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# Etude des comportements de mouvement sur 24h : de la méta analyse à l'étude interventionnelle

Javier Rodrigo Sanjoaquin

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**UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR**  
**COLLEGE SCIENCES SOCIALES ET HUMANITÉS – DÉPARTEMENT STAPS**

THÈSE EN COTUTELLE AVEC L'UNIVERSITÉ DE ZARAGOZA

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ÉTUDE DES COMPORTEMENTS DE MOUVEMENT SUR 24 HEURES :  
DE LA META-ANALYSE À L'ÉTUDE INTERVENTIONNELLE

ESTUDIO DE LOS COMPORTAMIENTOS DE MOVIMIENTO DE 24  
HORAS: DEL METAANÁLISIS AL ESTUDIO DE INTERVENCIÓN

STUDY OF 24-HOUR MOVEMENT BEHAVIOURS: FROM META-  
ANALYSIS TO INTERVENTIONAL STUDY

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## **ABBREVIATIONS**

CAS: Creating Active Schools

GAPPA: Global Action Plan on Physical Activity

H: Number of Hours

HPS: Health Promoting Schools

LPA: Light-Intensity Physical Activity

M: Mean

METs: Metabolic equivalents

Min: Number of Minutes

MVPA: Moderate- to Vigorous-Intensity Physical Activity

N: Number (of participants, studies, etc.)

PA: Physical activity

PE: Physical education

SB: Sedentary behaviour

SD: Standard Deviation

SDGs: Sustainable Development Goals

SES: Socio-Economic Status

SHE: Schools for health in Europe

ST: Sedentary Time

UNESCO: United Nations Educational, Scientific and Cultural Organization

WHO: World Health Organisation

Y: Years (of age)

## **ABSTRACT**

### **Background**

Insufficient physical activity (PA), as well as high levels of sedentary behaviours (SB), are two of the most important health behavioural risks for non-communicable diseases. In 2016, an integrated theoretical framework was developed in Canada, named the 24-Hour Movement Guidelines, integrating the recommendations for PA, SB and sleep. Furthermore, this model recognized the importance of movement behaviours to improve health outcomes in children and adolescents from an integrated perspective. Nevertheless, 80% of the world's children and youths do not meet the PA recommendations (i.e., 60 minutes of daily moderate to vigorous physical activity [MVPA]), SB take up over 50% of the waking day for children aged 7 to 10 years, and only 60% of children meet the sleep recommendations (i.e., 9-11 hours a day). Therefore, the overall aim of this doctoral thesis was to explore changes in 24-hour movement behaviours and their associations with school-based interventions among 5-12 years-old children. To achieve this objective, both a scoping review and a meta-analysis were carried out, as well as a school-based intervention.

### **Methods**

This thesis is comprised of five research papers, three of which are the protocol of a systematic review, a scoping review and a meta-analysis, and the other two are the protocol of the intervention and an original research study which lasted two years.

### **Results**

The scoping review included 37 studies with a total sample size of 27,145 school-aged children. As a whole, 62% (i.e., 23 intervention studies) effectively improved PA and/or reduced SB after the intervention, and only one study assessed sleep behaviour, PA and SB together. The meta-analysis is composed of 24 trials comprising 19,487 school-aged children. Intervention studies were ineffective for improving daily MVPA but were effective for reducing sedentary time. Furthermore, subgroup analyses for MVPA revealed that when studies had two intervention components, or high quality they were more effective for improving MVPA. The intervention study results showed significant improvements only in light PA, while a significant decrease in MVPA. In

terms of the proportion of children meeting the 24-hour movement guidelines, 42% of all school children met all recommendations and 0% met none.

## **Conclusion**

This thesis has provided new evidence to advance the contribution of school-based interventions promoting 24-hour movement behaviours among children. As a main gap, we identified that current school-based interventions do not promote the whole 24-hour movement behaviours among children, because there is a lack of intervention studies addressing sleep behaviour. Second, school-based interventions have been effective to reduce children's daily time spent in sedentary time, although there is no evidence of overall effectiveness of school-based interventions for improving daily MVPA in children. Third, the school-based intervention program showed significant effects increasing light PA, while significant effects reducing MVPA and non-significant effects for reducing sedentary time, reducing recreational screen time and improving sleep behaviour. Fourth, nearly half of the children participating in the school-based intervention met the 24-hour movement guidelines and there were not anyone not meeting any of the recommendations. Also, differences were found between gender as well as school stage regarding meeting the recommendations. Finally, it is encouraged for researchers to consider the recommendations provided in this thesis before designing future school-based interventions, especially if they are going to target 24-hour movement behaviours among 5-12 years-old children.



## **RÉSUMÉ**

### **Introduction**

Une activité physique (AP) insuffisante, ainsi que des niveaux élevés de comportements sédentaires (CS), sont deux des risques comportementaux de santé les plus importants pour les maladies non transmissibles. En 2016, un cadre théorique a été développé au Canada, nommé les directives de mouvement de 24 heures, intégrant les recommandations pour l'AP, le CS et le sommeil. En outre, ce modèle reconnaissait l'importance des comportements de mouvement pour améliorer les résultats de santé chez les enfants et les adolescents dans une perspective intégrée. Néanmoins, des enfants et des adolescents dans le monde ne respectent pas les recommandations en matière d'AP, CS et sommeil. Par conséquent, l'objectif global de cette thèse était d'explorer les changements dans les comportements de mouvement de 24 heures et leurs associations avec les interventions en milieu scolaire chez les enfants de 5 à 12 ans.

### **Méthode**

Cette thèse est composée de cinq études de recherche, dont trois sont le protocole d'une revue systématique, d'une revue exploratoire et d'une méta-analyse, et les deux autres sont le protocole de l'intervention et une étude d'intervention en milieu scolaire avec une durée de deux années.

### **Résultats**

La revue exploratoire a inclus 37 études avec un échantillon total de 27,145 enfants d'école primaire. Dans 62% des cas (soit 23 études d'intervention), l'AP a effectivement été améliorée et/ou le CS réduit après l'intervention, et une seule étude a évalué le comportement de sommeil, l'AP et le CS ensemble. La méta-analyse est composée de 24 essais portant sur 19,487 enfants d'école primaire. Les études d'intervention étaient inefficaces pour améliorer l'AP modérée-vigoureuse (APMV) quotidienne, mais étaient efficaces pour réduire le temps sédentaire. En outre, les analyses de sous-groupes pour l'APMV ont révélé que lorsque les études comportaient deux composantes d'intervention, ou une qualité élevée, elles étaient efficaces pour améliorer l'APMV. Les résultats de l'étude d'intervention n'ont montré des améliorations significatives que pour l'AP légère, tandis qu'une diminution significative du APMV. En

ce qui concerne la proportion d'enfants qui atteignent les recommandations de 24 heures, 42 % de tous les écoliers respectaient toutes les recommandations et 0 % n'en respectaient aucune.

## **Conclusion**

Cette thèse a fourni de nouvelles preuves pour faire avancer la contribution des interventions en milieu scolaire promouvant les comportements de mouvement sur 24 heures chez les enfants. On a identifié comme principale lacune le fait que les interventions actuelles en milieu scolaire ne favorisent pas l'ensemble des comportements de mouvement sur 24 heures chez les enfants, en raison du manque d'études d'intervention ciblant sur le comportement de sommeil. Deuxièmement, les interventions en milieu scolaire se sont avérées efficaces pour réduire le temps quotidien passé en TS par les enfants, bien qu'il n'y ait aucune preuve de l'efficacité globale des interventions en milieu scolaire pour améliorer l'APMV quotidienne chez les enfants. Troisièmement, le programme d'intervention en milieu scolaire a eu des effets significatifs sur l'augmentation de l'AP légère. Par contre, il a eu des effets significatifs sur la réduction de l'APMV et des effets non significatifs sur la réduction des temps sédentaire, la réduction du temps d'écran récréatif et l'amélioration du sommeil. Quatrièmement, près de la moitié des enfants participant à l'intervention en milieu scolaire ont respecté les recommandations de mouvement sur 24 heures et aucun d'entre eux n'a manqué à l'une ou l'autre de ces recommandations. Enfin, les chercheurs sont encouragés à prendre en compte les recommandations fournies dans cette thèse avant de concevoir de futures interventions en milieu scolaire sur les comportements de mouvement sur 24 heures chez les enfants de 5 à 12 ans.

