anthropometric data, we measured age, weight, height, BMI, subscapular folds, triceps folds, biceps folds, inner folds, axillary folds, supraspinal folds, abdominal folds, thigh folds, leg folds, humeral diameter, wrist diameter, femur diameter, waist diameter, hip diameter, contracted arm diameter, relaxed arm diameter, leg perimeter, and thigh perimeter. These data were also taken at different stages of the intervention (pre-/mid-/post-).

We also collected biometric data from sensors, specifically from pulsometers (heart rate) and accelerometers (steps, speed, distance, pace) during session interventions.

In addition, we also considered the geolocalization data of the patient's physical location, including time points and an individual patient's location history.

Emotional data is another critical dimension of our QS User model. We collected these data per session (at entrance and exit) through the instrument EMODIANA [51].

Regarding the behavioral data, Behavior Assessment System for Children (BASC) was selected [52], which allows collection of different physiological measures, such as negative attitude toward school, negative attitude toward teachers, atypicality, control locus, social stress, anxiety, depression, sense of disability, relationships, relationship with parents, self-esteem, self-confidence, clinical mismatch, school

mismatch, and personal adjustment. In addition, we included measurements relating to diet using the KIDMED questionnaire [53]. KIDMED provides data relating to adherence to the Mediterranean diet, namely, types of foods, frequency, and quantity. Moreover, data on healthy physical habits were considered in our model, such as states of physical activity, self-perception of motor competence, the usefulness of physical activity or sports, and data about health and personal well-being.

These data from BASC, KIDMED, and healthy physical habits were collected at different moments of the intervention (pre-/mid-/post-).

During face-to-face group sessions, we gathered data regarding the social dimension of gamification, such as the level of interaction in collaborative activities/games, the group's role, and social status. User experience data were also considered, such as UX satisfaction (i.e., included in TANGO: H) and the emotional variables using the Fun Toolkit Metrics.

Before the intervention phase of the project, we determined the characteristics of the study participants using the HEXAD instrument. Thus, we classified our users into different players (i.e., philanthropic, achiever, socializer, free spirit, or disruptor). Other data collected at this phase were related to socio-demographic information, environmental data (family and school), and personal characteristics (age, sex, educational level, attitudes, and motivation).

During the intervention, information related to the situational data and user preferences, and to different activities carried out in the project, was gathered. These included active videogames (TANGO: H); exercises with the WII Fit Plus (i.e., aerobics, balance, toning, yoga, exercise plus); type of exercise (i.e., hula hoop, bike ride, land on white, tightrope, warrior, tree, Zazen, etc.), level, and score; motor games (the type of motor games, intensity, perceived effort); mobile health apps (i.e., the name of the game/app, level reached, score); and other educational activities (with time spent) in PROVITAO platforms (i.e., Moodle, videoconferencing and social networks, and other physical activities developed by children, such as type sports, dancing, running, and walking).

4.3. A Recommendation System to Complement the QS Model: The Activity Recommender System (ARS)

As described earlier, given the QS model and the contextual information, the recommendation system provides a recommendation from a predefined set of actions at any time. Formally, it can be defined as a purely abstract system with two inputs, one output, and background knowledge, as shown in Figure 5. However, the system itself might be complex because of the nature of the information involved. The recommendation system should be divided into modules that are able to work independently of one another.

The architecture of the recommendation system is based on the interaction of three different components: (a) the recommender trigger, (b) the action selector, and (c) the action filter (Figure 5).

4.3.1. Recommendation Trigger

The recommendation system's success depends on appropriately selecting a time at which recommendations are provided to the user. This module explicitly targets this issue.

An action can be triggered by various aspects:

Time and schedule: Depending on the time and the schedule of the users and actions, some actions are required to be scheduled. Reminder actions, weekly results summaries, scheduled physical activity sessions, etc., can be triggered within this aspect.

Location: When the user visits specific locations, an action can be triggered. For example, if the user is walking near a sports center that offers activities the user might be interested in, a reminder can trigger this location.

User model update: If the user's QS model changes, an action can be triggered. Clear examples are the duration since the last physical activity session or time spent at a sedentary activity. When this time reaches a certain threshold, an activity recommendation is triggered.

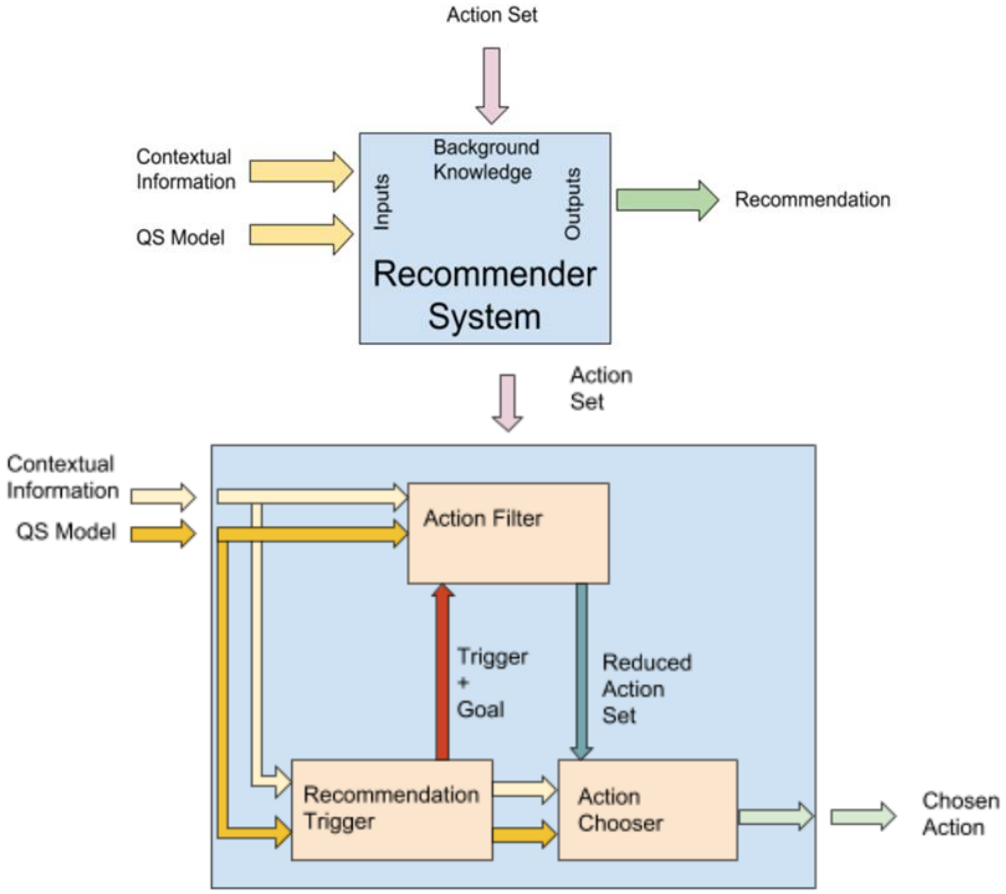

Figure 5. General model and sub-models of the recommendation system.

The result of the recommendation trigger is not only the trigger event itself, but also the trigger goal. The trigger goal is a composition of the variables that influenced the trigger, and, should be the chosen action's objective.

4.3.2. Action Filter

The action recommendation will strongly depend on the user context. Not all actions may be appropriate because a natural set of constraints might exist beforehand. This context awareness approach to recommendation will ensure that only actions that fulfill some previously designed conditions are chosen. The approach to the action filter was designed based on an automated planning approach. Each action from the action set is linked to a set of preconditions and a set of goals. The set of preconditions is aligned with the aspects of the QS model and the contextual information. The QS model includes objective aspects, subjective aspects, and user profile features. Contextual information includes environmental, socio-economic, and situational data. The situational data includes not only the location of the user, but also timing and schedule information.

The preconditions are explicitly expressed as binary clauses built from the available variables. The set of goals for the action indicates the consequences the action might have on the user. Actions might seek to improve the physical training of the users, change their mood, improve self-awareness, reinforce some cognitive ability, etc. Only the actions that satisfy requirements, given the contextual information, QS model, and trigger goal, are sent to the action chooser module. Actions might be sent individually, or as an ordered group of actions, called a plan. A plan is designed as a concatenation of actions to be executed in a specified order. The selected order guarantees that when the action is executed, the preconditions have been fulfilled, given the consequences and the initial conditions of the previous action.

4.3.3. Action Chooser

Once the recommendation is triggered, and the action set is filtered, a simplified version of the original recommendation system problem is addressed using the action chooser. Any of the filtered actions should be suitable for the user, and the time for the recommendation should also be appropriate. However, not every action is equally beneficial for users. Therefore, randomly choosing an action from the filtered action set is not an acceptable solution. The problem domain is significant, as is the number of dimensions, and therefore this does not seem appropriate for a content-driven approach to a recommendation. Even after the problem's dimensions are reduced, the number of features to consider is sufficiently large to suffer from the curse of dimensionality, given the limited expected volume of the platform's initial users. A traditional means of approaching such a recommendation is to build an expert system. The knowledge from professionals in the domain can be used to formulate rules to apply to the recommendation. One example of these systems is the fuzzy logic recommender, which encapsulates expert knowledge into a set of rules and a non-binary truth function. However, our proposed action chooser does not rely on some previously hardwired expert knowledge in the form of rules; on the contrary, a self-regulated learning algorithm is used instead. Based on a mix of content-based recommendations and collaborative filtering with learning, a reinforcement learning (RL) approach is used. Specifically, a simpler version of RL called the "Multi-Armed Bandit Problem" approach is implemented. The Multi-Armed Bandit Problem solution chooses the recommendation based on the expected output of that action in the current context. However, since, as previously stated, the dimension of the problem is large, it is assumed that the expected output for that specific context is merely a coarse approximation. More precise information about the expectation can only be retrieved after the experience of selecting different actions in the same context. The Multi-Armed Bandit Problem approach minimizes the number of incorrect recommendations that might be provided by the system before correcting its behavior. However, at the same time, a valuation of the results from the recommended action must be gathered from the user or the action to close the loop for the learning system.

4.3.4. Recommendation Examples

Some examples of the types of recommendations in the form of actions, challenges, events, and reminders that the system considers are:

Healthy food restaurants and meals: At lunch or dinner time, the recommendation could be for a restaurant with a balanced menu based on your current location, or for a balanced meal at a specific restaurant.
Healthy locations: When the system detects that the user is enjoying free time, it recommends places to visit nearby that have health benefits for the user.
Physical activities: At the scheduled time for physical activity, a kind of activity is recommended, given the user preferences and the surrounding locations.

4.4. UX Model Using a QS Approach

The key to any recommendation system is the algorithm that makes recommendations based on the user's data [54]. Thus, a large part of the research on recommendation systems has been devoted to creating and evaluating the best algorithms [55]. The better the algorithm, the better the recommendations it makes, and the better the UX will be in terms of the satisfaction and effectiveness of the system. Pu, Chen and Hu [56] evaluated the aspects related to recommendation systems from the user's perspective and presented a model named ResQue (Recommender System's Quality of User Experience) [57]. ResQue has four aspects: perceived system qualities, user beliefs as a result of perceived qualities, user subjective attitudes, and user behavioral intentions. However, other factors influence the user experience in recommender systems, such as situational and context factors, personal

aspects, or privacy concerns. Knijnenburg et al. described a framework for UX in recommender systems, which they divided into objective and subjective aspects that influence the user experience [58].

In the case of our UX, we considered for recommendation systems those aspects of QS that have not yet been thoroughly researched. Thus, we proposed a particular UX module that integrates the user experience point of view into the activity recommendation system. Adapting the model proposed by Knijnenburg et al. [59], our UX module considers six components: (a) the objective systems aspects (i.e., algorithms, biometrics, medical aspects, etc.); (b) the subjective system aspects (i.e., user perceptions of the objective aspects, subjective assessments of emotions, healthy habits, diet, etc.); (c) user experience (i.e., evaluation of the different parts (activities, systems, etc.) of the program); (d) interaction (i.e., interactions with different systems and platforms); (e) user profile (i.e., personal characteristics, player profile, preferences); and (f) contextual characteristics (i.e., environmental, socio-economic and situational data). In addition, we added a new module activity—gamification—to the model (Figure 6).

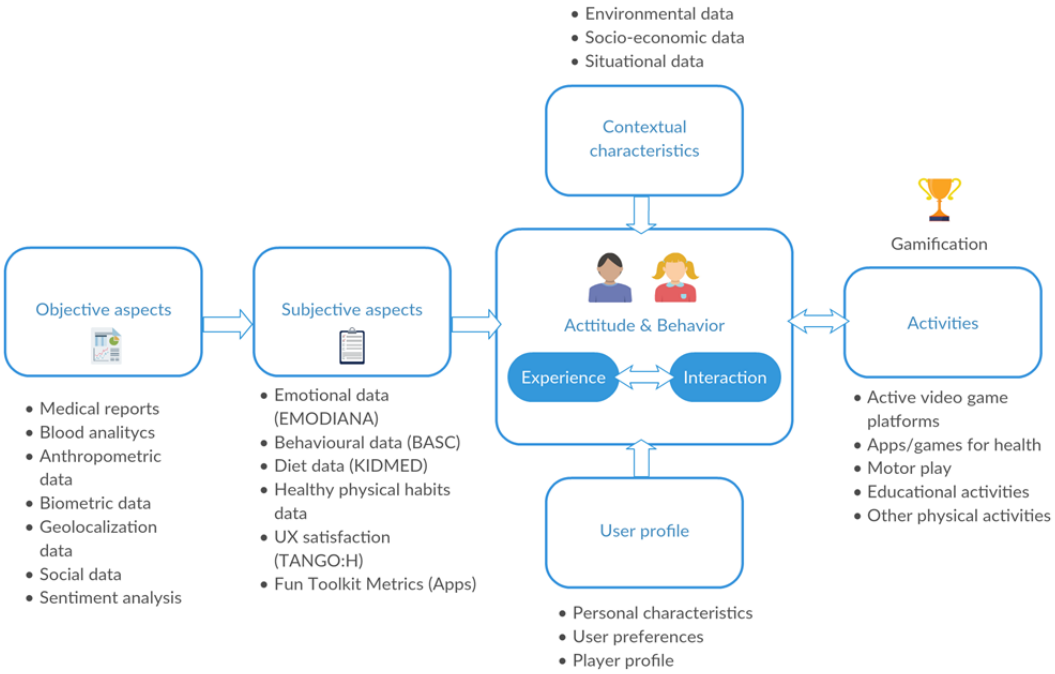

Figure 6. Components of our UX model for the PROVITAO recommendation system.

4.5. Gamified Technology-Based Intervention: The PROVITAO App Prototype

The above discussion presents the main contributions of this paper, which are related to the QS data set models. We now present a brief description of the PROVITAO App and its main functionalities. This web app was developed as a prototype to implement the different data models needed for the project, considering the varied data sources, instruments, and activities. This prototype was one of the tools developed as part of the PROVITAO project, however it was not used with the full intervention. Thus, the PROVITAO App was designed as a prototype of a progressive web app with a modular structure divided into the main roles or features to represent different patient therapy environments:

Clinical support. Allows therapists to design an appropriate protocol for each patient, including follow-up, the activities experienced by the patient, and the control of their effects.

Support at home. Allows communication between patient and therapist, enabling data of the process to be obtained and contributing to the child's health education.

Mobile support. Facilitates the child's access to advice and therapeutic instructions, and carries out the different weekly activities to achieve a series of rewards, making the treatment attractive.

This web app maintains communication between both parties, although each has specific functions (Figure 7). Thus, doctors can oversee monitoring of patients, advising families, and establishing weekly activities to encourage children to acquire healthy living habits. Children comply with these activities as part of their treatment. The activities provide children with points and rewards based on a pirate theme that ends with a final prize as they progress through a treasure map. With these small missions and games, children can remain active in the game, thus, not only complying with the treatment, but also implementing the knowledge they have acquired to date. Furthermore, the families' work is highly decisive since the children are expected to imitate the people around them. Therefore, parents can also visualize their child's evolution on a weekly basis, learning from doctors, nurses, and nutritionists, with the aim of integrating the child into the project quickly and comfortably.