## **RESUMEN**

### **Introducción**

La escasa actividad física (AF), así como los elevados niveles de comportamientos sedentarios (CS), son dos de los riesgos más importantes para la salud de las enfermedades no transmisibles. En 2016, se desarrolló en Canadá un marco teórico integrado, denominado “24-hour Movement Guidelines”, que integra las recomendaciones de AF, CS y sueño. Además, este modelo reconocía la importancia de las conductas de movimiento para mejorar la salud en niños y adolescentes desde una perspectiva integrada. Sin embargo, los niños y adolescentes no cumplen las recomendaciones de AF, CS y sueño a nivel mundial. Por lo tanto, el objetivo general de esta tesis doctoral fue explorar los cambios en las conductas de movimiento de 24 horas y sus asociaciones con las intervenciones basadas en la escuela entre los niños de 5 a 12 años.

### **Método**

Esta tesis se compone de cinco trabajos de investigación, tres de los cuales son el protocolo de una revisión sistemática, una revisión de alcance y un metaanálisis, y los otros dos son el protocolo de la intervención y un estudio de investigación original que analizan los datos recogidos a lo largo de una intervención escolar que duró dos años.

### **Resultados**

La revisión de alcance incluyó 37 estudios con un tamaño total de 27.145 niños de educación primaria. Un 62% de ellos (es decir, 23 estudios de intervención) mejoraron efectivamente la AF y/o redujeron el CS después de la intervención. Sólo un estudio evaluó el comportamiento del sueño, la AF y el CS conjuntamente. Por otro lado, el metaanálisis se compone de 24 estudios con 19.487 niños (51,3% niñas). Los estudios de intervención no fueron eficaces para mejorar la AF moderada-vigorosa (AFMV) diaria, pero sí para reducir el tiempo sedentario. Además, el análisis de subgrupos para la AFMV reveló que los estudios de intervención con dos componentes, y los que tenían alta calidad eran eficaces para mejorar la AFMV. Los resultados del estudio de intervención mostraron mejoras significativas únicamente en AF ligera, mientras que mostraron una

disminución significativa en AFMV. En cuanto a la proporción de niños que cumplían las pautas de movimiento de 24 horas, el 42% de los escolares cumplía todas las recomendaciones y el 0% no cumplía ninguna.

## **Conclusiones**

Esta tesis ha aportado nuevas pruebas en cuanto a la contribución de las intervenciones escolares que promueven las conductas de movimiento de 24 horas en niños. Como gap principal, identificamos que las intervenciones escolares actuales no promueven los comportamientos de movimiento de 24 horas entre los niños. Esto se debe especialmente a que hay una falta de estudios de intervención que aborden el comportamiento del sueño en educación primaria. En segundo lugar, esta primera revisión internacional sobre las conductas de movimiento de 24 horas en el ámbito escolar encontró que las intervenciones en el ámbito escolar son eficaces para reducir el tiempo diario que los niños pasan en tiempo sedentario. No obstante, no hay suficiente evidencia de la eficacia de las intervenciones en el ámbito escolar para mejorar la AFMV diaria en los niños. En tercer lugar, el programa de intervención escolar mostró efectos significativos en el aumento de la AF ligera, así como efectos significativos en la reducción de la AFMV y efectos no significativos en la reducción del tiempo sedentario, la reducción del tiempo recreativo de pantalla y la mejora del comportamiento del sueño. En cuarto lugar, casi la mitad de los niños que participaron en la intervención escolar cumplieron con las pautas de movimiento de 24 horas (42%), y no hubo ninguno que no cumpliera con ninguna de las recomendaciones. También se encontraron diferencias respecto al género y a la etapa escolar en cuanto al cumplimiento de las recomendaciones. Por último, se anima a que los investigadores tengan en cuenta las recomendaciones proporcionadas en esta tesis doctoral antes de diseñar futuras intervenciones escolares, especialmente si dichas intervenciones van a realizarse sobre las conductas de movimiento de 24 horas entre los niños de 5 a 12 años.

## **SECTION I. INTRODUCTION**

## **Chapter 1. Background**

### **1.1. Introduction in French**

Cette thèse a été réalisée en cotutelle entre deux pays appartenant à l'Union européenne, à savoir la France et l'Espagne. Ce type de thèse de doctorat vise à encourager le doctorant à acquérir un bagage international et linguistique, en plus des compétences liées à la recherche et à l'enseignement universitaire qui sont inhérentes à la formation doctorale. De même, ce type de format de thèse vise à promouvoir la coopération transfrontalière entre les groupes de recherche des deux pays. Pour cette raison, ce document est rédigé en trois langues différentes. Le français et l'espagnol, correspondant aux deux pays de cotutelle, et l'anglais, correspondant à la langue scientifique universelle, sont utilisés.

La réalisation de cette thèse a été effectuée conformément aux directives et à la législation françaises en raison de l'obtention du contrat doctoral à l'Université de Pau et des Pays de l'Adour. Elle s'est déroulée de janvier 2020 à décembre 2022. En outre, lors de la réalisation de la thèse de doctorat en cotutelle, la répartition du temps a été de 24 mois à l'Université de Pau (France) et de 9 mois à l'Université de Saragosse (Espagne). Enfin, dans le but d'améliorer la formation doctorale et d'obtenir le diplôme de doctorat européen, un séjour de recherche de 3 mois a été effectué à l'Université de Limerick (Irlande).

Avant d'introduire le sujet principal de cette thèse, il a été jugé nécessaire de contextualiser les circonstances dans lesquelles la thèse a été réalisée, notamment en ce qui concerne la pandémie et les confinements dus au virus COVID-19. Le début de la pandémie, ainsi que les confinements successifs en France et en Espagne depuis mars 2020, ont obligé tant le doctorant actuel que les directeurs et collaborateurs impliqués dans cette thèse à la restructurer. Il faut noter qu'avant mars 2020, il y avait une structure et des études à réaliser qui étaient complètement différentes de celles qui ont finalement été réalisées.

En ce sens, il a été prévu à l'origine une étude transversale transfrontalière (c'est-à-dire avec des données provenant d'Espagne et de France) et une intervention scolaire

dans une école primaire française et une école primaire espagnole. L'ajustement du projet aux contraintes de la pandémie a conduit, tout d'abord, à une étude de revue systématique et une méta-analyse car la collecte de données des enfants n'était pas nécessaire immédiatement. Deuxièmement, il a été décidé de ne réaliser l'intervention en milieu scolaire que dans une seule école en Espagne, l'accès aux écoles françaises étant interdit. Pour les mêmes raisons, il n'a pas été possible d'accéder aux écoles, ni au personnel extérieur ni aux parents eux-mêmes, avant septembre 2021.

Le thème principal de cette thèse de doctorat concerne l'étude et l'analyse des comportements de mouvement dans les interventions scolaires. Ces comportements de mouvement sont composés de l'activité physique, du temps sédentaire et du sommeil. Ce regroupement est justifié parce que les activités ou les mouvements qu'une personne peut effectuer au cours des 24 heures de la journée sont divisés de façon unique parmi les périodes de sommeil, de comportement sédentaire et d'activité physique à différentes intensités (Chaput et al., 2014; Tremblay et al., 2016). Par conséquent, le temps consacré à un comportement (par exemple, l'activité physique) déplace nécessairement le temps consacré à au moins un autre des deux comportements (par exemple, le comportement sédentaire), ce qui renforce l'importance d'analyser conjointement ces comportements de mouvement (Pedišić et al., 2017). Plus précisément, la littérature scientifique souligne que le temps consacré à chacun des comportements de mouvement est étroitement lié au développement physique et mental d'une personne, devenant très pertinent en particulier pendant l'enfance et l'adolescence (Carson et al., 2016; Poitras et al., 2016; Rollo et al., 2020).