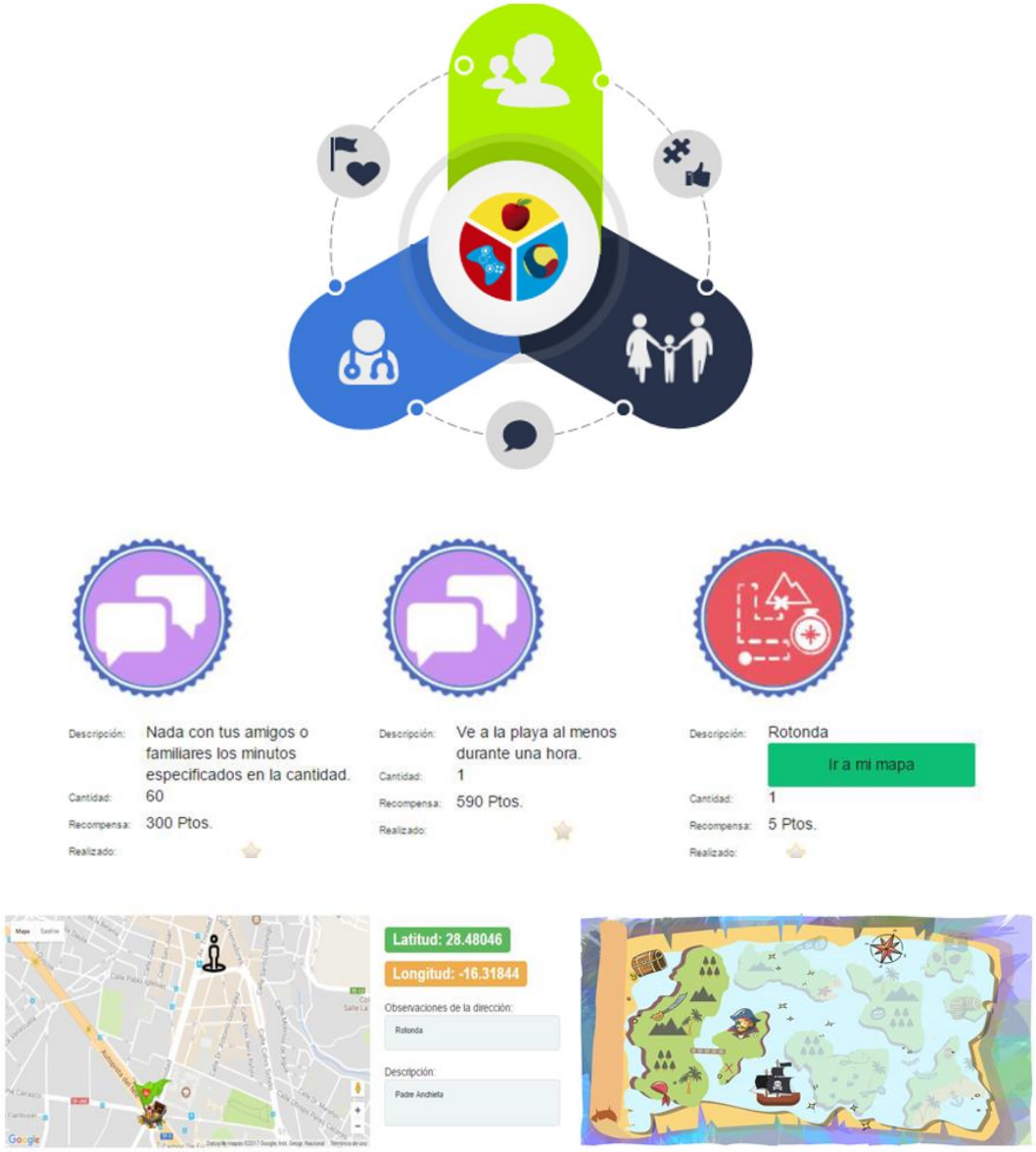

Figure 7. Roles in the PROVITAO App and examples of recommendations for three activities to undertake in a week, including description, time, and rewards, and the geolocalized activity "treasure map" with different islands to unlock.

In the next section, we present validations of the project. First, we present the validation of the QS model, followed by the usability of the prototype of the PROVITAO App, and, finally, the effectiveness of the gamified educational intervention in terms of learning and adherence to healthy habits.

5. Validation

In this section, we present the validations undertaken of this work. First, we describe the validation undertaken by the experts of the QS model; then, we present the validation of the user experience of the app; and, finally, we present the validation of the gamified technology-based intervention impact on the health of children.

5.1. Validation of the Multidimensional QS Model

The data sources of our QS model were validated by a convenience sample of 15 experts (eight female and seven male) from different areas of the PROVITAO project (medical, psychological, computer science, leisure-emotional, interactivity, health education) during iterative meetings. The experts were recruited based on their close relationship to the project and the relevance of their knowledge and area of expertise. These iterative meetings were held during the first six months of the project. The method used was a focus group, and a total of six sessions were conducted, organized into three phases (two meetings each phase, the first to propose and the second to refine).

The first phase's goal was to decide which instruments to use with the target group (control group and/or experimental group or family). The second phase's goal was to define the variables to be measured, their relationship to the research questions, and the systems and devices that could be used to collect data. The final phase in the definition and validation of the QS model involved organizing all of the data into different components, and validating them as inputs and outputs of the system. In the final phase, all of the experts shared their preliminary proposals to agree on the QS model's final proposal.

The experts were grouped by areas of expertise to discuss and decide on the proposed QS model as follows (Table 3).

Table 3. Experts organized by area of expertise.

	Medicine (Biomedical, Physiotherapy, Pediatrics, Nutrition and Endocrinology)					**Leisure-Emotion (Physical Education and Psychology)**				**Interactivity (Computer Science, Psychology)**				**Psychology and Education (Psychology, Health Education, Educational Technology)**			
Expert	E1	E2	E3	E4	E5 *	E6	E7	E8	E9	E10	E11	E12	E13 *	E13 *	E5 *	E14	E15
Age	40	58	50	60	25	58	44	43	28	34	43	33	29	29	25	25	26
Sex	M	F	F	M	F	M	M	F	F	M	F	M	F	F	F	F	M
Title	ME	ME	ME	ME	NU	PE	PE	CS	PS	CS	CS	CS	PS	PS	NU	ED	CS

F: Female-M: Male; CS: Computer Science (PhD); PE: Physical Education (PhD); PS: Psychology (PhD); NU: Nursing (Master's); ME: Medical Doctor (PhD), ED: Education (Master's); (*) Experts in certain areas took part in more than one discussion group.

5.2. UX Validation

The user interface of the PROVITAO App was heuristically evaluated with a group of 10 experts (six men and four women) in the areas of computer science, health, and education, and from different countries, such as the USA, Ecuador, and Spain. The experts addressed a significant usability issue based on Nielsen's established heuristics list (56). As a result, ten heuristics were evaluated.

Each team member independently performed each task on the website/app, documented usability problems and the heuristic infringements that took place, and rated each problem according to its severity. The usability problem severity rating was constructed as follows: 0—this is not a usability problem; 1—cosmetic problem; 2—minor usability problem; 3—major usability problem, requires fixing; and 4—usability catastrophe, must fix.

The chosen groups of usability findings were split into two parts: (a) negatives (Table 4) and (b) positives (Table 5). Five negatives and three positives are presented, associated with the specific issue and the heuristic(s) violated, and the severity of the issue is listed for each finding. Table 6 then shows the average user satisfaction for 82 heuristics evaluated by category.

Table 4. Negatives and proposed solutions.

##	Problem	Heuristic (s)	Severity	Detail
1	Navigation	#1 #3	2	Users found difficulties in navigation and misunderstood the nav buttons. Lack of buttons to move between activities and to move back and forward.
2	Consistency and standards	#2	2	Some words or symbols can be confused. For example, the gamification "star" symbol does not appear in health professional profiles.
3	Personalization	#7 #3	1	Need more personalization features in user profiles.
4	Error messages	#5 #6	2	Signs usually accompany some error messages at the beginning that divert attention from the error message. The corresponding solution should accompany error messages.
5	Help	#10	4	Need to expand the help section and to write more instructions on some patient options. There should be a help section or, in its absence, instructions on each page, especially doctors.

Table 5. Positives.

##	Success	Heuristic (s)	Detail
1	Language	#4	Correct language adapted to children (in this case, patients).
2	Design	#8	Nice, adequate, and minimalist design. The information displayed correctly.
3	Gamification	#7	Good approach, especially the rewards map.

Table 6. Average user satisfaction for 82 evaluated heuristics, presented by category.

#	Category	Quantity Of Heuristics Evaluated	Average Satisfaction (Min:1–Max:5)
1	Visibility of system status	19	2.3
2	Match between system and the real world	8	2.3
3	User control and freedom	8	3
4	Consistency and standards	14	2.1
5	Error prevention	9	2.4
6	Recognition rather than recall	4	2.8
7	Flexibility and efficiency of use	11	1.9
8	Aesthetic and minimalist design	2	3.4
9	Help users recognize, diagnose, and recover from errors	3	1.9
10	Help and documentation	4	2.9

5.3. Validation of the Gamified Educational Intervention

In this section, we describe a summary of the validation of the PROVITAO gamified program. The main goal was to validate the efficacy of a gamified educational program in minors with obesity. It was initially proposed that a criterion for inclusion of children in the second phase would be a type 2 diabetes diagnosis associated with obesity; however, it was challenging to find children admitted to hospital with both pathologies. This is because, since insulin resistance is detected, some medical treatments are actives; thus, the development of diabetes is stopped. Consequently, we studied the case of a child with obesity associated with metabolic syndrome and conducting a single case study [60].

We analyzed the results of questionnaires using SPSS 20.0 (Chicago, IL, USA). Then, we undertook a comparative analysis of the results obtained from the different data collection times (pre- vs. post-) and groups.

The responses of the children to the questions relating to health-related habits were analyzed and organized according to their self-perception of their motor competence, their opinion about the usefulness of physical activity or sport, their knowledge about healthy eating, and, finally, their perception of their health and well-being. Higher scores suggest healthier habits, better knowledge, and better satisfaction. The variables were distributed normally corresponding to the Kolmogorov–Smirnov test [61]. The similarity of the means in the baseline suggests that both groups showed analogous scores at the beginning of the study (see Table 7).

Table 7. Responses of children to the questions relating to health-related habits.

Group and Statistical Means and (Standard Deviations) of the Difference in Mean Scores in the Children's Baseline Questionnaires						
	Control N = 20	**Experimental N = 25**	**F(1,43)**	**p**	**η2p**	**P**
Self-perception of motor skills and the usefulness of physical activity or sports	22.25 (3.40)	20.36 (5.60)	1.75	0.19	0.04	0.25
Feeding	27.00 (3.64)	26.40 (2.66)	0.41	0.52	0.01	0.10
Personal Health and Wellness	40.75 (5.73)	39.32 (7.03)	0.54	0.47	0.01	0.11

Means and (Standard Deviations) of Questionnaire Rates Reported by the Two Groups of Children in the Follow-Up Assessments.				
	Short Term		**Long Term**	
	Control N = 16	**Experimental N = 17**	**Control N = 16**	**Experimental N = 15**
Self-perception of motor skills and the usefulness of physical activity or sports	22.69 (3.34)	20.59 (4.99)	20.81 (3.31)	19.80 (5.71)
Feeding	27.00 (2.88)	28.71 (2.62)	29.56 (2.50)	30.87 (2.95)
Personal Health and Wellness	40.25 (6.39)	40.18 (8.06)	40.63 (8.21)	38.80 (7.01)

Note: After Bonferroni adjustment.

No statistically significant improvement between the control and experimental groups in physical activity behaviors was found; however, compared to the control group, the experimental group revealed significant progress related to knowledge about healthy eating over the long term. The interaction between the monitoring and group factor was not significant ($F(2.50) = 2.582$; $p = 0.086$; $\eta 2p = 0.094$; $p = 0.492$), nor was there any significant group effect ($F(1.25) = 0.503$; $p = 0.485$; $\eta 2p = 0.020$; $p = 0.105$).

In contrast, there was a significant effect of the follow-up factor (F(2.50) = 28.647; $p = 0.000$; η2p = 0.532; $p \geq 0.999$). After applying the Bonferroni adjustment to the pair analyses, it was observed that the scores over the long term were significantly different from those of the baseline (t(23) = 7.002; $p \leq 0.001$; d = 1.2) and those of the immediate follow-up (t(23) = 6.234; $p \leq 0.001$; d = 0.99). Examining the progression of the means considering both groups together, in both cases the greatest means in knowledge were found in the long term (Table 7).

In addition, no significant differences were found between the control and experimental groups or between the different collection times in the anthropometric measures (Table 8). As a reference value of childhood obesity, we used the standardized growth charts of the Faustino Orbegozo Foundation, which is recommended by the Spanish Association of Pediatrics [62]. These tables establish reference values as follows: for boys with an age of 8.5 years the median BMI is 17.69, the median height is 1.32 m, the median weight is 30.97 kg; for girls at the same age, the median BMI is 17.32, the median height is 1.30 m, and the median weight is 29.71 kg. In addition, the BMI value indicating obesity at the age of 8.5 is 23.5 for boys and 24.7 for girls; at the age of 9.5m, this value is 25.3 for boys and 25.6 for girls. Table 8 shows BMI values decreased after the intervention and were increased at follow-up, for both control and experimental groups. Hence, we cannot determine that the reduction was due to the intervention. However, in the single case analyzed, we found improvements in BMI, waist circumference, and body fat percentage [63]. Furthermore, we found significant differences between the control group and the experimental group in the BASC questionnaire (Behavior Assessment System for Children adapted from Reynolds and Kamphaus) [64]. For the analysis of the data, only those participants who completed the study and were old enough to provide a self-report were included. To compare the scores of the different participants, regardless of their age and the modality of the application questionnaire, we used only the indices of the self-report and standardized scores, that is, the average scores extracted from the application of the published scales, organized by age. According to the guidelines for the interpretation of the instrument, standardized scores greater than or equal to 60 (less than 70) in the difficulty scales, and less than or equal to 40 (greater than 30), in the adaptive scales are considered to be at risk; and scores with probable clinical significance are considered to be greater than or equal to 70 for the former and less than or equal to 30 for the latter.

Table 8. Anthropometric measurements of control and experimental groups.

	Control Group											
	Year 1						**Year 2**					
	Pre-Test		**Post-Test (Short Term)**		**Post-Test (Long Term)**		**Pre-Test**		**Post-Test (Short Term)**		**Post-Test (Long Term)**	
	Median	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**
Age (years)	8.67	1.66	8.44	1.67	8.5	1.2	10.09	1.51	10.86	1.21	11.1	1.52
Weight (kg)	53	8.24	51.41	8.44	55	8.21	58.72	13.14	61.26	6.71	64.5	12.51
Height (m)	1.41	0.11	1.41	0.1	1.44	0.11	1.48	0.11	1.52	0.08	1.54	0.1
BMI (Kg/m^2)	26.82	3.13	25.56	1.89	26.49	2.11	26.53	3	26.42	2.75	27.13	2.91
W/H Ratio	0.91	0.15	1.99	3.04	0.96	0.06	0.95	0.05	0.97	0.03	0.92	0.05
	Experimental Group											
	Pre-test		**Post-Test (Short Term)**		**Post-Test (Long Term)**		**Pre-Test**		**Post-Test (Short Term)**		**Post-Test (Long Term)**	
	Median	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**	**Median**	**SD**
Age (years)	9.38	1.85	9.46	1.9	10.25	1.66	9.17	1.64	9	2.16	9.71	1.8
Weight (kg)	63.65	14.39	64.4	14.72	72.09	11.89	57.58	13.51	53.43	8.15	60.82	11.44
Height (m)	1.41	0.11	1.44	0.09	1.49	0.08	1.44	0.12	1.43	0.14	1.47	0.12
BMI (Kg/m^2)	31.72	5.87	30.49	5.06	32.52	4.07	27.52	3.59	26.1	1.96	27.98	2.37
W/H Ratio	1	0.05	0.99	0.06	0.99	0.08	0.96	0.06	1	0.08	0.93	0.06

For instance, in the experimental group, the feeling of responsibility and control over issues related to their lives increased. Nevertheless, negative sensations associated with social interactions

decreased, as did the index of depression. Thus, we can observe the effectiveness of our intervention on healthy habits and in the promotion of the integral health of the children [65].

Concerning the game-based group intervention, the emotional study showed positive emotions related to the activities (participants, companions, games, learning). These results confirm the motivational significance of face-to-face meetings. The analysis of the emotions referred to by the participants at the entrance and exit of the face-to-face sessions provides an indicator of their motivation to take part in the intervention. However, we were particularly interested in the informative characteristic of the emotional impact of the intervention. Thus, to value the emotional effect of gamification, the game dynamics undertaken, and the training, we compared the emotions stated before the sessions with those stated afterwards. We examined all of the assessments taken throughout the interventions (12 sessions across the two phases). The emotions recorded with the EMODIANA tool were categorized into positive, negative, and neutral, and the mentioned aspects were reviewed using these categories. In all of the cases in which neutral emotions were reported at the beginning of the intervention, positive emotions were reported at the end. A share of 80% of the cases with negative emotions at the beginning were modified to positive emotions at the end; the remaining 20% finished with neutral emotions. A share of 4.3% of the cases in which positive emotions were reported at the beginning reported negative emotions at the conclusion, and 94.4% maintained positive emotions. Statistical analysis confirms that the differences in the distribution of the emotional categories are statistically significant both at the entrance (χ^2 (2) = 195,571; $p \leq 0.001$) and at the exit (χ^2 (2) = 206,333; $p \leq 0.001$). Each of the participants was asked to justify their reported emotion. These explanations were categorized by three judges following the criteria designed in the EMODIANA validation. The resulting categorization was submitted to concordance analysis for more than two judges using Fleiss' Kappa. The first classification achieved a lower than desirable concordance, so some terms of the categories to be defined were clarified, and the independent categorization process was repeated for each judge. The resulting categorization was the one presented because it achieved a Fleiss' Kappa index of k = 0.84; that is, an index value considered to be excellent (higher than 0.75) according to Fleiss (1981) [66], or very good (0.81 to 1.00) according to Altman (1991) [67].

Physical activity using motor play was designed to have moderate intensity (each session lasted 45 min), but children perceived effort to be easy or very easy (88.9%). However, the activity conducted was moderate or intense according to sensor data, which reached peaks close to 200 ppm (pulses per minute) in some cases. Therefore, although the activities demanded an average effort, for some children, the activities involved intense physical activity, which was expressed in their perceptions (8.2% reported some effort and 3.4% reported effort of higher intensity).

In the next section, we summarize the main findings, conclusions, and contributions of this paper.

6. Conclusions

This paper focuses on enhancing healthy habits in children using a QS model as the basis for an activity recommender system. To address the severe problem of child obesity outlined in this paper, an intervention program was designed including physical activities in groups, using active videogames, and reinforcing the practice of sports and knowledge of healthy nutritional habits, among other critical health-related activities.

On the basis of the intervention, and the design and development of the associated tools, a QS model and recommender systems were described. The following research questions were answered.

- *RQ1. What is an appropriate multidimensional QS model for promoting healthy habits in children?* Many different data sources can be integrated into a QS model in the context proposed. These information sources were identified and integrated into a single QS model, which was defined and validated by experts after an iterative process in which the experts were classified by areas of expertise.
- *RQ2. How might a recommender system complement the QS model to help the user select the appropriate actions and when to do them?* A recommender system for a sophisticated QS model cannot be

designed as a single system. This paper proposes a recommender system supported by three different modules. One module selects when a recommendation should be made based on contextual and user information in the QS model. The second module filters recommendations to provide only appropriate actions for the user and the context, using an automated planning strategy. The third module selects the most appropriate action based on the action's content, the user filtering information, and a learning strategy that minimizes the selection of mismatched actions. These three modules combine to answer, first, the question of what to recommend and, second, of when to recommend it, to thus help children improve their healthy habits.

- *RQ3. How can the UX of using a QS approach for children be improved?* The PROVITAO App is the framework in which our recommender system was embedded. Improving the UX of the system was considered to be crucial. Consequently, a UX model was explicitly proposed. The PROVITAO App was validated by experts who highlighted usability issues of the application, and evaluation of average satisfaction based on heuristic categories identified areas where the application UX could be improved.
- *RQ4. How does a gamified technology-based intervention impact the health of children?* We presented a summary of the validation of the gamified program using different instruments and dimensions. The PROVITAO project created a game-based educational program for healthy habits using active games developed by the research group, such as TANGO: H, and commercial video games (Wii Fit Plus and apps). The project was carried out with 45 children suffering from childhood obesity, plus their caregivers. Various technological artifacts (exergames, serious games, web apps, sensorial libraries, wearable devices, etc.) have been developed as part of this project. Results of the project have not shown a significant immediate or general improvement in measures such as participants' body mass composition or percentage of body fat. However, there is evidence of a positive impact on the children, which might lead to a long-term positive effect. These changes include better knowledge about healthy eating, improved behavior and greater sense of responsibility, control over issues such as social stress and depression, a tendency to favor positive emotions after the intervention, and an improvement in the children's free-time habits. Furthermore, in a single case study with obesity and type II pre-diabetes, there were observed improvements in measurements of BMI, waist circumference, and percentage of body fat, and these improvements were maintained over time. For future interventions, it is recommended that the positive effects of the mentioned measures are analyzed during the process, rather than only the ultimate measures and BMI.

Furthermore, from an economic perspective, the proposed intervention should be analyzed thoroughly before it is generalized for other programs, and the intervention's economic analysis should be analyzed by estimating the program's costs and revenues.

From the cost perspective, analysis of at least two types of expenditures—materials and infrastructure—and the necessary human resources should be conducted to determine affordability. The proposed program was designed to be replicated with a low cost. The space needed for the intervention is typically available at schools with a sufficient number of children. The materials required for the games and exercises are also inexpensive and usually available in schools' sports facilities. The devices used by the children (wearables, sensors, videogames, etc.) were selected to be readily available technologies that are affordable for families. Although high precision sensors could marginally improve the recovered data, the information gathered using affordable and easily found home technology is sufficiently precise. From the perspective of human resources, PROVITAO program interventions have been supported by experts from a multidisciplinary research group: psychologists, nurses, medical doctors, physiotherapists, education and physical exercise experts, and computer science engineers. From this perspective, the cost of the sessions supported by these experts would make the intervention unaffordable in most cases.

Nevertheless, the number of professionals involved and their profiles were justified, not only to carry out the intervention, but also for validation from the perspectives of multiple disciplines.

Once validated and appropriate infrastructure is permanently established for all sessions, the intervention is able to be carried out by two adults—one specialized in physically active games and the other with a technological profile. The sessions are programmed to take 4 h per week per group of 12 children. An extra hour per session is necessary for material preparation prior to the session and analysis afterwards. Therefore, 12 worked hours per intervention per week are required, which is considered reasonable. Pre-tests and post-tests require input from a nurse and a psychologist. Nevertheless, this support is only needed at specific moments of the intervention. It is expected that most children in this situation would already be under the supervision of medical doctors who could perform the timely actions required.

From the revenue perspective, the improvement in the quality of life of children with healthier habits is both evident and difficult to quantify. However, even from the public health perspective, the positive economic impact of the intervention is clear. Obesity and diabetes, like other chronic diseases, have an enormous impact on health systems, with patients requiring treatment for extended periods. Furthermore, future health complications can make suffers less productive, or even dependent. Decreased incomes, reduced productivity, and high costs of health interventions make it clear that, even without quantifying the reduction in the quality of life, early intervention in the lives of children is beneficial for society. Nevertheless, future work could show more precise results of the economic calculus expressed here.

The main contributions of this paper include the following:

- A technological proposal based on a quantified-self user model to treat and prevent obesity in children was presented. These components were described in this paper (i.e., DS, QSUM, ASR, and UXM).
- An extensive list of data sources and the main mechanisms for data processing are provided in the DS component, which primarily uses the data to recommend healthy activities. In addition, the categories of DS and relationships are described in the QSUM component.
- A new approach for an activity recommender system is presented with the following characteristics:
    - A modular design comprising a recommendation trigger, an action filter working as a content-based recommender, and an action chooser as a collaborative filtering recommender.
    - Actions and action plans are built using an automated planning approach.
    - Action recommendation mismatches are minimized using a reinforcement learning strategy.
    - A multidimensional, goal-driven recommendation trigger is used that relies on the user's location, time, and schedule, as well as user model changes, as its primary considerations.
    - The UX model for recommender systems is extended from the one proposed by Knijnenburg (2012) to consider the QS particularities and gamification aspects.

Regarding the limitations of this proposal, its validation needs to be extended using a larger group of children, and evaluation of the recommender system's efficacy and experience. However, a preliminary validation of the user interface of the PROVITAO App was presented in this paper, with an expert validation of the described QS model. The results indicate that the design, adapted language, and gamification are the strongest points of the proposal, while the main issues involve navigation controls, consistency and standards, profile personalization, error messages, and support. As a result, ongoing work on the system is aimed at solving these problems and improving technological solutions.

Author Contributions: C.S.G.-G. conceived the proposal and focus of the work. N.G.-d.-R. coordinated the intervention with children, families, hospitals, and schools, collecting and analyzing data. All the authors—C.S.G.-G., P.A.T.-D., V.M.-C., N.G.-d.-R. and F.G.-P.—contributed to this paper's writing and content. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported partially by Fundación Caja Canarias, Project PROVITAO Ref. OBE05.

Acknowledgments: The authors, thanks to the children, families, schools, professionals, and collaborators of the PROVITAO project.

Conflicts of Interest: The authors declare no conflict of interest.

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Anexo 3.
Artículo 3

sensors

Open Access Article

Active Game-Based Solutions for the Treatment of Childhood Obesity

by Carina S. González-González [1,*], Nazaret Gómez del Río [2], Pedro A. Toledo-Delgado [1] and Francisco José García-Peñalvo [2]

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Academic Editor: Jemal H. Abawajy

Sensors **2021**, *21*(4), 1266; https://doi.org/10.3390/s21041266

Received: 28 December 2020 / Revised: 27 January 2021 / Accepted: 6 February 2021 / Published: 10 February 2021

Resumen

La obesidad es uno de los mayores problemas de salud a nivel mundial que, junto con el sedentarismo, requiere soluciones que aumenten el entusiasmo hacia la actividad física. Por ello, este trabajo describe dos soluciones basadas en juegos activos utilizando el sensor Kinect y sensores biométricos, diseñadas para el tratamiento ambulatorio de la obesidad infantil. Las soluciones se aplicaron en un programa de intervención basado en videojuegos activos y juegos motores, desarrollado con niños y niñas en tratamiento por obesidad infantil. Se utilizó un cuestionario ad hoc para conocer el nivel de satisfacción, diversión, aprendizaje y cambios de comportamiento en los niños y niñas del grupo experimental que desarrolló la intervención. Los resultados muestran un alto índice de satisfacción con el programa de intervención, así como con los juegos desarrollados. El 83,7% quería asistir a las sesiones semanales, motivados principalmente por jugar (58,3%), estar con sus compañeros (50%), aprender (50%) y ganar puntos (41,7%). Por tanto, observamos que el factor social del juego y la ludopatía son elementos fundamentales para la satisfacción de los menores. El 100% de los menores se divirtieron en las sesiones grupales, manifestando que disfrutaron de los juegos con sus compañeros y de los videojuegos activos (TANGO:H) que más les gustaron. Asimismo, se

valoró satisfactoriamente la satisfacción con otros elementos del programa de intervención, como el entrenamiento (75%) o los juegos motores (91,7%). TANGO:H fue valorado muy positivamente (83,4%) en las sesiones grupales. También las sesiones individuales en los hogares con la Wii fueron satisfactorias (66,7%), aunque algo menos que las sesiones grupales, siendo lo que más les motivó a jugar a los juegos divertidos (58,3%). Sin embargo, también se aburrían jugando en casa, principalmente porque utilizaban el mismo juego (Fit plus) (50%) y porque estaban solos (37,5%). Las emociones mostraron un impacto positivo en los menores y una alta satisfacción en las sesiones de grupo.

Se concluye que los videojuegos activos y los juegos en grupo son altamente motivadores y pueden promover el cambio de conducta hacia hábitos de vida más saludables en los niños y niñas.

sensors

MDPI

Article

Active Game-Based Solutions for the Treatment of Childhood Obesity

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Abstract: Obesity is one of the biggest health problems globally that, together with sedentarism, requires solutions that increase the enthusiasm towards physical activity. Therefore, this paper describes two solutions based on active games using the Kinect sensor and biometric sensors, designed for the outpatient treatment of childhood obesity. The solutions were applied in an intervention program based on active video games and motor games, developed with children in treatment for childhood obesity. An ad hoc questionnaire was used to assess the level of satisfaction, fun, learning, and behavior changes in the children of the experimental group that developed the intervention. The results showed a high index of satisfaction with the intervention program, as well as with the games developed. It is concluded that active video games and group games are highly motivating and can promote behavior change towards healthier life habits in children.

Keywords: active video games; exergames; childhood obesity; gamification

Citation: González-González, C.S.; Gómez del Río, N.; Toledo-Delgado, P.A.: García-Peñalvo, F. J. Active Game-Based Solutions for the Treatment of Childhood Obesity. *Sensors* **2021**, *21*, 1266. https://doi.org/10.3390/s21041266

Academic Editor: Jemal H. Abawajy
Received: 28 December 2020
Accepted: 6 February 2021
Published: 10 February 2021

1. Introduction

Children and adolescents are currently surrounded by technology on the one hand, and with high rates of sedentarism on the other. In this sense, active video games can be beneficial to health, and promoting healthy living habits [1,2]. Active video games can be useful to increase children's enthusiasm to physical activity [3]. Therefore, active video games are an excellent tool for improving children's health and fighting obesity.

Some active video games allow for healthy exercise and fun at the same time. Some commercial video games, such as the Wii Fit, or Wii devices or Kinect, have been used in medicine [4]. Likewise, other health video games have been used to prevent, promote, and improve health, others for the improvement or training of health personnel [5,6].

Research has shown that children with obesity generally have low perceived sports self-efficacy and body dissatisfaction and tend to have a more sedentary life [7]. The first difficulty encountered by pediatricians in applying the prescription for a sport to children with obesity who are being treated is a lack of motivation [8]. Therefore, intervention programs are required to maintain children's enthusiasm in the practice of physical activity [3,9].

On the other hand, there has been a popularization of biometric sensors in the sports sector. These devices, characterized by their reduced size, allow users to record physiological variables and other types of data related to sports practice. Currently, biometric sensors are part of an expanding market, and technology brands such as Apple and Samsung, not traditionally linked to sports, have become involved. Modern smartphones with biometric sensors and hardware are for sale, which allow connectivity with devices of some of the existing technologies. Different applications enable us to visualize the information collected or make use of it for other purposes. The two most popular wireless

communication protocols for biometric data are ANT+ and Bluetooth Smart, characterized by low energy consumption and transmission in the ISM bands, open for industrial, scientific, and medical applications. These communication protocols allow data transmission from one or several biometric sensors to a smartwatch, smartphone, or any other device capable of storing and/or displaying such information. The diversity of measurable variables together with relatively low costs have made biometric sensors key elements in two main fields: on the one hand, they allow both professional and amateur athletes to keep track of the variables that affect performance during sports practice, optimizing training, and help to track progress; on the other hand, they allow people with health problems to keep track of their constants to keep track of the evolution of illness, predict dangerous situations, and keep health personnel informed of the patient's condition. The fight against obesity implies, in addition to healthy nutrition, the incorporation of physical activity into the lifestyle. As an alternative to traditional exercise methods, there has been an increase in the market for so-called fitness games, more commonly known as exergames. Exergames are a type of video game oriented to promote the user's physical activity, and the term derives from the combination of physical exercise and video games [10]. This goal is usually achieved by implementing direct interaction technologies in the interface that require the movement of large body extensions, making the player's success depend on their degree of physical involvement. It is also increasingly common to incorporate these sensors to the sports environment (known as wearable sensors) and the development of biomechanical senses, which enable the analysis of the users [11,12].

Considering all the above, this paper presents two solutions based on active games created in the framework of a project called PROVITAO for the outpatient treatment of childhood obesity [9]. This project's objective was to support the treatment of obesity at an early age through a model of game-based educational intervention designed for education in healthy habits. This paper seeks to answer the following research questions:

RQ1. What is the level of satisfaction of children on active game-based solutions for the treatment of obesity?

RQ2. How does the educational intervention program based on active games influence children's healthy habits?

This paper is organized as follows. The related works are reviewed in Section 2. In Section 3, we present two active game-based solutions based on the Kinect and biometric sensors. Then, the methods and some results regarding the program of intervention are presented in Sections 4 and 5, respectively. Finally, we summarize the conclusions and discussion in Section 6.

2. Related Works

There are several studies on video games and physical activity related to energy expenditure in educational programs carried out at school [12,13], which conclude that they increase children's motivation to continue exercising outside of school [14]. However, the reduction in body weight depends on the frequency, duration, and intensity of the physical activity performed [15], and therefore not all active games are effective. Some studies have found that dance games' cardiorespiratory response could be compared to medium to high-intensity aerobic dance [15]. On the other hand, active video games can promote healthy and active lifestyles, considerably increasing energy expenditure [16–18], comparable to other physical activities such as walking, jogging, or swimming [19,20]. Some commercial solutions, such as the active commercial platform (Nintendo Wii), have also proven to be effective for a more active life [9]. Other studies have demonstrated the effectiveness of exergames in promoting physical activity and calorie burning in children [21,22].

Despite the positive findings of several studies on energy expenditure with exergames, sports cannot be replaced because only a few active video games actually provide moderate intensity [21]. Additionally, not all exergames can maintain interest in the long

term, for example, if performed as a routine or individual physical activity [19]. Interest and participation can be increased if games are played in group sessions [23].

Concern about sedentary lifestyles and their close relationship to the high rates of childhood obesity today acts as a catalyst for the development of new exergames and other forms of human–machine interaction and video game control variables, including heart rate [24]. As we have seen before, for a game of this type to be effective from a physiological point of view, it must demand a level of physical effort from the player that produces significant energy expenditure. In turn, overexertion, especially during prolonged periods, must be actively avoided from the game's development to prevent an overdemand that affects the player's satisfaction. However, there are physiological consequences of efforts close to or above the anaerobic threshold. According to [25], the use of non-conventional bio-controlled human–machine interfaces can result in performance or ergonomic benefits, among others. On the other hand, heart rate is valid when estimating physiological load during physical exercise and, in fact, according to Homan et al. [26], different studies show the existence of a linear relationship between the pulse and the intensity of submaximal exercise (i.e., below 85% of maximum heart rate). All of the above leads to the idea that using a heart rate monitor can help us improve the physiological effects of the game.

The idea of developing a game controlled almost entirely by the heart rate has been successfully carried out in various investigations. There are even applications on the market based on this principle [25,27,28]. The ones mentioned below are some examples:

Skip a Beat [27]. Skip a Beat is an application for smartphones with a heart rate monitor to train the user to control his heart rate. To do this, the game is divided into different levels according to the range of pulses. The pulses control the character's size and movement (the Skip frog), and by keeping within the selected range, a higher final score is achieved.

Press Masters Biathlon [25]. This prototype game, developed by researchers from the Helsinki University of Technology, consists of completing a ski slope in the shortest possible time, alternating with shooting tests. The heart rate is used, on the one hand, to control the speed of the run, so the higher the rate, the higher the speed; on the other hand, a higher pulse will negatively affect the accuracy of the shots. The main advantage of this type of interaction is that it can be played by practicing many different kinds of activities, such as a static bicycle or a race on site. However, the game is not specifically oriented to keep the players' pulses within a range.

Flitz! [28] is an exergame in which the user must avoid the items of penalization and press the corresponding buttons of the controller (a platform composed of two columns with buttons at different heights) to attain the reward items. The game will be faster or slower depending on the player's pulse and is the concept closest to being implemented in this study.

Next, two solutions created in the PROVITAO project [9] will be described as exergames for treating childhood obesity.

3. Active Game-Based Solutions Based on Kinect and Biometric Sensors

The two solutions created use the Kinect sensor, a device capable of recognizing the human body and its environment, allowing interaction with information systems without maintaining physical contact with traditional control systems. The common use of Kinect and its libraries enable tracking the user's joints in space, which makes it possible to control the avatar in the game using two fundamental methods. The first one consists of translating the tracked joints' positions to the positions of the avatar's joints in the virtual space. The main advantage of this method is a more detailed reproduction of the various positions adopted by the users within the sensor's limitations. However, certain combinations of joint positions and sequences of movements (such as jumps) are not reproduced reliably enough, leading to overlapping limbs of the avatar, in addition to it not being possible to apply gravity effectively.

The second method, the most widespread, is an indirect control of the avatar through gesture detection. In this case, tracking is used and compares the relative position of the joints of interest. If the joints pass through these positions within a specific time interval, then the gesture is considered complete.

The TANGO:H (Tangible Goals for Health) [24] platform uses the Kinect sensor, applying the human skeletal joint detection method and the cloud-based exercise creation tool. Another solution is describe, created to capture data from wearable biometric sensors and its integration with an exergame, using Kinect and applying the gesture detection method.