En raison de la création récente du concept de comportements de mouvement sur 24 heures, de nombreuses études ont été menées au cours des dernières années et ont confirmé sa pertinence (Pedišić et al., 2017 ; Rollo et al., 2020 ; Sevil et al., 2019 ; Tapia et al., 2022). Cela a favorisé un changement de paradigme, passant de la considération de chaque comportement de mouvement de manière isolée à l'analyse de leurs différentes combinaisons et associations ensemble (Pedišić et al., 2017; Rosenberger et al., 2019). En effet, plusieurs pays comme l'Australie, la Nouvelle-Zélande et le Canada ont également publié une série de documents et de recommandations sous cette conceptualisation visant à améliorer et à promouvoir la santé des enfants et des adolescents (Australian Department of Health, 2019; New Zealand Ministry of Health,

2017; Tremblay et al., 2016).

Depuis l'élaboration en 2016, des premières recommandations sur les comportements de mouvement sur 24 heures, de nombreux chercheurs ont mené des études transversales pour mesurer l'observance chez les enfants et les adolescents dans différents pays et régions du monde. En fait, plusieurs études récentes ont révélé que moins de 10% des enfants et adolescents dans le monde respectaient ces recommandations pour les trois comportements de mouvement (Rollo et al., 2020), et que plus de 20% n'en respectaient aucune (Tapia-Serrano et al., 2022). Il est donc essentiel de comprendre comment ces comportements se développent et évoluent en fonction de l'âge afin d'identifier les périodes et les contextes clés dans lesquels intervenir pour les améliorer. Par exemple, il semble que les enfants passent plus de temps dans des activités sédentaires et réduisent leur activité physique et leur temps de sommeil à l'approche de l'adolescence qu'au début de l'école primaire (Pearson et al., 2017). Cependant, la plupart des preuves concernant les comportements de mouvement sur 24 heures sont basées sur des études transversales et des revues systématiques de celles-ci. Par conséquent, d'autres types de recherches tels que des études longitudinales et d'intervention, sont également nécessaires pour compléter les preuves scientifiques sur les comportements de mouvement sur 24 heures pendant l'enfance et l'adolescence (Sampasa-Kanyinga et al., 2020; Tapia-Serrano et al., 2022).



## **1.2. Introduction in Spanish**

La presente tesis doctoral se ha realizado en formato de cotutela entre dos países pertenecientes a la Unión Europea, concretamente Francia y España. Este tipo de tesis doctoral busca fomentar que el doctorando adquiera un bagaje internacional y lingüístico, además de las competencias asociadas a la investigación y docencia universitaria propias de la formación predoctoral. Del mismo modo, este tipo de formato de tesis busca fomentar la cooperación transfronteriza entre los grupos de investigación de ambos países. Por ello, el presente documento aparece redactado en tres idiomas diferentes. Se utiliza el francés y el español correspondientes a los dos países de la cotutela y el inglés, correspondiente al idioma científico universal.

La realización de esta tesis doctoral se ha llevado a cabo siguiendo las directrices y la legislación francesa debido a la obtención del contrato de doctorado en la Université de Pau et des Pays de l'Adour. Esta normativa establece que la tesis doctoral debe llevarse a cabo en un período máximo de tres años si el doctorando tiene un contrato doctoral, comenzando en este caso en enero de 2020 y finalizando en diciembre de 2022. Además, al realizar la tesis doctoral en formato de cotutela, la distribución temporal ha sido de 24 meses en la Universidad de Pau (Francia), y de 9 meses en la Universidad de Zaragoza (España). Finalmente, con el objetivo de mejorar la formación doctoral y obtener el título de doctorado europeo, se realizó una estancia de investigación de 3 meses en la Universidad de Limerick (Irlanda).

Antes de introducir el tema principal sobre el que trata esta tesis doctoral, se ha considerado necesario contextualizar las circunstancias en las que se ha realizado la misma, concretamente en cuanto a la pandemia y los confinamientos debido al virus COVID-19. El comienzo de la pandemia, así como de los sucesivos confinamientos en Francia y en España desde marzo de 2020, obligó tanto al presente doctorando como a los directores y colaboradores que han participado en esta tesis doctoral a tener que reestructurarla. Es preciso destacar que antes de marzo de 2020 había una estructura y estudios a realizar completamente diferentes a los llevados a cabo finalmente.

En este sentido, debido a las características de la tesis en cotutela, se habían planificado tanto un estudio transversal transfronterizo (es decir, con datos de España y

Francia), como una intervención escolar en un colegio de educación primaria francés y otro español. No obstante, debido a la incertidumbre de la pandemia y a los sucesivos confinamientos durante 2020 y principios de 2021, se decidió reestructurar la presente tesis doctoral. En primer lugar, se abogó por realizar un estudio de revisión sistemática y metaanálisis debido a que no era necesario realizar tomas de datos en centros escolares. En segundo lugar, se decidió analizar una intervención escolar en un colegio de España, ya que no fue posible acceder a los colegios franceses. Una vez contextualizada la situación en la que se llevaron a cabo los estudios recogidos en este documento, se procede a continuación a describir la temática.

El tema principal de esta tesis doctoral se articula en torno al estudio y análisis de los comportamientos de movimiento de 24 horas en intervenciones escolares. Estos comportamientos de movimiento están integrados por la actividad física, el tiempo sedentario y el sueño. Esta agrupación se justifica debido a que las actividades o movimientos que puede realizar una persona durante las 24 horas del día se dividen únicamente en períodos de sueño, comportamiento sedentario y actividad física a diferentes intensidades (Chaput et al., 2014; Tremblay et al., 2016). Por lo tanto, el tiempo dedicado a un comportamiento (e.g., actividad física), necesariamente desplaza el tiempo dedicado a al menos otro de los dos comportamientos (e.g., comportamiento sedentario), reforzando así la importancia de analizar estos comportamientos de movimiento de forma conjunta (Pedišić et al., 2017). Concretamente, la literatura científica destaca que el tiempo dedicado a cada uno de los comportamientos de movimiento está estrechamente relacionado con el desarrollo físico y mental de una persona, adquiriendo una gran relevancia en la infancia y adolescencia (Carson et al., 2016; Poitras et al., 2016; Rollo et al., 2020).

Debido a la reciente creación del concepto de los comportamientos de movimiento de 24 horas, se han realizado numerosos estudios en el último lustro que han permitido confirmar su relevancia (Chaput et al., 2014; Tremblay et al., 2016). Esto ha fomentado un cambio de paradigma mediante el cual se dejó de considerar a cada comportamiento de movimiento de forma aislada para comenzar a analizar sus diferentes combinaciones y asociaciones de forma conjunta (Pedišić et al., 2017; Rosenberger et al., 2019). De hecho, varios países como Australia, Nueva Zelanda y Canadá también publicaron una serie de documentos y recomendaciones bajo esta conceptualización destinadas a mejorar

y promover la salud en la infancia y adolescencia (Australian Department of Health, 2019; New Zealand Ministry of Health, 2017; Tremblay et al., 2016).

Desde que en 2016 se elaboraron las primeras recomendaciones para los comportamientos de movimiento de 24 horas, numerosos investigadores han realizado estudios transversales para medir su grado de cumplimiento tanto en niños como en adolescentes en diferentes países y regiones de todo el mundo. De hecho, varios estudios recientes revelaron que menos del 10% de los niños y adolescentes a nivel mundial cumplían estas recomendaciones para los tres comportamientos de movimiento (Rollo et al., 2020), y que más de un 20% no cumplía ninguno (Tapia-Serrano et al., 2022). Por lo tanto, parece determinante comprender cómo se desarrollan y modifican estos comportamientos en función de la edad, para así identificar los períodos y entornos clave en los que intervenir para su mejora. Por ejemplo, parece existir cierta evidencia en cuanto a que los niños pasan más tiempo realizando actividades sedentarias y reducen su actividad física y tiempo de sueño cuanto más se acercan a la adolescencia que en las primeras etapas de educación primaria (Pearson et al., 2017). No obstante, la mayor parte de la evidencia sobre los comportamientos de movimiento de 24 horas está fundamentada en estudios transversales y revisiones sistemáticas sobre éstos. Por lo tanto, es necesario que también se realicen otro tipo de investigaciones y diseños como pueden ser los estudios longitudinales y de intervención, que permitan complementar la evidencia científica sobre los comportamientos de movimiento de 24 horas en la infancia y adolescencia (Sampasa-Kanyinga et al., 2020; Tapia-Serrano et al., 2022).

De esta forma, pese a ser un investigador en formación durante la realización de la tesis doctoral, el objetivo principal es aportar nuevas evidencias a la literatura científica, dando así respuesta a algunas de las necesidades planteadas en esta breve introducción. A continuación, se enumeran los objetivos y preguntas de investigación planteados en la presente tesis doctoral.

### **1.3.Aims and research questions**

The overall aim of this doctoral thesis was to study the implementation and effectiveness of school-based interventions targeting 24-hour movement behaviours in children. Also, another aim was to describe, register and assess the co-creation process of a school-based intervention to promote 24-hour movement behaviours in children. To

address these two aims, the following research questions were defined:

- Are school-based interventions implementing the 24-hour movement guidelines among children?
- Are school-based interventions effective for promoting movement behaviours among children?
- How effective can a co-created school-based intervention be to promote 24-hour movement behaviours in children?

#### **1.4.Overview of the thesis**

The format of this doctoral thesis is built from the general to the specific content. It starts with the study and research of the literature in our research field (i.e., scoping review and meta-analysis), ending with the design, implementation, and evaluation of a school-based intervention. This thesis is integrated by a compilation of five manuscripts: a first set of three articles includes a systematic review protocol, a scoping review, and a meta-analysis (Chapters 3, 4 and 5), and a second set is made of the intervention study protocol and an original research study (Chapters 6 and 7). Each manuscript is presented as an individual chapter in this thesis. Despite not being able to present all articles published due to the long review process existing in scientific journals, it has been considered appropriate to include the five studies that make up this doctoral thesis in chapter format.

Thus, this document is structured in three different sections, each of them consisting of several chapters. Before starting with the sections and chapters, the overall summary of the doctoral thesis is presented first. This summary is written in three languages, it contextualises the proposal and gives a brief justification of the object of study, the sample and the different objectives of the studies that make up the doctoral thesis. At the end of the summary, it can be found the results and the main conclusions drawn from the five studies.

The first section refers to the introduction and presentation of the doctoral thesis, as well as the main objectives and research questions of each one of the studies. At the end of this first section is described the theoretical framework where the state of the literature and the gaps detected prior to the completion of this doctoral thesis are explained in detail.

The second section corresponds to the central part of the doctoral thesis and presents five chapters corresponding to the five studies carried out in article format. In this section it should be noted that the five studies presented are submitted to different scientific journals. Two of the five studies have already been published, two are at a stage of revision and the last one has not been yet adapted to a journal format. The structure of all the studies that make up the doctoral thesis is a theoretical introduction, in which the main contributions to the literature, the state of the art of the study and the objectives are highlighted. This is followed by a description of the method, which integrates the study sample, the type of design, the participants, the instruments, and the statistical analyses used. Finally, it includes the results, discussion of those results with the existing literature, main limitations, prospective research and conclusions of the research carried out.

The third and last section corresponds to the final part of the thesis, which contains a chapter that includes a description of the main findings, a detailed general discussion of the results presented in the different studies, as well as a section with the limitations and strengths of the doctoral thesis as a whole. The second and last chapter of this section contains the research prospects for future projects that wish to further explore the results presented in this document, as well as the most relevant conclusions of the research.

Finally, the last two sections include the bibliographical references used in this document, as well as the annexes and the ethical regulations needed to conduct the different studies of this doctoral thesis.

## **Chapter 2. Theoretical framework**

Chapter 1 provided the introduction and rationale for the research undertaken as part of this thesis. This chapter aims to provide an in-depth review of the literature about health behaviours, 24-hour movement behaviours and the school setting. A review of the literature describing the prevalence of movement behaviours and different school-based interventions is also provided. Finally, the last section of chapter 2 outlines the literature gaps that need to be addressed and will be addressed in this thesis.

### **2.1. Conceptualization of health behaviours.**

As previously explained, this thesis is focused on the study of 24-hour movement behaviours. However, before going deeper with this concept, it is important to clarify that 24-hour movement behaviours belong to time-use movement behaviours and health behaviours, so it is provided a wider description of both terms in the following paragraphs.

#### **2.1.1. What are health behaviours?**

The first wave of interest in health behaviours and how to correctly promote them started in the 1950s, when some community studies investigated the link between behavioural risks of mortality and illness rates (Armstrong, 2009). Nowadays, health behaviours are a simple term but a complex concept which refers to actions that a person engages intentionally or unintentionally that affect their health either positively or negatively (Short & Mollborn, 2015). Thus, health behaviours are both leading to an improved health (e.g., being physically active or sleep well) and/or to an increased risk of disease (e.g., alcohol intake, drug use or smoking). Some authors coincide to classify them as healthy and unhealthy behaviours instead of only using the term health behaviours (Kohl et al., 2012; Patterson et al., 2018; Soriano et al., 2018). Furthermore, they are usually grouped as individual level behaviours, but they can be analysed even for groups and big populations. Moreover, health behaviours can also vary over the lifespan, across different settings, and over time (Short & Mollborn, 2015).

Initially, health behaviours were studied from a biomedical approach, but this perspective was only focused on the improvement of the outcome and did not consider

some other aspects like personal engagement, limitations and adherence to the behaviour acquired (Armstrong, 2009; Cockerham, 2005). Therefore, a sociological approach emerged in the 1970s decade emphasising the need to examine health behaviours regarding the social environment and the context (Short & Mollborn, 2015). Currently, the areas of health sciences and social psychology are the most important in the study of health behaviours (Conner & Norman, 2017).

In the early 2000s, some authors created the concept of “healthy lifestyle” as another remarkable improvement in the health research field (Armstrong, 2009; Cockerham, 2005). Then, a healthy lifestyle approach allowed to encompass more than one behaviour, rather than just focusing on improving a single health behaviour (Short & Mollborn, 2015). Furthermore, it was the start of research on several health behaviours in the same study, as well as their associations, which would also inspire some other concepts like time-use behaviours or movement behaviours in the 2010s decade. Nowadays, several studies and interventions have been carried out to research about the combination of different healthy and unhealthy behaviours. However, a narrative review showed that the most studied behaviours in the health sciences area (i.e., sports sciences, clinical health, medicine, etc.), were PA, healthy eating, alcohol consumption and smoking (Conner & Norman, 2017).

After this brief introduction about the health behaviours meaning, their origin and their different types, the next parts will describe in depth the main topic of this thesis.

#### **2.2.24-Hour movement behaviours**

A detailed conceptualisation and definition about time-use movement behaviours, 24-hour movement behaviours, their background, guidelines and perspective are provided in the following paragraphs.

##### **2.2.1. Time-use movement behaviours**

Each moment of our day is spent in one of the three following behaviours, PA, SB, and sleep, being mutually exclusive, and having different energy expenditures from each other (Pedišić, 2014; Pedišić et al., 2017). For example, PA is associated with >1.5 metabolic equivalents (METs) of energy expenditure, SB with <1.5 METs and sleep with ~0.9 METs (Pedišić, 2014). These behaviours are also linked to the daily biological clock

(i.e., the circadian cycle), that helps to align the wake-sleep and sleep-wake cycles with the solar cycle (Falck et al., 2021; Pedišić et al., 2017). Furthermore, time-use behaviours can be organised in two different types of behaviour considering circadian cycle. These are as follows: sleep-based behaviour and wake-based behaviour (Falck et al., 2021). In this regard, sleep belongs to sleep-based behaviour and PA and SB to wake-based behaviour.

There is not a clear consensus in the literature on how to correctly define PA, SB and sleep, with four different frameworks used to describe them. First, there is the previously described time-use movement behaviours concept (Pedišić, 2014; Pedišić et al., 2017). Second, “physical behaviours” is another term used by some researchers to describe the behaviour of a person in terms of body postures, movements, and daily activities (Busmann & van den Berg-Emons, 2013). Third, the concept “24-hour activity cycle” encompasses light physical activity (LPA), moderate to vigorous physical activity (MVPA), SB and sleep (Rosenberger et al., 2019). Finally, the last term used to refer to these three behaviours is the “24-hour movement behaviours” summarised and broadly explained in the Canadian 24-hour Movement Guidelines (Tremblay et al., 2016).