3.1. TANGO:H Web Designer

The TANGO:H platform realizes exergames using the Kinect sensor. The TANGO:H platform has different player modes: the single-player mode, and the multiplayer mode. The sensor detects two human bodies simultaneously, and sequential, competitive, or collaborative exercises can be created in the multiplayer mode. The platform also has an integrated administrator that enables the management and grouping of users, and assigns exercises. Once the exercises are performed on the platform, they are stored to retrieve a statistical analysis of the results. The execution of the exercises can be assessed (Figure 1).

In addition to performing exercises, TANGO:H has an exercise designer, called TANGO:H Designer. This tool allows the design of exercises adapted to the users' needs through a simple and intuitive interface. To make this design tool available without any installation and accessible from anywhere through the internet and a browser, a web solution has been developed for it. Hosted in a cloud server, this web solution allows the creation of and access to exercises. Additionally, the cloud platform must have user management, as well as its desktop version. The exercises created in both desktop and web versions are fully compatible and allow their execution in the TANGO:H client for final interaction with the user/patient.

Figure 1. Execution of the exercises created in TANGO:H (Tangible Goals for Health) Designer.

The software allows the creation of different types of exercises: physical, cognitive, and free. In turn, cognitive exercises can be of matching, sorting, and classification genres. Each one of the exercise types has different interaction functionalities in the user interface. An exercise consists of a set of steps, and these, in turn, are organized into a set of phases. The phases are made up of a set of objectives with different joints of the human body's skeleton associated with them, which will be the points of contact. For TANGO:H to interpret an exercise, the information must be structured as described above in an XML file. The hierarchy of the elements that make up the file structure is exercise, steps, phases,

objectives, and the associated joints. Additionally, TANGO:H Designer uses multimedia files to design exercises, such as images or audios.

This paper describes the application developed for the cloud, consisting of three fundamental modules: the user interfaces for interaction with the system; the database management module; and the server module that hosts the application. Each of these modules is implemented through different technologies. The graphic interface was implemented in HTML5 and CSS3, and the functionalities were implemented in JSP, JavaScript, and PHP. The database module was implemented in MySQL, and the server was implemented in XAMPP.

The editing interface is the main screen of the application (Figure 2), because it is where the user defines the exercise's parameters. This interface consists of the following elements:

(a) Menu bar: Executes the actions on the exercise file and the editor configuration.
(b) Exercise panel: Visualizes the outline of an exercise, allowing navigation through its components and performing actions on each of its elements.
(c) Target panel: View and edit the properties of the selected target.
(d) Available objectives panel: Contains objectives that can be used in creating an exercise.
(e) Design panel: Component where the exercise is designed, allowing the dragging of objectives to this panel.

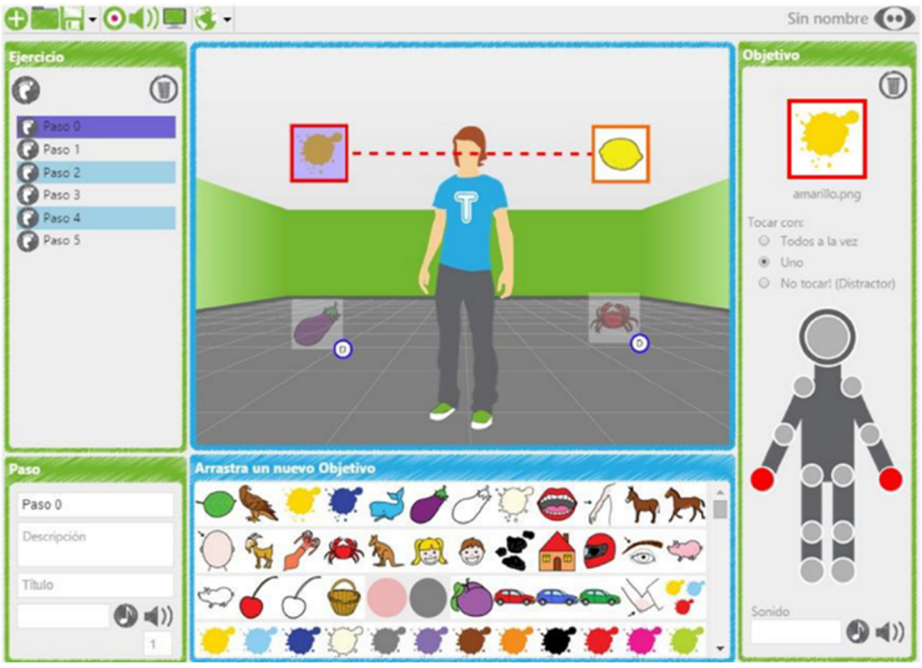

Figure 2. Exercise editing interface with its main elements.

The elements mentioned above are described in detail below.

(a) Menu Bar

The bar at the top of the window contains the access buttons to the application's different options and tools. The elements available in this menu bar are explained in order from left to right.

- New. Create a new exercise. It directs the user to the selection window.
- Open. Opens an exercise from a file and loads it into the application. Only the exercises that belong to the user will be displayed.
- Save. It saves the current exercise.
- Objectives manager. Accesses the objective image management window.
- Sound manager. A sound management window is accessed.

- Background manager. The window for managing backgrounds is accessed.
- Languages. Selects the language preferences for the application.
- Information on the exercise. On the right side of the menu bar, information about the exercise being edited is displayed. Clicking on this information will open a window where the exercise's name and description can be modified.

(b) Exercise Panel

This outlines the different components of an exercise: Steps, Phases, and Objectives. It allows the adding or removal of components and modifying some of their properties. This panel has the following components:

- Add new components. A set of controls located at the top of the panel. These enable the addition of a new step or phase. For cognitive exercises, the concept phase will not be used; each step will contain a set of objectives to be achieved.
- Step properties. In the lower part of the panel, there is a formula in which the selected Step properties are shown and edited. Here, the name, description, title, and audio file for the step can be edited.

(c) Target Panel

This panel displays and edits the properties of a Target. A Target presents color, sound, and behavior concerning the contact points: All at once, One, and Distractor. This panel has the following elements:

- Target and color. The upper part of the panel shows the target's image, surrounded by a frame of the associated color.
- Contact points. The assignment of contact points to the lens is made on the character image shown at the bottom of the panel. The selected contact points are shaded with the color associated with the target. It is possible to update the behavior of the target using the controls located on the image.
- Sound of the target. At the bottom of the panel, there is a set of controls that facilitate sound to the target.
- Delete a lens. The control in the upper right corner of the panel allows the target to be removed from the exercise.

(d) Available Objectives Panel

Centered at the bottom of the main application window is the panel containing the set of images available as objectives (targets). These are the images available on the server. To add a new Objective to the exercise, the desired image is dragged to the Design Panel.

(e) Design Panel

The Design Panel refers to the arrangement and characterization of the objectives for each of the steps that make up the exercise which will be finally presented to the user on-screen. The basic actions that can be carried out on the Design Panel are the following:

- Insert target. To add a lens to the exercise, the desired image is dragged from the panel of available lenses to the day panel.
- Select a target (or several). A target is selected by clicking on it with the mouse. To select several targets at once, the "Ctrl" key is held while each of the desired targets are selected.
- Move one target. To move a target, it must be double-clicked and moved with the cursor around the Design Panel.

By clicking the right mouse button, a menu will be displayed with the following options:

- New step. It will add a new step to the structure of the exercise.
- Delete step. It will remove the current step from the exercise.
- Phase properties. It will access the properties of the selected phase.
- Matching (only for cognitive matching exercises). Allows pairing two selected objectives.

Having explored one of the active game-based solutions created to treat childhood obesity, in the next section, we will present another solution designed to integrate the biometric data provided by wearable sensors into an exergame.

3.2. Exergame with Sensory Integration of Biometric Signals

Next, we will describe the solution created for the design of exercises in the cloud (web), as well as the design of a library of sensory integration for the creation of interfaces and registers of biometric signals.

The main sensory integration objective is to have an online measure of physical effort. Firstly, it can be used to modulate the activity to keep the user in the desired range of intensity. Secondly, the energy burn can be estimated for the user's self-awareness.

As mentioned above, the heart rate is a good indicator of the physical effort to which the body is subjected. The heart rate (HR) from which severe health damage can occur is known as the maximum heart rate (HRmax) and serves to calculate the intensity ranges at which we are working. Although we should subject everyone to a stress test for an accurate calculation of the HRmax, several formulas allow us to estimate it with some precision. Despite the accuracy of formulas of estimation when applied to children it is lower than with adults: compared to the traditional equation HRmax = 220−age, the equation HRmax = 208−(0.7 * age) has proven to be more accurate [29–31], and is recommended to be used in these circumstances [31]. Therefore, the latter was used in this project.

Depending on the maximum heart rate percentage, we can establish the intensity ranges shown in Table 1.

Table 1. Intensity ranges according to the percentage of maximum heart rate (HRmax) [32].

Zone	Range	Characteristics
1	50–60% HRmax	Low intensity. Indicated for heating and recovery after exercise.
2	60–70% HRmax	Moderate intensity. Zone indicated for the increased metabolism of adipose tissue.
4	80–90% HRmax	Aerobic limit.
5	90–100% HRmax	Beginning of the anaerobic training zone (oxygen deficit).

The cited study, carried out by Keytel et al., estimated an equation of prediction of energy expenditure (EE) from the pulse, age, sex, and body mass, and whose expression is:

$$EE = sex * (55.0969 + 0.6309 * HR + 0.1988 * weight + 0.2017 * age) + (1-sex) * (-20.402 + 0.4472 * HR - 0.1263 * weight + 0.074 * age)\ kJ/min$$

where sex = 1 for males and sex = 0 for females, HR is expressed in ppm, weight in kg, and age in years.

As with the maximum heart rate, an accurate calculation of energy consumption during physical activity can only be achieved by performing calorimetry tests on each individual. However, we can approximate indirect calorimetry using the heart rate because there is a linear relationship between the pulse and the energy expenditure in the range of approximately 90–150 ppm [33].

For the game to be executed correctly, it is a requirement to define a user profile in which the sex, weight, and age are specified. Secondly, it must be possible to connect with a heart rate sensor (pulsometer) through a USB–ANT+ interface.

The game's main objective is to keep the user performing a physical effort (aerobic activity) within a range of healthy pulses. This is within the moderate zone defined by a HR in the range 60–70% of the HRmax. For this to happen, the user must perform specific exercises that involve the movement of large muscle groups, mainly the lower body, defined below:

- Jump. The central hip joint is raised above 12 cm from its previous position within 1.5 s.
- Squat. The center hip joint is lowered by six inches from its previous position in a 1.5 s interval.
- Lateral jumps. Starting from a position with the feet together (distance between the joints of the feet less than 30 cm) and finishing in this same position but having moved 25 cm to the right or left, depending on the response.
- Punch. The left or right hands advance in an interval of 1.5 s.

The game interface shows a small area of the scene in which the avatar is centered, and there are no more movements of the avatar except the lateral steps that must be executed to avoid certain objects. Overlaying this is a heads-up display (HUD) through which the player is provided with feedback on specific aspects of the game, such as:

- Heart Rate: Located in the upper right corner, it indicates the user's heart rate, which changes color from blue to red depending on the range of heartbeats.
- Calories: Indicates the accumulated energy consumption since the beginning of the game and are based in the energy expenditure estimation explained above.
- Score: Fraction that indicates the number of objects drawn or destroyed satisfactorily concerning the total number of objects that have appeared.
- Time Left: Time to analyze the game.

To encourage the user to perform the exercises, the avatar is presented with a series of items that must be avoided or destroyed. When the user performs one of the actions, the avatar emulates it and, if it is one of the actions appropriate to the object, it will be successfully dodged or destroyed. Throughout the game, all the objects that have appeared as well as the number of them that have been drawn/deleted thanks to the actions executed by the user are counted; this relationship (presented as a fraction and percentage) is what we take here as a score. The objects and their corresponding action or actions are:

- Cylinders ("logs" or "barrels"): dodge by jumping.
- Blocks: destroy by frontal hit (punch).
- Shurikens: dodging by squats.
- Spheres: destroy by lateral jumps. They are presented in series and always appear in front of the user.

To keep the user intensity in the desired range, the following control loop has been implemented. As the user's clicks move closer to the upper limit, the user will have to dodge fewer objects. On the other hand, when the user's pulsations start to become too low, the number of objects to avoid increases. This situation is maintained until the game is analyzed once the programmed period has elapsed (five minutes). After this, the user has the option to retry or quit the game.

The mechanics of the game serve to keep the player active, and all its aspects are built directly or indirectly around this premise, advocating simplicity without forgetting that the goal is to demonstrate the usefulness of the incorporation of biometric sensors.

The start menu, besides preparing the user for the beginning of the game, has the function of guaranteeing that the intensity of the exercise is adequate and that the calories are estimated: on the one hand, knowing the age allows us to calculate the maximum heart rate, and with it the intensity intervals; on the other hand, in addition to age, we need to know the sex and weight of the user to estimate the energy expenditure. This is why there is also a specific range of permissible values for each field.

During the game, the avatar emulates the player's movements as a mirror, which is considered the most natural method and allows better visualization of the objects because the avatar is facing the player.

Moreover, the HUD elements are arranged in such a way that the user can easily access the information, but with as little disruption to the game as possible.

Calculating the intensity intervals serves as a basis for controlling the rest of the game. Increasing or decreasing the frequency with which objects appear has no other purpose than intensifying or reducing the level of effort the user makes, respectively, to keep their heart rate within the ideal range.

Thus, the fact that the game score is represented as a proportion is a direct consequence of the fact that, on the one hand, the game takes place during a period previously assigned and, on the other hand, that the time between the appearance of two different obstacles depends on the player's pulse because this means that during the programmed time, the number of total obstacles may vary.

At the same time, setting a period to play, without contemplating an end, responds to the indicated objective of keeping the player moving while maintaining simplicity.

Different software has been used to implement the exergame, such as Visual C#, Visual C++, ANTware II 4.100 tools, SimulANT+ 1.6, Unity and the Kinect for Windows SDK. In addition, different hardware devices were used, such as the ANTUSB2 Sticks from Geonaute (two units), the Geonaute pulsometer, model SHRM1G, ANT+ technology and the Kinect sensor. Figure 3 presents a simplified diagram of the solution created.

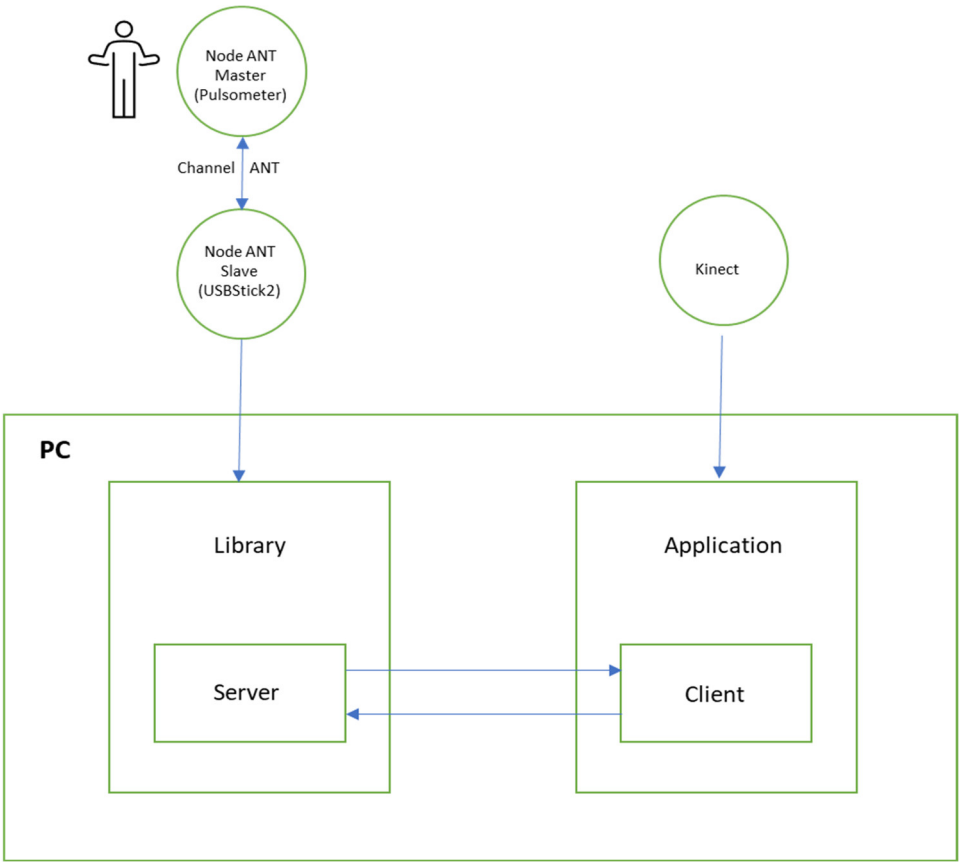

Figure 3. Simplified scheme of the adopted solution.

To test the effectiveness of the game, the heart rate of different subjects was recorded. The data analyzed corresponded to a five-minute game, requiring the participant to have not done any physical exercise in the previous hours. For example, Figure 4 shows the evolution of the heart rate of one of the subjects analyzed (Figure 5). In this case, the beginning of the aerobic zone is at 135 ppm. The initial heart rate is 99 ppm, and a slow but relatively constant increase is observed, reaching 120 ppm for the first time after 88 s. The pulses remain between 98 ppm at the beginning and a maximum of 138 ppm. The average is 121 ppm, somewhat lower than desired, although in this case, it neither exceeds the upper limit of the aerobic zone nor falls from the zone of moderate intensity.