Although several definitions and concepts emerged to refer to these behaviours, this doctoral thesis is mainly focused on the study and analysis of 24-hour movement behaviours. The reason is this concept has been the most extended around the world and the most used by researchers in terms of children’s health promotion, thus being the most studied by far. Also, this concept has provided numerous studies in the last decade and several guidelines have been published in different countries and world associations, allowing for deeper and sound research about PA, SB and sleep.

### 2.2.2. Definition of 24-hour movement behaviours

As explained above, the co-dependence and benefits between PA, SB, and sleep, added to the finite nature of a day (i.e., 24 hours), make it necessary to analyse these behaviours together rather than individually (Chaput et al., 2017; Dumuid et al., 2017). Furthermore, 24-hour movement behaviours are more than three behaviours, as two of them are an integration of others. Physical activity is subdivided by its intensity in MVPA and LPA, and SB is distinguished by sitting time versus standing time and screen-time versus non-screen time (Tremblay et al., 2016). Screen time refers to time spent in front



of a screen (i.e., television, computer, tablet, mobile phone, etc.), and can be classified as either occupational or leisure-time. Thus, 24-hour movement behaviours can be defined as physical behaviours occurring over a daily time frame across a movement intensity continuum (Chaput et al., 2014).

### 2.2.3. 24-Hour Movement Guidelines

Since the development of 24-hours movement behaviours, numerous studies have been conducted and, consequently, general guidelines have been created. Some countries such as Australia, New Zealand and Canada have also published a guideline under this concept. They aimed at improving and promoting children and adolescent health (Australian Department of Health, 2019; New Zealand Ministry of Health, 2017; Tremblay et al., 2016). Furthermore, some other guidelines have been published recently for pre-schoolers aged 0-4 years (Tremblay, Chaput, et al., 2017), adults aged 18-64 years and even older adults aged 65 or more years (Ross et al., 2020).

According to the recommendations provided in Figure 1 by the 24-hour movement guidelines (Tremblay et al., 2016), children and adolescents aged 5–17 years should accumulate >60 min of daily MVPA, spend several hours in a day doing LPA, sleep 9 to 11 hours per night for children aged 5 to 12 years and 8 to 10 hours for adolescents aged 12-17 years, and dedicate less than 2 hours each day to leisure sedentary screen-time behaviours. Although SB is not only integrated by screen-time and PA is not only made up of MVPA, there are not specific recommendations for sitting time and LPA (Tremblay et al., 2016). In this regard, the authors point out that it is not possible to specify recommendations for all behaviours that made the whole day as the ranges of some recommendations are not completely closed (e.g., 9-11 hours of sleep duration). Nevertheless, Tremblay et al., (2016) highlighted the importance of limiting sitting time, as well as the importance of doing light activity several hours a day.

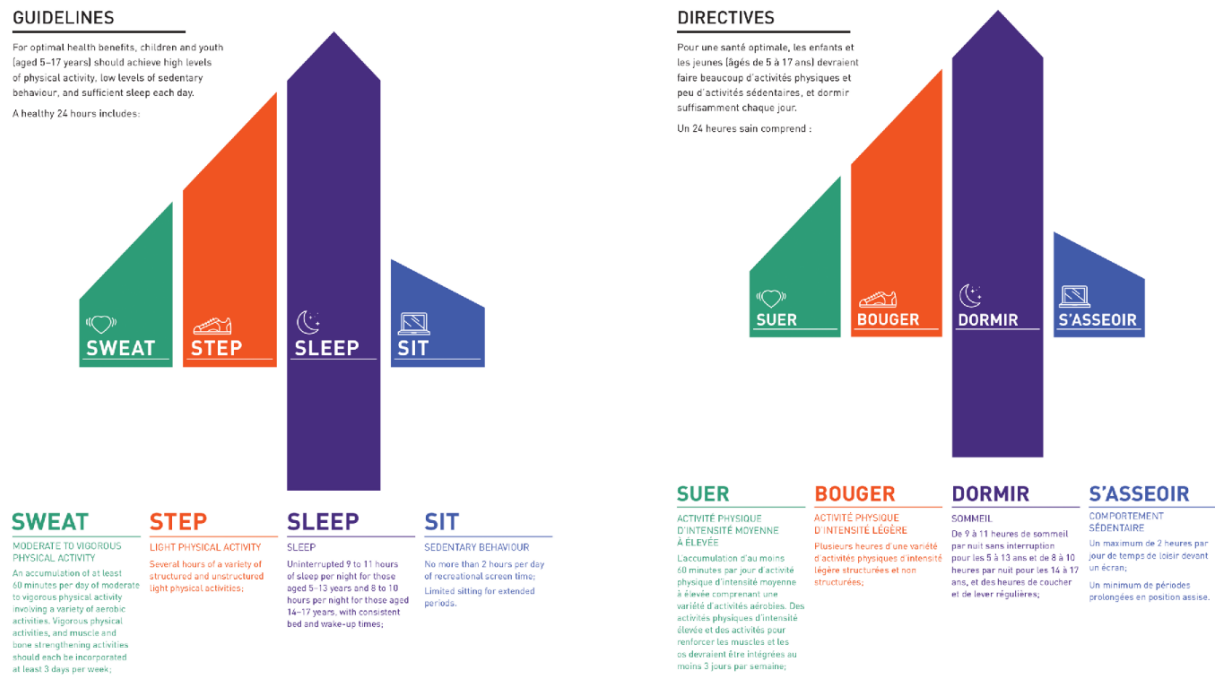


Figure 1. 24-hour movement guidelines (extracted from Tremblay et al., 2016).

### 2.3. Methods and measurement tools to assess movement behaviours

PA is an important health behaviour, but it only accounts for a small part of daily time, while SB and sleep make up the majority of the 24-hour period. Then, the study of these behaviours through this 24-hour approach presents an added difficulty in that it can require both objective and subjective assessments (e.g., using accelerometers, questionnaires, mixed methods, etc.). Therefore, the following paragraphs discuss different methods for assessing 24-hour movement behaviours in school-aged children.

#### 2.3.1. Physical activity

This movement behaviour is defined as a wake-based behaviour of any bodily movement produced by skeletal muscles which results in energy expenditure over the metabolic rate (Caspersen et al., 1985; Chaput et al., 2020). In general terms, physical activity can be defined by its frequency (i.e., days, week, etc), duration (i.e., time), the energy expenditure or intensity, and the type of PA performed (i.e., endurance, strength, etc.). Nevertheless, in terms of quantitative assessment, its intensity can only be measured by light, moderate and vigorous PA (DiPietro et al., 2020; Tassitano et al., 2020).

Then, PA assessment can be classified as objective or subjective measures. The

first one (i.e., objective measure), mainly uses devices like accelerometers, pedometers and heart rate monitors. Also, PA can be measured by direct or indirect calorimetry, doubly labelled water and multimodal sensors, but these last instruments are not considered when assessing children in the school setting. The second one (i.e., subjective measure), assesses a subjective experience of PA using questionnaires, logs, diaries or surveys (Falck et al., 2021). There are some advantages and limitations for both types of measure. For example, subjective measures are inexpensive and easier to use than objective, but they have significant biases like over or underestimation of the behaviours, as well as a recall bias (Sallis & Saelens, 2000). Otherwise, the objective measure is considered more accurate and reliable in terms of recall bias (Ekelund et al., 2020; Tassitano et al., 2020). Nevertheless, they are limited by their price, by non-wear time (i.e., the person forgets to wear the device), and by some activities like cycling or swimming where it is not possible, or at least it is technically more difficult to use objective measures (Lee & Shiroma, 2014).

### 2.3.2. Sedentary behaviour

SB is defined as any waking behaviour characterised by a low energy expenditure (i.e.,  $\leq 1.5$  METs), such as sitting, reclining or lying posture (Pate et al., 2008; Tremblay et al., 2017). This movement behaviour may be classified by its frequency, duration, and type (i.e., sitting, screen-time), but it cannot be classified by its intensity since all types of SB are characterised by a low energy expenditure (Tremblay et al., 2017). Furthermore, some occupational activities doing sitting time or screen-time can improve cognitive health (Falck et al., 2021). Then, SB is not the opposite of PA, it is an independent behaviour with its own characteristics and distinctive effects on health (Chaput et al., 2020; Falck et al., 2021). Nevertheless, there is not consensus about that in the literature, and the discussion remains opened as some authors suggest SB is the opposite of PA (van der Ploeg & Hillsdon, 2017).

In terms of SB assessment, there are some differences with previous types of PA measurements. In this regard, some devices used to objectively measure PA (i.e., pedometers and heart rate monitors), are useless to calculate SB. However, accelerometer devices and subjective measures (e.g., questionnaires), are effective and commonly used to assess SB in the school setting (Chaput et al., 2020; Tassitano et al., 2020).

### 2.3.3. Sleep behaviour

Human sleep behaviour is defined as a recurring, reversible state of perceptual disengagement from the environment, which is generally accompanied by horizontal posture, behavioural quiescence and closed eyes (Carskadon & Dement, 2011). Many aspects like duration, efficiency, timing, alertness and satisfaction influence sleep behaviour, being each of them expressed in either positive or negative terms (e.g., insufficient and sufficient sleep duration, efficient and inefficient sleep, etc.). Thus, it is a multi-dimensional behaviour that can be measured across multiple perspectives of analysis (Falck et al., 2021). Nevertheless, as this doctoral thesis is focused on schoolchildren movement behaviours, only sleep assessments commonly used and affordable in the school setting are detailed.

With respect to assessment, as previous movement behaviours, objective and subjective methods can be used to assess sleep behaviour and it is important to point out that due to its complexity there is no best measure for assessing sleep. Regarding objective measure, a wrist-worn accelerometer is a valid and popular device for measuring sleep, especially since it can be used to record several days of sleep under normal conditions (Falck et al., 2021). In terms of subjective measures, they are easier to implement, but they are not able to detect important changes in sleep quality (Falck et al., 2021). The most used subjective measures are questionnaires and diaries, being questionnaires the ideal in educational settings.

### 2.3.4. 24-hour movement behaviours

The precise measurement of 24-hour movement behaviours presents several challenges for researchers when considering its assessment. Furthermore, to measure these behaviours continuously presents an important level of complexity (Falck et al., 2021). However, the literature suggests that the most common and reliable assessment to measure 24-hour movement behaviours continuously is using accelerometer devices, as they allow to collect objective data from several behaviours and over extended periods of time (Duncan et al., 2018; Falck et al., 2021; Migueles et al., 2017). In fact, Tudor-Locke et al., (2015) published a protocol to improve the reliability and validity of 24-hour assessment by increasing wear time compliance (i.e., participants were asked to not remove their accelerometers at night). Nevertheless, the accelerometer assessment is not free of weaknesses. In this regard, some researchers pointed out that there is not a gold

standard able to test which analytical approach is the best for a given research question (Dumuid et al., 2017; Falck et al., 2021; Migueles et al., 2022). Also, other limitations are the discrepancies between researchers about the accelerometer placement, data collection and analysis criteria (i.e., wrist or hip placement, wear-time, cut-points, epoch length, etc.), which can influence the outcome, validity, and reproducibility of the studies (Burchartz et al., 2020; Migueles et al., 2017). Thus, current evidence highlights the need for more harmonised device-based data worldwide for a more fine-grained picture of overall adherence to the 24-Hour Movement Guidelines (Migueles et al., 2022; Tapia-Serrano et al., 2022).

Then, there are some movement behaviours without a specific time-use recommendation like sedentary time (ST) and LPA, while leisure screen-time cannot be measured with accelerometer devices (Rollo et al., 2020; Tremblay et al., 2016). In this regard, sleep assessment has also the limitation of wearing an accelerometer device during bedtime, thereby usually measured subjectively in several settings different from clinical research (Falck et al., 2021; Rollo et al., 2020). Objective and subjective assessments can provide complementary data about each movement behaviour, and the benefit of using different measures (e.g., objective and subjective) is dependent upon the research design and the question of interest (Falck et al., 2021). For example, measuring screen-time and sleep by questionnaire may be practical when the sample size is extremely large (e.g., the school setting), or when available resources are limited (Falck et al., 2021; Rollo et al., 2020). Although the use of objective and subjective assessment of movement behaviours seems valid, it is impossible to measure all of them with only one type of measure. Thus, the mixed assessment of 24-hour movement behaviours seems to be the best option to use in the school setting.

## **2.4.Prevalence of movement behaviours in school-aged children**

This section highlights the prevalence and compliance of each movement behaviours separately and together in children. Moreover, the prevalence of movement behaviours for Spanish and French children are described in detail.

### **2.4.1. Prevalence of physical activity**

The prevalence of PA worldwide is usually measured according to the World Health Organization (WHO) guidelines. This guideline is the same as the one adopted by

the 24-hour movement guidelines (Tremblay et al., 2016), and was recently updated and described in depth by some researchers (Bull et al., 2020). This guideline recommends children and adolescents to accumulate at least 60 minutes of daily MVPA, as well as to do intense activities that strengthen muscle and bones at least 3 days a week (Bull et al., 2020).

Then, the most recent WHO study about global trends in PA, which was conducted in 146 countries, including 1.6 million students aged 10–17 years, found that 81% of them were not physically active (i.e., performed less than 60 minutes of MVPA per day), being 77.6% of boys, and of 84.7% girls (Guthold et al., 2020). Some other findings in this study showed inconclusive results according to country income group, with 27 countries reporting a prevalence of insufficient PA for 90% or more in girls, whereas this was the case for only two countries regarding boys (Guthold et al., 2020). In terms of specific countries, this study found that Spain has reduced its youth's physical inactivity data, being 75.4% in 2001 and 71.8% in 2016, specially in boys (going from 74.4% to 69.8%) but also in girls' samples (84.1% to 83.8%). Otherwise, French results were not as promising as the Spanish ones showing an increase of physical inactivity in its youths, being 86.2% in 2001, and 87% in 2016. In this case, French boys' data showed more increase (going from 81.1% to 82.4%), than girls (91.4% to 91.8%). Anyway, it is still alarming such a high percentage of physical inactivity in most countries, but especially in girls' data (Bull et al., 2020).

The last "Global Matrix 3.0 Physical Activity Report Card" conducted in 49 countries from all continents among children and adolescents aged 5-17 years (Aubert et al., 2018), found that the degree of PA compliance was the measured behaviour with the lowest score, having a median "low/poor" D level (i.e., 27-33%). Similar results were found individually in the last "Report Card on Physical Activity for Children and Youth" in Spain and France, which highlighted the low proportion of youths who reached the PA recommendations, especially girls (Aubert et al., 2018; Roman-Viñas et al., 2016). Furthermore, another French study showed during 2015 that only 28.1% of boys and 18.1% of girls aged 6-17 years old reached the PA recommendations (Santé Publique France, 2017). The International Children's Accelerometry Database (ICAD) conducted in 10 countries, with a sample size of 27,637 children aged 2-17 years, highlighted that only 9% of boys and 2% of girls aged 5-17 years met the PA recommendations, being

this percentage higher in boys than girls in all included countries (Cooper et al., 2015). In terms of European studies, a systematic review found that less than 50% of European children and adolescents met the PA recommendations (Van Hecke et al. 2016), regardless of the measurement method used (i.e., accelerometer or subjective measurement). The Health Behaviour in School-aged Children (HBSC) study found only 19% of children and adolescents aged 11-15 years-old achieved the recommended 60 minutes of daily MVPA (Inchley et al., 2020). In addition, MVPA levels have declined around a third since the last survey in 2014 at all ages and in almost all countries, with being boys more likely than girls to be physically active. This study also points out that PA engagement is reducing from childhood to adolescence (Inchley et al., 2020). Spain and France data of this study shows that 34% of Spanish and 17% of French boys, as well as 23% of Spanish and 9% of French girls aged 11 years-old met the PA guidelines (Inchley et al., 2020; Moreno et al., 2019). Moreover, a cross-country comparison between French and Spanish adolescents found that French adolescents (especially French girls), are also less physically active than Spanish (Aibar et al., 2013, 2014).