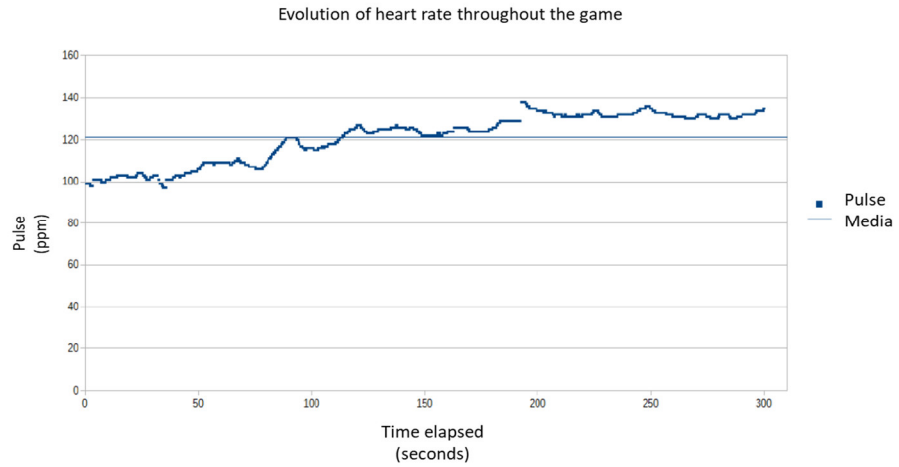

Figure 4. Evolution of the heart rate of a person playing the exergame.

Figure 5. Subject playing exergame integrated with biometric sensors.

The next section describes the method followed during the intervention program named PROVITAO.

4. Method

As mentioned above, the PROVITAO project aims to assist in the treatment of obesity in children by improving their life habits towards healthier behaviors [7]. The methodology followed in this study is quasi-experimental, with two annual phases. The sample is divided into an experimental group (children with obesity who participate in the intervention program) and a control group (children with obesity who do not participate in the intervention program). The target population was children diagnosed with obesity/type II diabetes seen in the hospital of reference.

4.1. Participants

The sample consisted of 45 children between 6 and 12 years old (25 girls and 20 boys). The experimental group consisted of 25 children (15 girls and 10 boys), and the control group consisted of 20 children (10 girls and 10 boys). This convenience sample was selected using inclusion criteria to be diagnosed with childhood obesity (BMI > PC95; unit of measure kg/m^2). The guidelines and ethical principles for medical research in humans, established in the Declaration of Helsinki, have been followed in implementing the project. Therefore, the knowledge and approval of the parents or guardians responsible for the children themselves were ensured. Furthermore, the research has been approved by the ethics committee of the University Hospital of the Canary Islands and by the ethics committee of the University of La Laguna.

4.2. Instruments

We have selected different instruments according to the areas of research of the project. All the questionnaires to be used in the project have been previously validated. Thus, the instruments and variables are described below:

- Biomedical area (pediatrics, nutrition, nursing)
  - *Variables*: age, weight, height, BMI, skin folds, body perimeters, percentiles, blood pressure, and analytical parameters
  - *Instruments:* weight, height meter, BMI formula, lipo calibre, inextensible tape measure, growth curve, sphygmomanometer, and blood analysis.
- Psychological and psycho-pedagogical area:
  - *Variables* to be measured in children: evaluation of emotions resulting from human–computer interaction-observational measures; interpersonal relationships, relationships with parents, self-esteem, and self-confidence; knowledge and attitudes about healthy living habits and active video games.
  - *Instruments*:
    - EMODIANA [34]. An instrument which allows measuring 10 basic emotions, represented with different expressions of a character associated with their corresponding labels, adjusted to children's language. It is used during group intervention sessions.
    - BASC (Behavior Assessment System for Children and Adolescents) [35]. This is a multidimensional questionnaire which measures numerous aspects of behavior and personality.
    - Adaptation of the questionnaire on Physical-Sports Activity and Health-Wellness [36].
    - Player profile test. Adaptation of the questionnaire on use and attitudes towards video games [37].
    - Mediterranean Diet Quality Index—KIDMED Questionnaire (Mediterranean Diet Quality Index for children and teenagers) [38].
    - Questionnaires for children and parents ad hoc. Items to collect information about the intervention carried out during the project.

In this paper, we present some results of the questionnaire passed to children of the experimental group, due to this group having worked with active video games.

4.3. Procedure

The intervention of the project was organized in different yearly phases and during the year in different moments. The first task was to select the sample and the diagnosis (medical and pre-tests) in both groups (experimental and control). Then, we carried out the yearly educational intervention according to the school's academic course with the experimental group. The intervention was divided into three parts. The first consisted of different sessions developed for three months. During this part of the intervention, the

researchers worked with children group sessions weekly. The learning goals of the intervention program were related to healthy habits. Additionally, regarding the game-based intervention, before starting the study, we collected and analyzed our sample's game preferences using an adaptation of the Player profile test [37].

Regarding the intervention carried out with the experimental group, the structure of sessions related to active video games can be seen in Figure 6.

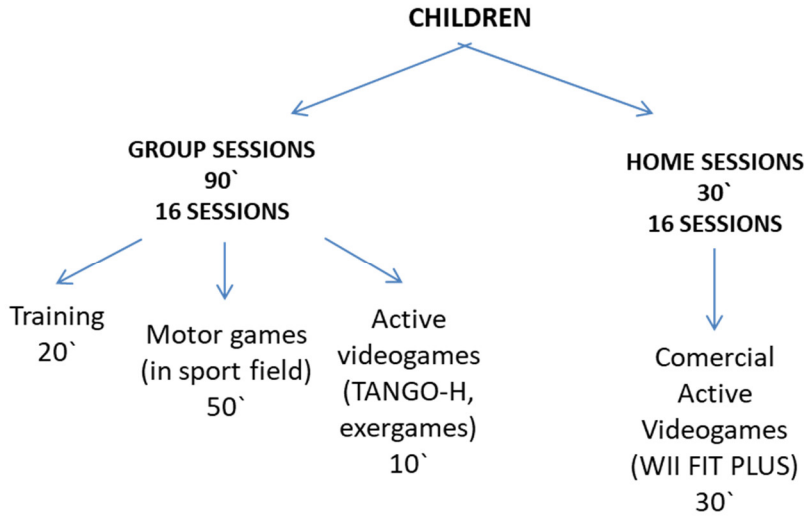

Figure 6. Structure of the intervention with the experimental group in PROVITAO.

The data collection was performed at the end of the intervention through a questionnaire created ad-hoc. The instrument consisted of 43 questions, mostly with a Likert scale from 1 to 5 on the level of agreement or disagreement with the questions, and open-ended questions to find out opinions about the intervention program's aspects. The questionnaire's main objective was to assess the level of satisfaction of the children with the educational intervention program in its different phases. Regarding active video games, variables such as satisfaction, fun—both in group sessions and at home—and comfort in the use of wearables were measured. We also sought to know how the intervention program influenced learning and behavior change in healthy living habits. The 43 items of the scale were independently measured from 1 (totally disagree) to 5 (totally agree) by each of the five experts. On the other hand, each item was scored in four predefined dimensions: (1) relevance of the question: the item is needed to the domain of study; (2) content adequacy: the extent to which the theme of the item reflects an important content of the field of study; (3) clear formulation: the use of a language that can be easily understood; and (4) target population addressing: how the items focus on the specific group of people (children) to which they are intended. The Kendall's W non-parametric static was used to calculate the interrater agreement in the ordinal scale. Kendall's W ranges from 0 (no agreement) to 1 (complete agreement). The results obtained showed a high agreement in the different dimensions: relevance of the question (0.88); content adequacy (0.76); clear formulation (0.73); and target population addressing (0.83). The researchers of the project collected the answers of children and explained the questions to them. The type of statistical methods used for data analysis for this instrument was descriptive statistics (frequency, mean and standard deviation). The main results of some variables analyzed through this instrument are presented below in Section 5.

Afterward, during the second part of the intervention, children designed a vocational project related to healthy habits. During this part of the intervention, the researchers developed group sessions with children and parents monthly. The last part of the intervention was developing the designed vocational project under the researchers' supervision.

During these moments, we collected data about different areas of the study using the instruments mentioned above. We have analyzed the results of questionnaires using SPSS 20.0. Afterwards, we conducted a comparative analysis using the obtained results of the different moments (pre/post) and groups.

Below are some results obtained in the educational intervention program using exergames, such as those described above, and motor games to support outpatient treatment of childhood obesity.

5. Results

In this section, we present some of the program's main results concerning the active video games applied to the experimental group, diet, and the anthropometric variables measured during the intervention program related to obesity applied to both groups (experimental and control).

As we can observe in Figure 7, there are some preferences about the type of video games between girls and boys. However, no significant differences have been found (boys 10.0% and girls 13.3%).

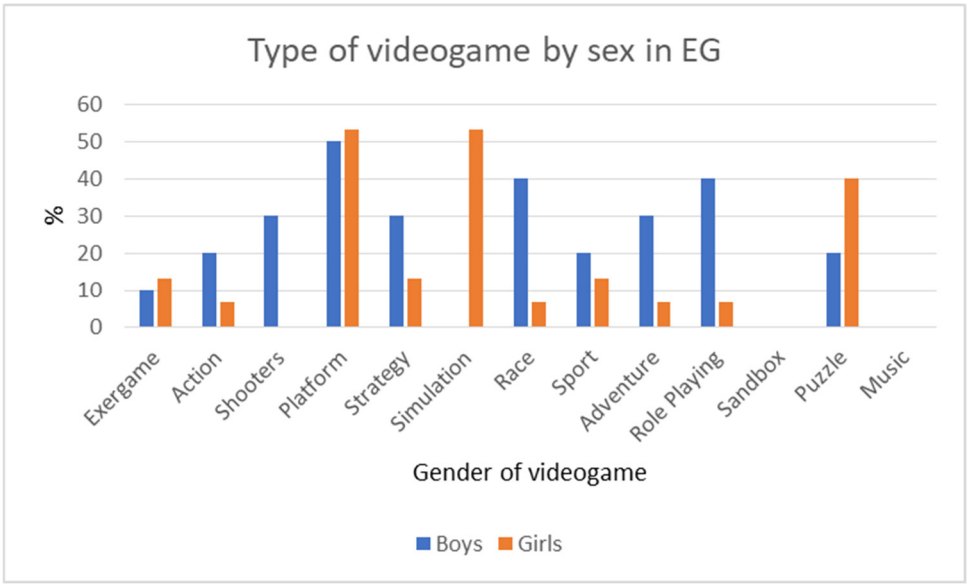

Figure 7. Preferences in the type of video games of the experimental group (EG) by sex.

5.1. Perceived Variables Related to Active Video Games

This section presents the satisfaction questionnaire results about the PROVITAO intervention program [9] for the experimental group, which used active video games in the group sessions and individual homes, in addition to having developed weekly motor games.

(a) Satisfaction

As shown in Figure 8, most of the children wanted to attend the weekly sessions of the intervention program (83.3%). On average, the level of desirability was 3.41 (1—very undesirable, 5—very desirable) (horizontal axis in Figure 8). No significant difference between girls (3.43) and boys (3.4) was found.

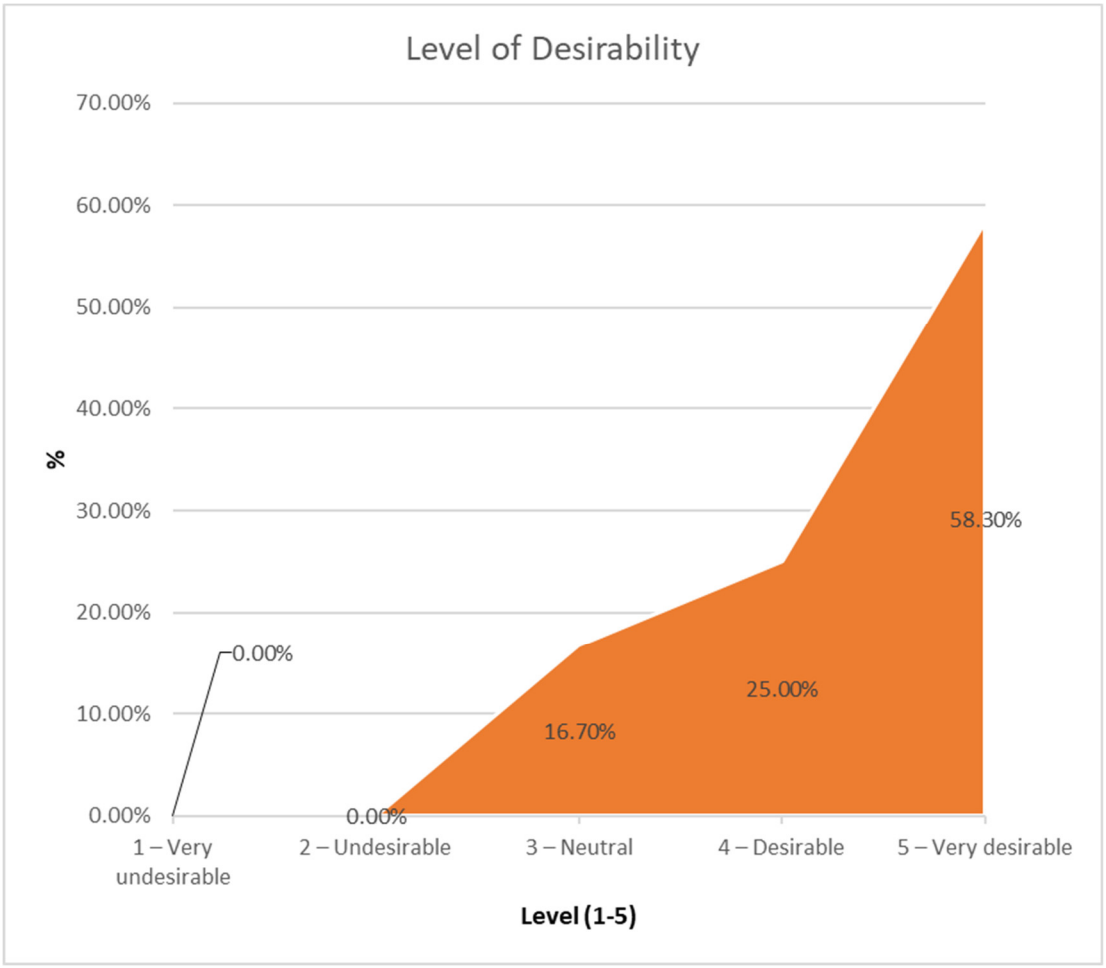

Figure 8. Answers to the question "Were you looking forward to the weekly sessions?".

When asked what encouraged them to attend the weekly sessions, they replied as follows:

- What I learned (50%);
- Play (58.3%);
- Do physical activity (25%);
- Earn qualifying points (41.7%);
- Being with colleagues (50%);
- Being with the professionals (8.3%);
- Improve my lifestyle (25%).

Regarding the level of satisfaction with the training received in the group sessions, they said that they were moderately satisfied (25%), very satisfied (41.7%), and extremely satisfied (33.3%); there was a high level of satisfaction with the training received (75%). The level of satisfaction with the training on average was 4.08 (1—very unsatisfied, 5—extremely satisfied). No significant difference between girls (4.14) and boys (4.00) has been found.

On the other hand, they were asked about their level of satisfaction with the motor games held on the sports field, answering that they were moderately satisfied (8.3%), very satisfied (25%), and extremely satisfied (66.7%); 91.7% were highly satisfied with this part of the program. The level of satisfaction with the motor games on average was 4.58 (1—very unsatisfied, 5—extremely satisfied). No significant difference between girls (4.43) and boys (4.80) was found.

As for the active games, we asked participants what their level of satisfaction with TANGO:H was, with their answers being the following: moderately satisfied (16.7%), very

satisfied (41.7%), and extremely satisfied (41.7%). Therefore, we observed a high satisfaction with TANGO:H (83.4%). The average level of satisfaction with TANGO:H was 4.25 (1—very unsatisfied, 5—extremely satisfied). No significant difference between girls (4.14) and boys (4.40) was found.

Concerning the sessions in the house carried out with the Wii, the level of satisfaction they showed was the following: moderately satisfied (33.3%), very satisfied (8.3%), and extremely satisfied (58.3%). The level of satisfaction with the Wii in the home was on average 3.25 (1—very unsatisfied, 5—extremely satisfied). No significant difference between girls (3.14) and boys (3.40) was found. We also asked them what motivated them to conduct the Wii sessions at home, and they answered the following:

- It was fun (58.3%);
- Do physical activity (25%);
- That it was mandatory (8.3%);
- Other (8.3%).

(b) Fun

As for fun, we asked them if they had fun in the group sessions, answering often (33.3%) and always (66.7%); the enjoyment by the participants (Figure 9) was high (100%). The level of fun in the group sessions was on average 3.66 (1—never, 5—always). No significant difference between girls (3.71) and boys (3.60) was found.

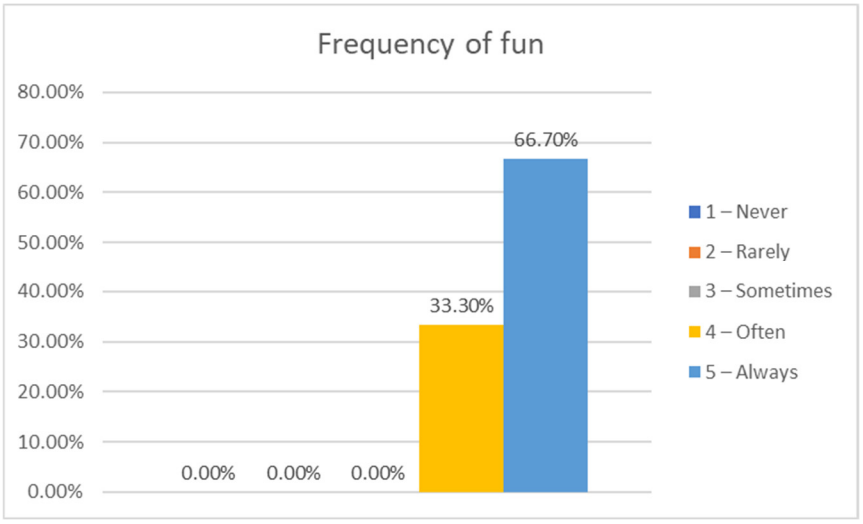

Figure 9. Answers to the question, "Did you have fun in the weekly sessions?".