Finally, LPA is a variable understudied in the PA research field. It may be due to the lack of a specific guidelines, but from a public health perspective LPA is important because more people can do this type of PA compared to MVPA (DiPietro et al., 2020). Therefore, all previous reports and research studies suggested a great level of concern in terms of children's PA worldwide. They coincide to detail that 70% to 85% of children and adolescents do not achieve MVPA recommendations, highlighting even lower levels in girls. The comparison of French and Spanish children pointed out that French children (especially French girls), are also less physically active than Spanish.

#### 2.4.2. Prevalence of sedentary behaviour

SB is determinant when examining its contribution to the health of children and adolescents (Chaput et al., 2020). The most common SB among children include screen-time (e.g., smartphone use, computer use, TV viewing, etc.), and sitting time (i.e., reading or studying), being excessive SB widespread among children and adolescents around the world (Bull et al., 2020; Chaput et al., 2020). Nevertheless, despite specifying a quantitative threshold on the amount of ST has been strongly considered, there was not enough evidence to determine a guideline in terms of frequency and duration of sedentary breaks (Bull et al., 2020). Therefore, the main recommendation provided by the WHO is

to reduce as much as possible the total time doing sedentary activities (Bull et al., 2020; WHO, 2020). Then, most studies of our research field consider the 24-hour movement guidelines (Tremblay et al., 2016), to report and reduce leisure screen-time (i.e., <2 hours/day).

In this regard, the last report “Global Matrix 3.0” of SB conducted in 49 countries representative from all continents found that the degree of recreational screen-time compliance (i.e., < 2 hours/day), had a median D+ level (i.e., 34-39%). In France and Spain, this study also indicated the proportion of children and adolescents who reached the recommendations was very low (Aubert et al., 2018). Some years ago the “Identification and prevention of Dietary and lifestyle induced health Effects In Children and infantS (IDEFICS)” study conducted in eight European countries with a sample size of 15,330 children aged 2-10 years, showed that the proportion of children who do not meet the recommendations for screen time was 29% (33% of males and 25% of females), being this fact more evident during weekend (64%) days (Santaliestra-Pasías et al., 2013).

Also, the “Anthropometry, Intake, and Energy Balance in Spain (ANIBES)” study concluded that a high percentage (48.4%) of children and adolescents in Spain do not meet the recommendations regarding recreational screen-time (Mielgo-Ayuso et al., 2017), which is especially high during weekends (84.0%). Furthermore, a French research study about sedentary outcomes called “Étude de santé sur environnement, la biosurveillance, l'activité physique et la nutrition (ESTEBAN)”, confirmed that almost half of French children (45%) aged 6-10 years reported to spend 3 hours or more in front of a screen every day in 2015, and this proportion reached 70% of children and adolescents aged 11-14 years (Santé Publique France, 2017). Also, a cross-country study which compared French and Spanish screen-time showed no differences between Spanish and French adolescents (Aibar Solana et al., 2015). Likewise, another study carried out in Spain showed that the mobile phone is already the most used screen technology, ahead of video games, computer-use, or television (Adelantado-Renau et al., 2019).

From a longitudinal perspective, a research study highlighted that SB (i.e., referring to ST and screen-time), takes up over 50% of the waking day for 7-year-old children and 75% for 15-year-old adolescents (Janssen et al., 2016). Furthermore, a review of longitudinal studies coincided with the previous study and found an increase in



ST, being more pronounced from the school entry stage (i.e., age 6) to adolescence (Reilly, 2016). Indeed, a recent study called “Global Prevalence of Meeting Screen Time Guidelines Among Children 5 Years and Younger” with a sample of 63 studies and 89,163 children concluded that the mean prevalence of meeting the recreational screen-time guideline for children aged 2 to 5 years (i.e., 1 hour per day), was 35.6% (McArthur et al., 2022). Therefore, the study and vigilance of SB prevalence seems crucial because of emerging evidence on the negative health effects and the potential public health burden are associated with high levels of SB (Chaput et al., 2020; Gibbs et al., 2015).

In terms of ST, little has been researched in terms of prevalence when comparing with recreational screen-time. Nevertheless, a recent meta-analysis provided ST data of 187 studies and 74,870 youths (i.e., aged 3 to 18 years). This study reported their ST analysis only attending specific settings (e.g., ST in the school setting, ST in the after-school programs, etc.), but they did not detail daily ST (Tassitano et al., 2020). A cross-country study which compared French and Spanish ST in adolescents found similar results between both samples, being Spanish adolescents (and specially girls) little more sedentary than French (Aibar et al., 2015).

Therefore, the described studies showed that recreational screen time in children is far higher than the recommended 2 hours per day, although the prevalence of ST is less documented in our research field. Then, it is possible that the lack of a specific ST guideline makes it difficult to be grouped in bigger studies of prevalence. Nevertheless, some general considerations have been recently updated for future research about ST (DiPietro et al., 2020). Moreover, some new international school-related SB recommendations have been recently created for children and adolescents (Saunders et al., 2022). These recommendations mainly refer to increase sedentary breaks during the school time as well as incorporating movement activities and active breaks between daily schedule classes as much as possible. Finally, the literature has shown that total recreational screen time seems to be a little higher in boys than in girls, and it seems to be even higher on weekend days than on weekdays. ST and especially recreational screen-time seems to be increased while children grow from childhood to adolescence, and similar results have been found between Spanish and French studies.

### 2.4.3. Prevalence of sleep

Nowadays children sleep less and less, with only 60% of them meeting the sleep recommendations worldwide (Matricciani et al., 2012). According to this systematic review of 690,747 youths aged 5 to 18 years, children sleep almost one hour less than 100 years ago, especially boys and during school days (Matricciani et al., 2012). Regarding school-aged children, another study also pointed out that sleep time has been decreasing compared with a few decades ago (Keyes et al., 2015), being a negative outcome because sleep has an important correlation with other health behaviours (e.g., well-being, health nutrition, PA, etc.) and several diseases (e.g., obesity and mental issues) especially in children (Chaput et al., 2016; Matricciani et al., 2012). The recommendations for sleep time are different for pre-schoolers aged 3-5 years-old (10-13 hours), children aged 6-12 years-old (9-11 hours), adolescents aged 13-17 years-old (8-10 hours), adults aged 18-64 years-old (7-9 hours), and older adults (7-8 hours) aged 65 or more years-old (Hirshkowitz et al., 2015; Tremblay et al., 2016, 2017). Then, nocturnal sleep time seems to differ substantially between European countries, showing shorter sleep duration in Southern Europe than in other European regions, thus being strongly associated with a higher probability of suffering from overweight in school children (Hense et al., 2011). This is even more relevant because recent findings concluded longer nocturnal sleep duration and lower levels of sleep disturbances were associated with higher psychosocial well-being in European children (Thumann et al., 2019).

The HBSC study found that a mean of 24% of children and adolescents aged 11-15 years reported difficulties and problems to fall asleep, being this percentage higher in girls (28%), than boys (20%). More specifically, 41% of French girls and 38% of boys, and 12% of Spanish girls and boys aged 11 years reported sleep problems (Inchley et al., 2020). A meta-analysis about sleep prevalence integrated 79 studies in 17 countries and 7,367 youths aged 3 to 18 years highlighted that children mean sleep duration was 9.68 hours in 3–5 years old, 8.98 hours in 6–8 years old, 8.85 hours in 9–11 years old, and 8.05 hours in 12–14 years old (Galland et al., 2018). Therefore, children aged 6-11 years old mainly achieved sleep recommendations (i.e., sleep at least 9 hours for children aged 6-12 years). However, children's daily sleep time was clearly decreasing over the years, becoming a health problem (Galland et al., 2018). Furthermore, the authors pointed out that it was not possible to determine gender differences in sleep duration as most studies did not report different data for boys and girls (Galland et al., 2018). Similarly, a

longitudinal study conducted in Spain between 1987 and 2011 on 24,867 youths aged 2-14 years concluded that only 55% of Spanish children were sleeping enough, thus showing a progressive decrease in sleep duration across different age ranges (de Ruiter et al., 2016). According to the same study, since 1987 to 2011, sleep duration of children aged 2-5 years decreased from 10.67 to 10.27 hours, from 9.85 to 9.51 hours in children aged 6-9 years, and from 9.32 to 8.86 hours in children aged 10-14 years-old (de Ruiter et al., 2016).