Regarding what they liked best about the weekly group sessions, they answered the following reasons:

- The games and being with the companions;
- Because I had fun games;
- Improve my sessions and have a lot of fun;
- That I learned new things and had fun with all;
- To play;
- That I played and sweated and had a lot of fun;
- We learned;
- The games;
- Everything we did;
- The games were fun;
- That I had fun and had more friends to play;
- TANGO:H;
- The games we made.

As for the sessions at home, they were asked if they had become bored using the Wii. As shown in Figure 10, 66.7% disagreed with that statement, showing fun, but 25% did express boredom. Girls showed less boredom (90% disagreed with the question) using the Wii at home than boys (60% agreed to the question). They were asked, in the case that they had become bored, what had discouraged them, their answers being the following: always playing the same game (Fit plus) (50%), playing alone (37.5%) and other (12.5%).

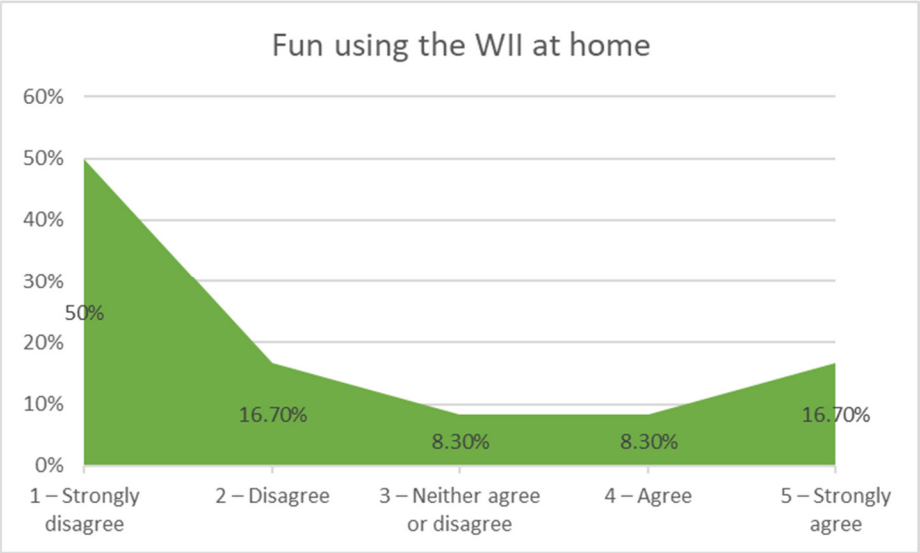

Figure 10. Answers to the question "Did you get bored of using the Wii at home?".

(c) Comfortability

Concerning the use of the wearables used in the intervention (wristwatch and Geonaute band), we asked them about the comfort level, and as can be seen in Figure 11, we saw that 66% stated that they had not been comfortable. The wearables' level of comfort was on average 2.33 (1—not all comfortable, 5—extremely comfortable). Boys showed more tolerance to wearables (3.2) than girls (1.71).

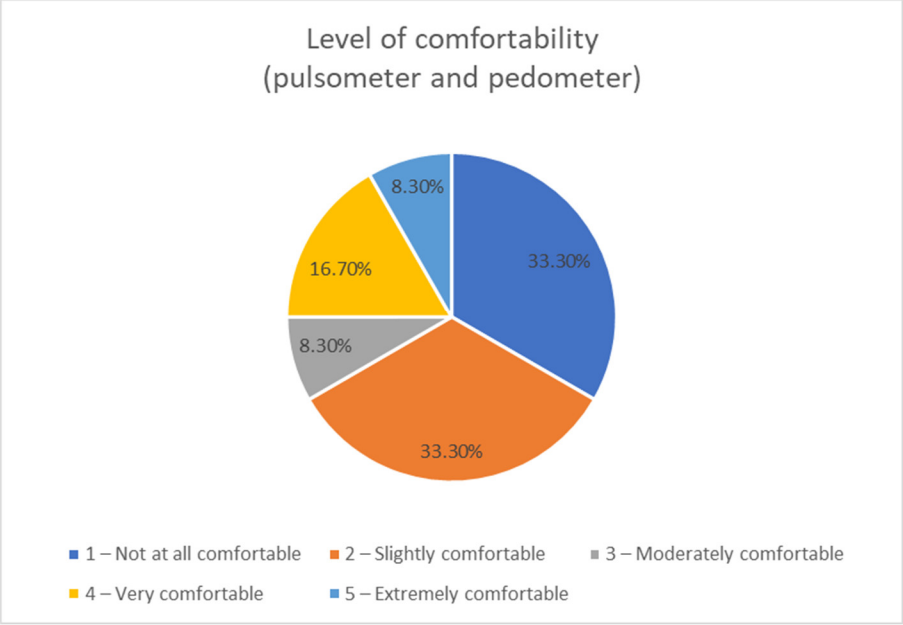

Figure 11. Answers to the question "Was it uncomfortable to wear the pulsometer (heart rate monitor) and pedometer?".

(d) Learning

During the group sessions, we carried out training sessions about healthy habits (diet and physical activity), and all the games were designed around these topics. In terms of learning during the sessions, participants felt that they had learned moderately (16.7%), very (41.7%) and extremely well (41.7%). Therefore, we observed a high level of perceived learning (83.4%). Likewise, we asked them if they thought the learning obtained was useful, and 66.7% thought it was, 25% were neutral, and 8.3% disagreed with the statement. On the other hand, we asked them if they had learned about healthy living habits, with 91.7% answering that they had learned healthy living habits and 8.3% being neutral to this statement. The learning level on healthy habits was on average 3.58 (1—not at all, 5—extremely). No significant difference between girls (3.57) and boys (3.60) was found.

(e) Behaviors

In terms of behavior change concerning their physical activity habits, 91.7% responded that the intervention program had changed their habits (where 100% of boys and 85.7% of girls answered yes) (Figure 12). Likewise, 90.9% thought they had changed their diet behaviors (where 100% of boys and 85.7% of girls answered yes), now being more balanced and healthier.

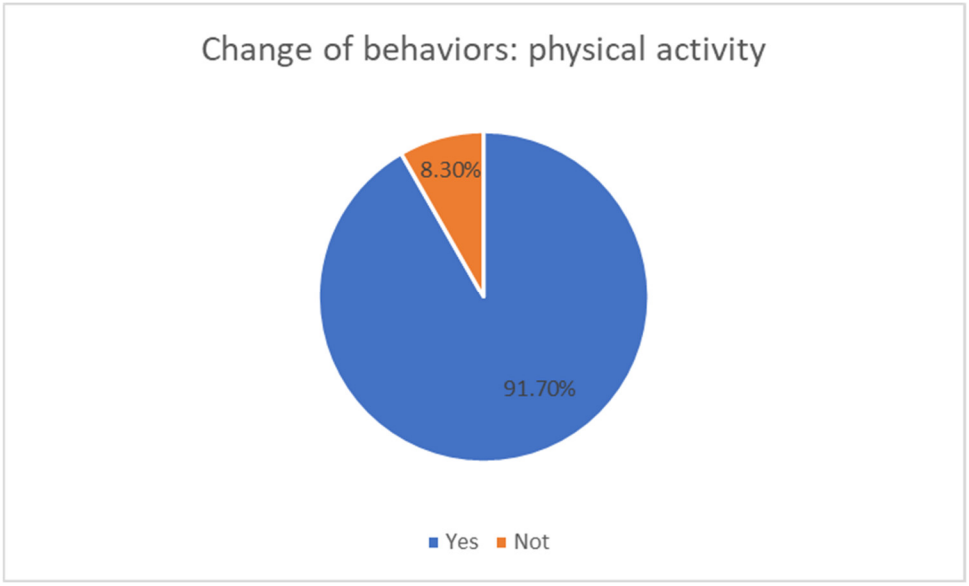

Figure 12. Answers to the question "Do you think the physical activity of the program has changed the way you behave for your physical activity habits?".

5.2. Emotions Related to the Intervention

The analysis of the emotions referred by children of the experimental group at the entry and exit of the group sessions gave us an indicator of the motivation with which they attended the intervention. However, we are especially interested in the informative nature of the emotional impact of the intervention.

To assess gamification's emotional effect, the dynamics of play and training, we compared the emotions reported before starting the sessions with the emotions at the end. The emotions were registered with the Emodiana tool and have been categorized into positive, negative, and neutral [39].

All (100%) of the cases in which neutral emotions were reported at the session's entry referred to positive emotions at the exit. Most (80%) of the entry's negative emotions were modified to positive ones at the session's exit, and 20% varied to neutral ones. A small number (4.3%) of the cases in which positive emotions reported at the entry changed to negative emotions, and the remaining cases maintained positive emotions. The statistical analysis confirmed that the differences in the distribution of the emotional categories were

statistically significant both at the entry (χ^2 (2) = 195.571; $p \leq 0.001$) and at the exit (χ^2 (2) = 206.333; $p \leq 0.001$).

We also asked the participants to justify the referred emotions. The resulting categorization was subjected to the concordance analysis for more than two judges by means of Fleiss' Kappa [40]. The resulting categorization, which achieved a Fleiss' Kappa index of $k = 0.84$; an index considered excellent (greater than 0.75) according to Fleiss (1981). Most of the attributions included reasons related to the structure of the developed activity. Thus, we can see the positive impact of the group sessions in the experimental group's children.

5.3. Anthropometric Variables Related to Obesity

No significant differences were found between the control and experimental groups or between the pre- and post-intervention on the anthropometric measures. We used, as a reference value of childhood obesity, the standardized growth charts of the Faustino Orbegozo Foundation, recommended by the Spanish Association of Paediatrics [41]. A BMI value of obesity at the age of 8.5 years is established as 23.5 for boys, and 24.7 for girls, and at the age of 9.5 years is 25.3 for boys and 25.6 for girls. Thus, we can see in Table 2 that both control and experimental groups reduced BMI after the intervention, but the weight decreased in the experimental group, while in the control group it increased.

Table 2. Anthropometric measures pre- and post-intervention of both groups.

Variables		Pre-Test		Post-Test	
		Median	**SD**	**Median**	**SD**
Age	Experimental Group	9.275	1.745	9.23	2.03
	Control Group	9.38	1.585	9.65	1.44
Weight	Experimental Group	60.615	13.95	58.915	11.435
	Control Group	55.865	10.69	56.335	7.575
Height	Experimental Group	1.425	0.115	1.435	0.115
	Control Group	1.445	0.11	1.465	0.09
BMI	Experimental Group	29.62	4.73	28.3	3.51
	Control Group	26.675	3.065	25.99	2.32
Waist-to-hip ratio	Experimental Group	0.98	0.055	0.995	0.07
	Control Group	0.91	0.15	1.55	2.28

5.4. Healthy Habits

Regarding the impact of the program on healthy habits, particularly on their habits on feeding, we applied the KIDMED test as a tool to evaluate the adherence to the Mediterranean diet for children and youths [38]. The index ranges from 0 to 12, and is based on a 16-question test, administered by the researchers of the project. Questions denoting a negative connotation concerning the Mediterranean diet were assigned a value of −1, and those with a positive aspect +1. The sums of the administered test values were classified into three levels: (1) >8, optimal Mediterranean Diet; (2) 4–7, improvement needed to adjust intake to Mediterranean patterns; (3) ≤3, very low diet quality. The KIDMED index showed a slight improvement that was not significant in the experimental group, while the control group saw a worsening in its KIDMED index, which was significant (Table 3).

Table 3. Index of KIDMED by groups and moments.

Group	Stage	KIDMED Index
Experimental Group Min = 5.00 Max = 11.00	Pre-test	7.67
Control Group Min = 4.00 Max = 11.00	Pre-test	7.11
Experimental Group Min = 5.00 Max = 10.00	Post-test	7.65
Control Group Min = 5.00 Max = 10.00	Post-test	6.78

We started from a sample with homogeneous measures about the quality of the Mediterranean diet. Still, after the intervention, we found significant differences in the experimental group's post-test and control (0.23). So, we can affirm that the means corresponding to the two groups are equal. This means that the children who participated in the experimental group managed to improve their diet quality [38].

6. Discussion

Regarding the research question RQ1 (What is the level of satisfaction of children on active game-based solutions for the treatment of obesity?), we can confirm that the designed investment program achieved a high satisfaction on the part of the children. A total of 83.7% wanted to attend the weekly sessions, mainly motivated by playing (58.3%), being with their peers (50%), learning (50%), and gaining points (41.7%). Therefore, we observe that the social factor of playing and gambling are fundamental elements for the satisfaction of minors. All (100%) of the children had fun in the group sessions, stating that they most enjoyed the games with their classmates and the active video games (TANGO:H). Likewise, satisfaction with other intervention program elements was evaluated, such as the training (75%) and the motor games (91.7%). TANGO:H was valued very positively (83.4%) in the group sessions. Additionally, the individual sessions in the homes with Wii were satisfactory (66.7%), although somewhat less than the group sessions, with the social aspect being what most motivated them to play the fun games

(58.3%). However, they were also bored playing at home, mainly because they used the same game (Fit plus) (50%) and because they were alone (37.5%).

We have analyzed the gender differences in the different variables. No significant difference between girls (3.43) and boys (3.4) has been found in the group sessions' level of desirability. Additionally, no significant difference between girls (4.14) and boys (4.00) has been found in satisfaction with the training. Moreover, regarding the level of satisfaction with the motor games, no significant difference between girls (4.43) and boys (4.80) has been found. The level of satisfaction with TANGO:H was similar in girls (4.14) and boys (4.40), as was the use of Wii at home (girls (3.14) and boys (3.40). The group sessions' level of fun was similar in girls (3.71) and boys (3.60). However, girls showed less boredom using the Wii at home than boys. Notably, in the pre-test, we found that only almost 10% of our sample played with the exergames, and children had other preferences in the types of video games. Boys prefer shooters, action, race, adventure, and role-playing video games, while girls like to play simulation games and puzzles.

Additionally, we observed the emotions as an indicator of the motivation and interest with which children attended the weekly interventions. The emotions showed a positive impact on children and a high satisfaction to the group sessions. They have related positive emotions to the structure of the activity. Thus, we can see the positive impact of the group sessions on the experimental group's children.

Concerning the research question RQ2 (How does the educational intervention program based on active games influence children's healthy habits?) we can observe that the designed program was effective in the perceived learning of healthy living habits (91.7%), in addition to having changed their perceived behaviors for their physical activity habits (91.7%) and diet (90.9%).

Moreover, no significant difference between girls (3.57) and boys (3.60) has been found in the level of learning about healthy habits. However, through the KIDMED index we observed a slight improvement in the experimental group's diet habits compared to the control group.

Besides, we measured anthropometric variables, such as BMI or weight, and no significant differences were found between the control and experimental groups or between the pre-and post-intervention stages. Both groups reduced BMI after the intervention, but the weight increased in the control group and decreased in the experimental group.

We also highlight that the use of biometric sensors with children is not always perceived as comfortable (66%), perhaps because of the bands' use. We found that boys showed more tolerance to wearables (3.2) than girls (1.71). Besides, some children played with their wristwatches, and when a fault was detected, they would be taken out of the game to correct and reactivate the measurements. All this could influence their negative assessment of the use of these sensors.

7. Conclusions

This paper has presented different active game-based solutions based on the Kinect and biometric sensors for the treatment of childhood obesity in the framework of an educational intervention program called PROVITAO. Based on the obtained results, we conclude that active game-based interventions have a positive effect in the treatment of children with obesity.

We can mention the following as the main contributions of this work:

- The creation of a web-based solution for creating active video games: TANGO:H designer, which allows for designing games in the cloud, and then be downloaded to be used with the Kinect sensor.
- The creation of a heart rate-controlled exergame that uses biometric sensors and the Kinect sensor.

- An educational intervention program approach to childhood obesity using commercially available active video games created by the research group, both at home and in weekly group sessions.

As the main limitations, we need to extend the program's validation to more children and evaluate the biometric sensors' effectiveness integrated into the exergames created. Moreover, validation is required from medical professionals as to the program's efficacy in the long-term treatment of childhood obesity, especially when it comes to maintaining healthy behaviors. On the other hand, the coronavirus disease 2019 pandemic (COVID-19) [42–44] has affected the population's physical activity and mental health [45]. Therefore, it is necessary to study whether this type of active video games can help maintain a healthy physical activity and at the same time, help people's mental health.

In conclusion, active video games and gamification can increase motivation toward physical activity, learning, and healthier living behaviors in children.

Author Contributions: C.S.G.-G. conceived the proposal and focus of the work. N.G.d.R. coordinated the intervention with children, families, hospitals, and schools, collecting and analyzing data. P.A.T.-D. conceived the active videogame using biometric sensors. F.J.G.-P. supervised and reviewed the work. All the authors—C.S.G.-G., N.G.d.R., P.A.T.-D. and F.J.G.-P.—contributed to this paper's writing and content. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been partially funded by the Spanish Government Ministry of Economy and Competitiveness throughout the DEFINES project (Ref. TIN2016-80172-R) and partially by Fundación CajaCanarias, Project PROVITAO OBE05.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee on the University of La Laguna Ref. CEIBA2020-0410.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical guidelines.

Acknowledgments: The authors would like to thank researchers and participants involved in the project PROVITAO.

Conflicts of Interest: The authors declare no conflict of interest.

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Anexo 4.
Artículo 4

Springer Link

Education & Training | Published: 22 May 2019

Effects of a Gamified Educational Program in the Nutrition of Children with Obesity

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Journal of Medical Systems **43**, Article number: 198 (2019) | Cite this article

1186 Accesses | **12** Citations | **5** Altmetric | Metrics

Resumen

La Organización Mundial de la Salud (OMS) considera la obesidad como una epidemia mundial del siglo XXI. En concreto, Canarias tiene el nivel más alto de esta enfermedad en Europa y el 40% de los niños en España tienen sobrepeso u obesidad. Este aumento es consecuencia directa de los cambios en los estilos de vida de la población y de su alimentación. Por ello, hemos diseñado un programa educativo basado en juegos motores, videojuegos activos y entornos virtuales de aprendizaje para mejorar la salud de los niños y niñas a largo plazo.

Este artículo presenta y analiza los resultados de un estudio sobre los conocimientos nutricionales y la adherencia a la dieta mediterránea de 46 menores obesos de 6 a 12 años de Canarias que participaron en un programa educativo. El diseño del estudio fue cuasi experimental, con dos grupos (experimental y control). Se realizó un estudio longitudinal a largo plazo (3 años). Se utilizó un conjunto de instrumentos de evaluación para las diferentes fases.

Los resultados muestran mejoras significativas entre los grupos experimental y de control en cuanto a sus conocimientos sobre nutrición saludable y su adherencia a la dieta mediterránea.

Como principal conclusión, destacamos que un programa de intervención educativa gamificado y apoyado en las TIC ayuda a motivar y promover mejoras en la nutrición de los niños y niñas.

Journal of Medical Systems (2019) 43: 198
https://doi.org/10.1007/s10916-019-1293-6

EDUCATION & TRAINING

Effects of a Gamified Educational Program in the Nutrition of Children with Obesity

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Received: 9 January 2019 / Accepted: 15 April 2019 / Published online: 22 May 2019

Abstract

Obesity is considered a global epidemic of the twenty-first century by the World Health Organization (WHO). Specifically, the Canary Islands has the highest level of this disease in Europe and 40% of children in Spain are overweight or obese. This increase is a direct result of changes in the lifestyles of the population and its nutrition. Because of this, we have designed an educational program based on motor games, active videogames and virtual learning environments to improve the long-term health of children. This article presents and analyzes the results of a study on the nutritional knowledge and adherence to the Mediterranean diet of 46 obese children aged 6 to 12 years in the Canary Islands who participated in an educational program. The study design was quasi-experimental, with two groups (experimental and control). A long-term longitudinal study (3 years) was carried out. A set of evaluation instruments was used for the different phases. The results show significant improvements between the experimental and control groups in terms of their knowledge of healthy nutrition and their adherence to the Mediterranean diet. As a main conclusion, we emphasize that a gamified educational intervention program supported by ICT helps to motivate and promote improvements in the nutrition of children.

Keywords Childhood obesity · Active videogames · Nutrition · Gamification

Background

Childhood is the stage of life where the habits that will be consolidated throughout our lives begin to develop. Educating children in healthy habits from an early age is the most effective preventive measure to improve their health and quality of life. In 1998, the World Health Organization [1] warned in its annual report of the incidence of obesity as an emerging public health problem, and in 2004, it declared it a global epidemic as it affected more and more countries around the world. This organization estimates that in 2016, more than 41 million children under the age of five were overweight or obese [2]. Childhood obesity is of concern not only due to the increased prevalence of the disease in populations around the world, but to the multiple health consequences in the short, medium and long term, such as the increase in risk factors for the development of cardiovascular and metabolic diseases. There are also psychological and social problems associated with bullying and comments from their peers. In the long term, the persistence of obesity leads to an increase in disabilities or premature death. All these health problems have serious repercussions on the well-being and finances of those affected, their families and society as a whole. The Spanish Society for the Study of Obesity [3] confirms that 44.5% of Spanish children suffer from excess weight. This means that practically one in two children is overweight with respect to the growth patterns established by WHO. Only Italy and

This article is part of the Topical Collection on *Education & Training*

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Cyprus surpass these figures at the European level, according to the IDEFICS study [4]. The ALADINO study of 2011 [5] notes that 26.2% of the infant population between the ages of 6 and 9 years is overweight and 18.3% is obese. In the Canary Islands, the results were 28.4% and 21.2% respectively, placing it as the Spanish autonomous community with the highest rate of childhood obesity, together with Andalusia. In its latest report [6], the results are encouraging for the Canary Islands, which found that the prevalence of overweight/obesity is five percentage points less than in the previous report. The figures, however, continue to be very high (overweight 24.3% and obesity 19.9%). Already in 2016, the WHO [7] issued a report by the Commission to end childhood obesity which includes six recommendations for governments to reverse this global trend. Among these recommendations, we highlight the following:

- Apply comprehensive programs that encourage physical activity and reduce the sedentary habits of children and adolescents.
- Apply comprehensive programs that promote healthy school environments, health and nutrition education, and physical activity among school-age children and adolescents.
- Offer weight control services to the obese pediatric population based on family and lifestyle and with multiple components.

The World Health Organization (WHO) and other international organizations (such as the World Heart Federation, the International Diabetes Federation, among others) have defined strategies in an effort to contain high levels of obesity and physical inactivity. The general guidelines they establish rely on changing food types to reduce fat and caloric intake and increasing physical activity in the individual [8].

However, autonomous motivation is especially important for adherence to change, but despite the knowledge that lifestyle change is the most effective method for long-term weight management, adherence to exercise and physical activity can be difficult to maintain [9, 10]. In children, the reasons for ceasing physical activity are related mainly to the difficulty in adapting to schedules, the refusal to adhere to the routine, dissatisfaction with the results, etc. [11]. Therefore, it is necessary to work not only with people affected by obesity but also to educate their relatives, since it is in the family environment where lifestyles are acquired and perpetuated. It is families that motivate change by using all the tools available to help loved ones adhere to treatments. Likewise, healthy living habits must begin to work from childhood. For children, play is a natural way of learning and can be an excellent strategy to apply in educational intervention programs. Technology also provides very useful tools to support children in their games and education. In this sense, we have designed a gamified educative program using technologies, such as exergames, sensors, apps and virtual platforms, to support health professionals for ambulatory treatment of the obesity in children.

This intervention program was designed, conducted, supervised and analyzed by professional researchers in the areas of Health (Medicine, Physiotherapy, Nursing, Psychology, Physical Education and Sports), Education and Computer Science [12]. Each area of this study focused on analyzing different characteristics of the intervention. In this study we will focus specifically on ascertaining the knowledge and eating habits of children before and after the intervention with our program.

> RQ1. How does the educational intervention program influence children's knowledge of healthy eating?
> RQ2. Is it possible to effect a change in the long-term eating habits of children through a gamified educational intervention program?

Below we present the study design, its main results, a discussion of our findings and the conclusions.

Related works

There are different studies on educational programs that prove the efficacy of caloric expenditure associated with the use of exergames [13–17], as well as the effectiveness of using technologies and gamification with children to promote healthy habits in the short term [18, 19]. But there are few studies in the literature that evaluate the real effectiveness of using videogames as a means to promote long-term physical activity among children and adolescents, and very few that focus on their use as part of treating obese children, probably because it is a relatively new phenomenon [20, 21].

Also, in relation to the world of videogames and their use as an application to promote healthy living habits, there are several related examples, such as Let's Move! (To move!) [22], a comprehensive program created by Michael Obama in 2010 to prevent and treat childhood obesity, which included a contest to reward the best application for child health. There are several similar applications for health, such as "Counting Carbohydrates with Lenny," a Lion that teaches children with diabetes to learn the carbohydrate content of foods [23]. Also, there are different wearable game-based technologies used to increase healthy habits in children, like LeapBand [24]. With this band the children can interact with a virtual pet, which forces them to keep moving through a series of activities and challenges, and thus encourage a healthier lifestyle. Another related example of this kind of technology is Zamzee, a program to encourage physical activity among adolescents, where the physical activity is recorded with a device (accelerometer) and a computer then calculates the amount

of points generated, which can be exchanged for products from participating companies [25]. Another system that is very similar to the previous one was created by the company GeoPalz and is called iBitz, which seeks to encourage physical activity in children and measures the number of steps that children take by means of a pedometer. With it, children can see the steps they have taken and enter them on the website. The steps become points that can be redeemed for gifts in different portals that the parents have previously selected. In addition, the number of points collected during the day will buy a few minutes of play; when they expire, the game is closed until the child moves a little more. GeoPalz has partnered with game developers so that the child's points can be used to unlock secrets and achievements in certain games [26].

Despite the market being full of videogames and technologies to promote healthy habits, the research into the behavioral change in children undergoing a long-term treatment of this kind still poses a challenge [27]. Besides, there are very few studies on whether educational interventions on healthy habits with gamification and video games work in the long term. Taking into account previous studies, an educational program based on motor games, active video games and virtual learning environments was designed to promote a change in the long-term health lifestyles of children suffering from childhood obesity, and of their families.

Material and methods

Design and participants

The study was a mixed, quasi-experimental, longitudinal and prospective three-year study (2014–2017). It consisted of two annual phases, with the same intervention being repeated in both with different subjects. Each annual intervention phase was designed to be carried out with an experimental group and a control group, with 10–15 primary school children, all of them from the northern area of the island of Tenerife.

The inclusion criteria for the sample were age (6–12 years old); body mass index (BMI) in the 97th percentile or higher [28]; having the permission of the parents or legal guardians to participate in the study; not suffering from pathologies preventing them from participating in the study; and not having participated in another clinical trial in the last 12 months. The educational level of the parents was considered as a socioeconomic indicator and was grouped into three categories: high (university studies); medium (secondary education), and low (no education or only primary education) [29].

In Phase 1, the sample consisted of children selected from the outpatient pediatrics clinic of the University Hospital of the Canary Islands (HUC) in outpatient treatment for childhood obesity. The Experimental Group (G1) consisted of 13 obese children (5 boys and 8 girls) who participated in the intervention program. The Control Group (G2) was composed of 10 children (7 boys and 3 girls) who did NOT participate in the intervention program.

In Phase 2, because the hospital patients did not yield a large enough sample to satisfy the inclusion criteria, the participants were selected from different public education schools in the district of La Laguna. It is important to note that the public reference hospital of the children in this Phase 2 is the same hospital as in Phase 1, but some of them are not in treatment yet at the hospital. There are mainly two reasons why they are not in treatment in their hospital: a) the pediatrician in the health center has not referred the patient to the hospital because he wants to wait for the children to improve until they reach adolescence, or b) the parents reject the idea that their children have an illness (obesity). Thus, the Experimental Group (G3) consisted of 12 obese children (5 boys and 7 girls) who participated in the intervention program. The Control Group (G4) was composed of 11 children (4 boys and 7 girls) who did NOT participate in the intervention program.

The assignment of the participants to the experimental and control groups in both phases was not carried out randomly. Those children who were able to attend all the activities and evaluations were assigned to the experimental group, while those in the control group only attended the periodic evaluations. The experimental groups (G1, G3) and control groups (G2, G4) were separated during the study because of their different recruitment contexts.

Table 1 shows the participants' details, including BMI and some demographic variables.

Instruments

The study involved the use of different instruments to analyze different data in each study area. To measure body composition and make biomedical measurements, the following were used: digital scale with height meter, lipocalipter, inextensible tape measure, BMI formula, growth curve to determine the percentiles, and blood tests were used to determine biochemical values. To analyze the emotions during the intervention, we used the Emodiana [30], an instrument that allows measuring ten basic emotions, represented using different emojis and their corresponding labels, adjusted to the language used by children ages 8 to 12. To study the behavior and personality of children and adolescents, we selected the BASC (System for assessing the behavior of children and adolescents) (Spanish adaptation of the CRC by Reynolds and R.W. Kamphaus) [31], a multidimensional questionnaire that measures numerous aspects of the child's behavior and personality. In the self-report, the child or adolescent describes their emotions and perceptions and provides information on clinical, adaptive and general parameters. To determine the children's gaming profile, we selected the Player Profile Test [32], a questionnaire with a total of 12 questions that focus on the type of videogames that the minor plays, the hours a week spent playing, and their values and beliefs regarding videogames.

Table 1 Participants' details

Phase 1											
G1	Sex	Age	BMI*	School	Socio-economic level	G2	Sex	Age	BMI*	School	Socio-economic level
GE01	F	11	33,3	Public	L	GC01	M	6	22,91	Public	L
GE02	F	8	22,16	Public	M	GC02	F	11	25,57	Private	M
GE03	M	10	26,96	Public	L	GC03	F	10	25,42	Public	M
GE04	F	10	35,72	Public	L	GC04	M	8	26,65	Public	L
GE05	F	7	40,32	Public	L	GC05	M	7	32,85	Public	L
GE06	F	10	31,68	Private	M	GC06	F	8	29,28	Public	L
GE07	F	6	21,73	Public	M	GC07	M	6	21,3	Public	M
GE08	M	11	34,82	Public	L	GC08	M	10	27,8	Public	L
GE09	M	9	33	Public	M	GC9	M	8	25,78	Public	L
GE10	F	7	40,54	Public	L	GC10	M	10	26,75	Public	L
GE11	M	11	31,01	Public	L						
GE12	M	10	27,87	Public	M						
GE13	F	12	33,46	Public	M						
Phase 2											
G3	Sex	Age	BMI*	School	Socio-economic level	G4	Sex	Age	BMI*	School	Socio-economic level
GE14	F	6	23,68	Public	M	GC11	F	12	30,63	Public	M
GE15	F	9	31,01	Public	M	GC12	M	10	29,88	Public	M
GE16	F	8	34,94	Public	L	GC13	M	9	28,1	Public	M
GE 17	F	11	31,17	Public	M	GC14	M	12	24,95	Public	H
GE18	M	11	24,67	Public	L	GC15	F	11	30,1	Public	H
GE19	F	10	25,64	Public	M	GC16	M	10	23,52	Public	M
GE20	M	9	30,13	Public	L	GC17	F	12	27,93	Public	M
GE21	F	8	25,76	Public	M	GC18	F	10	25,56	Public	M
GE22	M	11	23,63	Public	M	GC19	F	8	24,61	Public	M
GE23	M	8	25,71	Public	M	GC20	F	8	21,33	Public	M
GE24	F	8	28,65	Public	L	GC21	F	9	25,17	Public	H
GE25	M	11	25,09	Public	M						

*Percentile > = 97 according to WHO [28]

Next, we will focus on describing the questionnaire, the results of which are discussed in this article:

- Healthy diet: To determine adherence to the Mediterranean diet, the KIDMED questionnaire was selected [33] (Appendix Table 6). This test has 16 yes/no items to represent the main indicators of nutrition. Affirmative answers to those questions that have a negative connotation in relation to the Mediterranean Diet are worth −1 point, and affirmative answers to those questions that represent a positive aspect in relation to the Mediterranean Diet are worth +1 point. This index can range between −4 and 12.
- Healthy habits in nutrition: In order to ascertain their physical activity habits and their perception of well-being, we opted for the Adaptation of the Questionnaire on physical activity/sports and health/well-being of M. Delgado and P. Tercedor [34], a 22-item questionnaire that evaluates the following categories: amount of physical activity (physical activity or sports practiced, days and hours a week, hours of inactivity, etc.), enjoyment of physical activity; self-perception of motor competence and utility of physical activity and sport; nutrition; health and personal well-being. In this study we present the results of category related to nutrition (Appendix 2).

Procedure

The procedure for this study was as follows: First, the corresponding permits and informed consent forms were requested. In phase 1, approval for the investigation was requested from the Ethics Committee of HUC, and in phase 2, authorizations were also requested from the Territorial Directorate of Education of the Government of the Canary Islands and subsequently from Management at each participating center.

Next, the study physicians conducted the search for potential participants. Once the sample was selected, an information

letter was sent to the parents or legal guardians in which the main characteristics of the study to be carried out were detailed, ensuring the anonymity of the data and the scientific purposes of the same. During a face-to-face meeting with the parents, their questions were answered and they were asked to participate in the study, either in the experimental or control group. The study sample was confirmed once the parents or guardians who decided to participate in it signed the informed consent. Finally, the study was conducted to coincide with the corresponding academic school year (from September to June) for each annual phase. The work sessions were divided into three quarterly stages: intervention, creation of the vocational project and development of said project (Fig. 1). The evaluations carried out with the instruments described in the previous section were carried out before, during and at the end of each of the annual phases.

First stage: Intervention

The intervention consisted of a two-hour, weekly group session in person (a total of 12 sessions) (Fig. 2). In these sessions, the participants were given training activities on healthy habits and health education on obesity (60 min); traditional motor games were practiced and activities involving an active videogame with contents on healthy habits were carried out in pairs (60 min). All the sessions were designed from a play point of view, meaning that after the theoretical content was presented, it was reinforced with a game (using motor games and the active videogame TANGO:H [35]). Thus, each session featured a game designed specifically for this content. This was complemented with two weekly 30-min physical activity sessions at home with a commercial video game (Wii Fit Plus). We also worked with the parents, mothers and/or guardians of the minors, who received a 90-min educational session during which three topics were discussed: healthy lifestyle habits, obesity as a disease, and false beliefs about video games. We accounted for the diversity of the geographical origins of the families (different Spanish autonomous communities, Venezuela, China, etc.) to educate them in nutritional habits. There was a good rapport and communication between the team and parents, and in order to provide support and motivation to positively influence changes in habits, ICT tools such as instant messaging services (WhatsApp), social networks (Facebook) and Google apps were used to maintain this relationship.

a) Initial training in group sessions
b) Motor play in group sessions
c) Nutritional activities in TANGO:H
d) Training with parents using Classdojo

Second stage: Creation of vocational project

This stage entailed the creation of a vocational project intended to identify healthy activities that the participants might like in their environment. This activity was supervised through a weekly videoconference session and the use of the Moodle virtual platform. Likewise, the program of activities with Wii Fit Plus continued at home with two weekly sessions lasting 30 min each.

Fig. 1 Stages and instruments used in each annual phase

Fig. 2 Different moments and strategies used in the educational intervention. **a** Initial training in group sessions. **b** Motor play in group sessions. **c** Nutritional activities in TANGO:H. **d** Training with parents using Classdojo

The periodicity of the face-to-face group sessions became monthly. These sessions lasted 2 h and focused on reinforcing the activities carried out throughout the week. Also done on a monthly basis were several orientation activities with the parents to support the development of their children's vocational project, as well as to answer questions regarding the use of the different ICT tools (videoconference and Moodle platform).

Third stage: Development of vocational project

This last stage required each participant to develop their own vocational project on healthy activities and provided support the children as they started their new activities. To this end, individual, home and continuous care was offered, supported by ICT (videoconferences and the Moodle platform, and Classdojo for follow-up). In addition, the two weekly at-home physical activity sessions with the Wii Fit Plus were continued, as was the counseling for parents on the development of the vocational project. We also gave talks and workshops on healthy lifestyle habits to students from 3rd to 6th grade in primary schools, showing them how to use TANGO:H and other technological tools (Kahoot!) (Fig. 3).

In each phase of the study, we collected data for that year for further analysis prior to, during and at the end of the intervention.

Results

Knowledge of nutrition throughout the study

In this section we analyze the participants' answers involving their knowledge of healthy nutrition. In all cases, higher scores indicate better habits, knowledge and satisfaction. All the variables involved in these analyses exhibit a normal distribution, as per the Kolmogorov-Smirnov test. The comparison of the means of the two groups in the baseline indicates that both presented similar scores at the beginning of the study in the indices studied (Table 2).

Fig. 3 Use of active videogames in schools

For each indicator, the analysis of repeated measurements is performed, with a group as an inter-subject factor and an intra-subject factor with three levels that we have called "Tracking" (Table 3). Each level is defined by one phase of the intervention: the baseline (measurements taken before the intervention began), the immediate follow-up (evaluation done at the end of the face-to-face intervention phase), and the long-term follow-up (evaluation done after finishing the intervention with the children and removing the follow-ups). When the sphericity of the variance-covariance matrices is not met, the epsilon correction is applied using the Greenhouse-Geisser method. In the case of the main effects of the intra-subject factor, a posteriori analysis is performed with the Bonferroni adjustment; likewise, if in the analysis of the main effects the criterion of homogeneity of the variances is not met, the robust Welch test is performed.

The interaction between the Tracking and Group factor is not significant (F (2.50) = 2582, $p = .086$, $\eta 2p = .094$, $P = .492$), there is no significant Group effect (F (1.25) = 0.503, $p = .485$, $\eta 2p = .020$, $P = .105$). On the other hand, there is a significant follow-up factor effect (F (2.50) = 28.647, $p = .000$, $\eta 2p = .532$, $P \geq 0.999$). When looking at the analysis by pairs with the Bonferroni adjustment, we find that the scores in the long-term follow-up are significantly different from those of the baseline (t (23) = 7.002, $p \leq .001$; d = 1.2) and those of the immediate follow-up (t (23) = 6.234; $p \leq .001$; d = 0.99). Analyzing the evolution of the means (See Fig. 4), and considering the two groups together, shows that, in both cases, the highest means for the knowledge variable are given in the long term.

The graph representing the means indicates that, although the interaction between the Tracking and Group factor is not significant, there may be interaction between the baseline and the immediate follow-up, that is, the one done just after the face-to-face intervention phase. Therefore, this phase will be analyzed independently. In this case, the variance-covariance matrix does not exhibit a sphericity pattern, so the Epsilon correction will be done using the Greenhouse-Geisser method. The interaction between the immediate follow-up factor and the Group is significant (F (1.00, 31.00) = 6.911, $p = .013$, $\eta 2p = .182$, $P = .721$), as is the main effect of the immediate follow-up factor (F (1.00, 31.00) = 6.911, $p = .013$, $\eta 2p = .182$, $P = .721$), but not of the Group factor (F (1.31) = 0.215, $p = .646$, $\eta 2p = .007$, $P = .073$).

As shown in Fig. 4, when we averaged the scores of the two groups, the means in the follow-up exceeded those of the baseline; on the other hand, the interaction observed and the review of the means indicates that the scores of each group describe a different evolution between the baseline and immediate follow-up.

Table 2 Mean and group (standard deviations) and statistics of the difference of means of the scores in the questionnaires of the participants in the baseline

	Control $N = 20$	Experimental $N = 25$	F (1.43)	p	η2p	P
Nutrition	27.00 (3.64)	26.40 (2.66)	0.41	.52	01	.10

Bonferroni adjustment

Table 3 Means and (standard deviations) of the indices of the questionnaires reported by the two groups of minors in the follow-up evaluations

	Immediate		Long term	
	Control $N = 16$	Experimental $N = 17$	Control $N = 16$	Experimental $N = 15$
Nutrition	27.00 (2.88)	28.71 (2.62)	29.56 (2.50)	30.87 (2.95)

Bonferroni adjustment

Adherence to the Mediterranean diet

In this section we analyze the responses of the children in the questionnaire on the quality of the Mediterranean diet - KIDMED. We analyze the data of the pretest and the immediate posttest (after the face-to-face intervention). As the data show, at the beginning both groups had an average KIDMED index of 7 (average adherence). However, after the intervention, the experimental group showed a slight improvement in this index, while in the control group it declined. These differences in the KIDMED index are not significant. Therefore, we decided to provide the following tables where each item in the KIDMED questionnaire is shown as a percent for both the control group and the experimental group. These tables show significant differences in vegetable intake (one or more), and the consumption of fish, pasta and cereals. Also

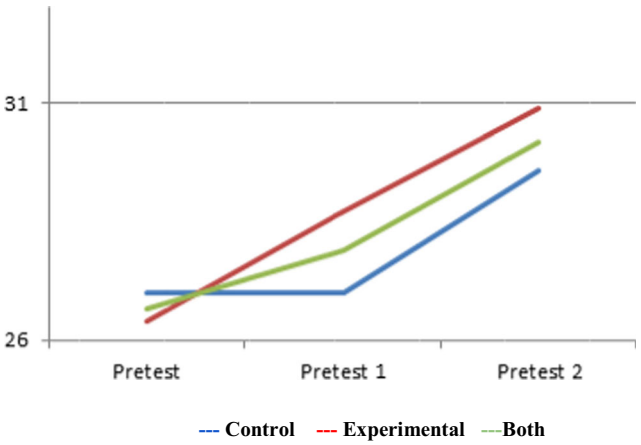

Fig. 4 Knowledge about nutrition during the study

Table 4 KIDMED index for different times and groups

Index KIDMED	Experimental group Pre Min = 5.00 / Max = 11.00	Experimental group Post Min = 5.00 / Max = 10.00	Control group Pre Min = 4.00 / Max = 11.00	Control group Post Min = 5.00 / Max = 10.00
Mean	7.67	7.75	7.11	6.78

significant is the number of children who have stopped eating industrial pastries for breakfast.

Regarding the impact of the program on dietary habits, as Table 4 shows, in the experimental group, the KIDMED index exhibits a slight improvement that is not significant, while the control group sees a worsening in its KIDMED index that is significant.

In Table 5 below, we can see represented in percentages the items according to the group to which they belong and the time when all the participants were evaluated.

Relationship between results

Regarding the results on healthy habits [34] in particular, we presented the results on the "nutrition" category. The results show a slight improvement in the GE (baseline = 26.40; post immediate intervention = 28; long-term post intervention = 30.87) compared with the GC (baseline = 27; post immediate intervention = 27; long-term post intervention = 29.56), and as Fig. 4 shows, a better evolution in GE than GC.

About the KIDMED [33], the results show a small improvement in the GE index (pre-test = 7.67; post-test = 7.75) and a minor worsening in the GC index (pre-test = 7.11; post-test = 6.78). Also, analyzing all the items that comprise the KIDMED test according to the group to which they belonged, it became clear that there were improvements in the experimental group involving the consumption of vegetables (pre-test = 91.6; post-test = 100), fish (pre-test = 66.6; post-test = 83.3), or cereals for breakfast (pre-test = 83.3; post-test = 91.6), and that all of them stopped eating industrial pastries for breakfast (pre-test = 8.3; post-test = 0). In contrast, the control group stopped having vegetables regularly (pre-test = 77.7; post-test = 55.5), and also exhibited worse indicators related to industrial bakery and sweets (pre-test = 0; post-test = 11.1). Then, the "t" test was performed for related samples, which allowed us to confirm whether or not there were significant differences between the pretest and the posttest both in the experimental group and in the control group. In both cases, we must accept that the measure in the population in both the experimental group (0.72) and the control group (0.563) is the same, and no significant differences were found when the values were greater than 0.5. Subsequently, the "t" test was done for independent samples, relating first the pretest in the experimental and control groups. This did not reveal any significant differences in the questionnaire between the experimental and control groups (0.54). Thus, we started with a sample with homogeneous measurements in relation to the quality of the Mediterranean diet, but after the intervention, we found significant differences in the post-test of the experimental and control groups (0.23). We can thus affirm that the means corresponding to the two groups are equal, meaning that the children who participated in the experimental group managed to improve the quality of their diet.

To summarize the results, we observed a slight improvement in the GE's knowledge of healthy nutrition and a better adherence to the Mediterranean diet compared to the GC, both in the immediate post intervention and in the long term.

Table 5 Results by item of the KIDMED test

KIDMED test	Experimental group Pre	Experimental group Post	Control group Pre	Control group Post
Has a fruit or fruit juice every day	66.6	66.6	77.7	66.6
Has a second fruit every day	25.0	0.0	33.3	33.3
Has fresh or cooked vegetables regularly once a day	91.6	100.0	77.7	55.5
Has fresh or cooked vegetables more than once a day	41.6	25.0	11.1	11.1
Consumes fish regularly (at least 2–3/week)	66.6	83.3	77.7	66.6
Goes >1/ week to a fast food restaurant (hamburger)	0.00	0.0	0.0	0.0
Likes pulses and eats them >1/week	91.6	83.3	77.7	66.6
Consumes pasta or rice almost every day (5 or more per week)	25.0	50.0	33.3	33.3
Has cereals or grains (bread, etc.) for breakfast	83.3	91.6	77.7	77.7
Consumes nuts regularly (at least 2–3/week)	16.6	16.6	33.3	55.5
Uses olive oil at home	91.6	91.6	100.0	100.0
Skips breakfast	0.0	0.0	0.0	11.1
Has a dairy product for breakfast (yogurt, milk, etc.)	100.0	100.0	88.8	88.8
Has commercially baked goods or pastries for breakfast	8.3	0.0	22.2	11.1
Has two yogurts and/or some cheese (40 g) daily	75.0	66.6	44.4	55.5
Eats sweets and candy several times every day	0.0	0.0	0.0	11.1

Discussion and conclusions

Throughout the phases of the study, we observed a significant improvement in both groups' knowledge of healthy eating, reaching higher levels in the long term than in the two previous evaluations. On the one hand, this common drift may be reflecting the benefits of formal, family and health education, which was available to both groups in the community and whose access was promoted by the Project. By focusing only on the times before and immediately after the face-to-face intervention, we found a different trend in the scores of both groups. Looking at the means, we see how the experimental group's knowledge of healthy eating is higher than the baseline, while that of the control group remains stable. From that moment, the knowledge of the two groups increases with a similar profile, evolving in parallel. Having participated in the experimental group seems to be a benefit, since the gap in the knowledge gained by the experimental group after the face-to-face intervention remains in the long term. Likewise, a significant improvement was observed in adherence to the Mediterranean Diet (MD) of the experimental group compared to the control group. In addition, we observed that the control group worsened in some items compared to the experimental group. This result is important because the MD is traditionally a model of heart-healthy food, one that is characterized by a high consumption of vegetables, legumes, fruits, nuts and cereals and, especially, olive oil. The MD also includes recipes and cooking methods. It is probably one of the healthiest dietary models that currently exists. Numerous epidemiological studies [36–38] highlight the beneficial effects of this type of diet in combatting cardiovascular diseases, diabetes, certain tumors and other pathologies associated with oxidative stress. In this sense, the MD is related to a higher life expectancy and a lower incidence of chronic-degenerative diseases [39], evidencing that a small increase in the rate of adherence to the MD leads to a significant reduction in the risk of mortality and in the incidence of these diseases [40]. This study, however, presents a series of limitations. We must bear in mind that we had a sample of 46 participants during the two phases; however, the participants' withdrawal from the study over the months meant the loss of data. In addition, the participants came from different social contexts so we had to adapt the recommendations on eating habits and physical activities to the economic possibilities of each family. Moreover, in phase 1, the participants attended private and public schools, so there was no homogeneity of knowledge. Finally, the children had different leisure interests and attention spans, so we had to work quickly to create a circle of trust among the participants.

Finally, although it was not the goal of this paper to describe the general intervention program and all its results, we will highlight its strong points:

- The PROVITAO project has developed a gamified educational program for healthy habits, based on active video games and motor games. It has created and validated a frame of reference for intervention, monitoring and emotional, biomedical, interactive, social, psychological and educational evaluation, based on games, applied to the treatment of childhood obesity and to preventing associated complications. It has also produced various technological products (exergames, serious games, webapps, sensory libraries, wearables, etc.).
- The program developed consists of a plan of activities specifically designed around healthy habits with motor games, commercial video games (Wii Fit Plus and apps), and internally-developed games such as TANGO:H, which can be presented at home and in group face-to-face sessions. PROVITAO was applied to a total of 46 children with childhood obesity and their caregivers during the school year, in two phases.
- The research design used was of the quasi-experimental mixed type, with two control groups and two experimental groups.
- The research group has participated in various activities at the local level (talks in schools, conferences, workshops, etc.) to promote healthy habits.
- This study was carried out over 3 years, from 2014 to 2017, thanks to the joint work done by a multidisciplinary team of professionals in the areas of Physical Education, Psychology, Pedagogy, Health Sciences and Computer Science who designed, supervised, executed and studied the program proposed in this article.

Despite the limited scope of this study, it has great potential to gain knowledge on the childhood population with obesity because:

- It takes place in one of the Autonomous Communities with the highest rates of obesity in Spain and in Europe.
- It provides information on the healthy habits of an intercultural population.
- In involves an age group where healthy living habits can be more easily promoted.
- It educates and raises awareness in the entity that is ultimately responsible for the eating habits and physical activity of children: the family [41].
- It is one of the first programs to use gamification tools focused on non-formal educational learning involving obesity and lifestyle and their long-term assessment.

Acknowledgements We would like to thanks to the children and their families who have participated in this study. Also, we gratefully acknowledge the researchers and collaborators of PROVITAO from different areas: Health (Carmela Quirce González, Norberto Marrero Gordillo, Honorio Armas Ramos, Mariana E. Cairós González, Josue Monzón Diaz, Mercedes Murray), Technology (Yeray del Cristo Barrios Fleitas, Alberto Mora Carreño, Belén Armas Torres, Vanesa Muñoz Cruz, Lorenzo Moreno Ruiz, Jesús Rodríguez Alamo, Miguel A. Padrón,

Niobe Jerez, Belén Armas Torres, Pablo V. Torres Carrion) and Education (Luis Navarro Campillo, Elisenda Espino Espino, Silvia Vera González, Isa Neves). Besides, we thank the Canary Islands Government Education Counseling and the schools and teachers who collaborated with the project.

Funding This study was funded by "Fundación Caja Canarias" (grant number OBE05).

Compliance with ethical standards

Conflict of interest Authors declares that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the research committee of "Hospital Universitario de Canarias" and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix 1

Table 6 KIDMED [20]

Test to assess adherence to the Mediterranean Diet	
KIDMED test	Scoring
Has a fruit or fruit juice every day	+1
Has a second fruit every day	+1
Has fresh or cooked vegetables regularly once a day	+1
Has fresh or cooked vegetables more than once a day	+1
	+1
Consumes fish regularly (at least 2–3/week)	−1
Goes >1/ week to a fast food restaurant (hamburger)	+1
Likes pulses and eats them >1/week	+1
Consumes pasta or rice almost every day (5 or more per week)	+1
	+1
Has cereals or grains (bread, etc) for breakfast	+1
Consumes nuts regularly (at least 2–3/week)	+1
Uses olive oil at home	+1
Skips breakfast	−1
Has a dairy product for breakfast (yogurt, milk, etc)	+1
Has commercially baked goods or pastries for breakfast	−1
Has two yogurts and/or some cheese (40 g) daily	
Eats sweets and candy several times every day	
KIDMED index	Adherence to Med Diet
Score < =3 points	Poor
Score 4–7 points	Medium
Score > =8 points	High

[20] Adapted from: Serra-Majem, L.; Ribas, L.; García, A.; Pérez-Rodrigo, C.; Aranceta, J. Nutrient adequacy and Mediterranean Diet in Spanish school children and adolescents. Eur J Clin Nutr. 2003; 57, 35–9

Appendix 2

Health questionnaire [21]

(*) Category Nutrition: [the HIGHER the score, the BETTER the knowledge of eating habits]

-Indicate which of these foods you consider to be more or less healthy.

	Healthy	Unhealthy
Coffee	1	0
Milk or shakes	1	0
Refreshments	0	1
Packaged juices	0	1
Natural juices	1	0
Hamburgers or sausages	0	1
Sausages such as chorizo, mortadella, sausage ...	0	1
Homemade or bagged potato chips	0	1
Cakes and sweets	0	1
Vegetables	1	0
Fruit	1	0
Candies (candies ...)	0	1
Nuts (seeds, peanuts, nuts ...)	1	0
Legumes (chickpeas, lentils ...)	1	0
Butter or margarine	0	1
Yogurt	1	0
Fresh cheese	1	0
Yellow cheese	0	1
Chicken or turkey	1	0
Meat with a lot of fat	0	1
Fish	1	0
Eggs or omelet	1	0

-What foods should we consume daily, weekly and monthly?

	Daily	Weekly	Monthly
Eggs	0	1	0
Fish	0	1	0
Olive oil	1	0	0
Sweets	0	0	1
Vegetables	1	0	0
Cheese, milk, yogurt	1	0	0
Cereals, bread, pasta, rice, potatoes ...	1	0	0
Poultry	0	1	0
Meat	0	0	1
Fruits	1	0	0
Beans, legumes and nuts	1	0	0

-Overall, do you think your diet is healthy?

· No [0]
· A little [1]
· Enough / Could be improved [2]
· Very [3]
· I do not know [0]

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