A brief report about the prevalence of sleep in Spanish children concluded that 50.2% of children aged 11-12 years achieved the sleep guidelines in weekdays, being this percentage higher in boys (Moreno et al., 2019). However, this prevalence seems to increase in weekend days, achieving the recommendation 64.7% of children aged 11-12 years and being this prevalence higher in girls (Moreno et al., 2019). In terms of socioeconomic status (SES), the prevalence of children aged 11-14 years who meet the sleep recommendations on weekdays are 39.8% in families with high SES, 39.1% in medium SES, and 34.4% low SES respectively. Otherwise, there are not differences in prevalence of sleep on weekend days (Moreno et al., 2019). Better results were found in a Spanish study conducted among children aged 10-14 years, as they found that 62.2% of participants met the sleep recommendations (de Ruiter et al., 2016). Nevertheless, another study with Spanish children which measured sleep with accelerometer devices found that less than 18% of the children aged 5-12 years old achieved the sleep guidelines (Ávila-García et al., 2021).

As a conclusion of this section, sleep duration among children seems to have decreased notably in the last decades worldwide. Also, most of the studies described before highlighted that, in average, 30-40% of children do not achieve sleep recommendations for their age range, with a higher percentage of prevalence in boys. Furthermore, the literature supports that children sleep more during weekends, and a higher SES increase the prevalence of meeting the sleep guidelines compared to lower SES. According to Spanish and French studies, the number of studies of both countries is too different to draw sound conclusions or potential differences about sleep prevalence. However, the prevalence levels of sleep for both countries are low. Finally, accelerometer assessed studies seem to indicate less prevalence of the sleep guidelines compared to self-reported studies, thus indicating an important gap in terms of data collection and analysis.

#### 2.4.4. Prevalence of 24-hour movement guidelines.

Evaluating the prevalence of 24-Hour movement behaviours is made possible by examining adherence to the three movement behaviours of the guideline (Tremblay et al., 2016). The analysis of this prevalence is important to determine the distribution of movement behaviours over the 24-hour period. Also, this information can identify which distribution of the composition is more effective and sustainable for targeting in children's interventions (Pedišić et al., 2017). However, due to the recent creation of these guidelines there are not so many studies that collect or synthesise the current evidence for children in different countries (Rollo et al., 2020). Thus, the little evidence available to date as systematic reviews, meta-analysis and longitudinal studies are described in the following paragraphs.

A global study called the “International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)”, researched about the 24-hour compositional data measured with accelerometer devices. This study was integrated by 12 countries from different continents and 5,759 children aged 9-11 years. They found that children spent an average of 9.1 hours/day sleeping, 8.7 hours/day being sedentary, 5.3 hours/day in LPA, 41 minutes/day in moderate-intensity of PA, and 15 minutes/day in vigorous-intensity of PA (Dumuid et al., 2017, 2018). Thus, the data supported the compliance with the sleep and the MVPA guidelines. However, two recent longitudinal studies with smaller sample sizes conducted in Canada (Chemtob et al., 2021), and Finland (Leppänen et al., 2022), showed a low overall adherence to the 24-hour Movement Guidelines. These studies reported low adherence to the three recommendations during both childhood (14.2%) and adolescence (6.1%) periods (Chemtob et al., 2021), and the overall adherence decreased over the 2 years follow-up from 52.5% to 24.9% (Leppänen et al., 2022), suggesting a declining trend.

Regarding bigger studies of prevalence, a systematic review of 51 studies in 20 different countries that included school-aged children and adolescents (i.e., aged 5 to 17 years) found that only a small proportion of children aged 5-12 years (i.e., 4.8%-10.8%), and adolescents aged 13-18 years (i.e., 2.6%-9.7%), met the overall 24-hour Movement Guidelines of all three movement behaviours (Rollo et al., 2020). Furthermore, a recent meta-analysis of 63 studies and 387,437 participants aged 3 to 18 years showed that the overall adherence to 24-hour movement guidelines in youths was 7.12% (Tapia-Serrano

et al., 2022). More specifically, this study highlighted that only 11.26% of pre-schoolers, 10.31% of children and 2.68% of adolescents met the full guidelines (Tapia-Serrano et al., 2022). Then, the overall adherence found in this study was significantly lower in girls (3.75%) than in boys (6.89%). When comparing by age groups, this difference remained between children's girls (6.94%) and boys (11.05%), but there were not differences by sex in pre-schoolers and adolescents' samples (Tapia-Serrano et al., 2022). Also, geographical analyses revealed that overall adherence was 17.20% for Africa, 3.80% for Asia, 9.62% for Europe, 7.88% for North America, 10.87% for Oceania, and 2.93% for South America (Tapia-Serrano et al., 2022), showing low rates all over the world.

Looking at the fulfilment recommendations with other perspective, 19.21% of youths did not meet any of the 24-hour movement guidelines, being 8.81% in pre-schoolers, 15.57% in children, and 28.59% in adolescents respectively (Tapia-Serrano et al., 2022). Overall prevalence was little higher in girls (15.66%) than boys (12.95%), without specific sex differences among pre-schoolers, children, and adolescents. This study also reported full absence of compliance the guidelines of the three 24-hour movement behaviours by geographic area, being 9.99% for Africa, 25.77% for Asia, 13.48% for Europe, 17.70% for North America, 11.06% for Oceania, and 31.72% for South America (Tapia-Serrano et al., 2022), also becoming a problem all around the world.

As a conclusion, most children and especially girls seem to not meet with the 24-Hour Movement Guidelines, being a public health concern. Hence, the actual prevalence of this compliance rate worldwide points out the need for integrating specific strategies regarding sex, age, and geographical area to support children movement behaviours over the time.

## **2.5.The school setting and health promotion**

The literature recognises the importance of some settings and relationships that comprise the immediate social context of children's lives and shows how family, peers and school can provide supportive environments for a healthy development (Kolbe, 2019). Also, childhood is an important phase of rapid growth and development in physical, psychological, and cognitive domains where it becomes very important to make early prevention efforts because health-related behaviours acquired at this age usually

tend to persist into adulthood (Telama et al., 2014). Therefore, the following paragraphs and subsections aim to describe the school setting, the importance of school health promotion and how movement behaviours should be promoted through school-based interventions.

#### 2.5.1. The school setting

The school setting is identified as an ideal setting for introducing lifestyle change and health promotion, it acts as a cross-disciplinary field of study and a fundamental setting that can be used to improve both health and education outcomes (Kolbe, 2019; van Sluijs et al., 2021). In most countries, school is obligatory until adolescence; hence, all children irrespective of their background can be reached, which makes schools a perfect setting to reduce health inequalities (Åvitsland et al., 2020). Then, the school setting is highly relevant in children's development as most of them spend half of their daily waking time there (Hegarty et al., 2016) and schools can reach several target groups other than children, such as school staff, teachers, families and even members of the community (Gugglberger, 2021).

The HBSC study highlighted that school and home are two of the main settings in which children learn. It found that many school-aged children reported that they lack supportive environments, especially as they get older (Inchley et al., 2020). Furthermore, this study revealed that only 28% of youths aged 10-15 years, reported liking school a lot. However, these results have been better in children aged 10-12 years, where 43% of girls and 35% of boys reported liking school a lot (Inchley et al., 2020). It seems that schoolwork pressure increased with age, from 26% of 11-years-old to 44% of 15-years-old students respectively, and this increase was seen in 41 countries for girls and 34 for boys (Inchley et al., 2020). On the other hand, nearly 59% of youths reported high levels of support from other students at school, with boys (62%) being more likely to report higher student support than girls (56%). Also, over half of youths (56%) reported high levels of support from their teachers, this percentage being higher among children (i.e., 72% of 11-years-old reported high support), compared to adolescents (i.e., only 52% by age 13 and 44% by age 15). Specifically, girls at age 11 reported a significantly higher prevalence of teacher support than boys. In contrast, boys were more likely to report higher levels of support from their teachers than girls, at age 13 and 15 years (Inchley et al., 2020). Therefore, compared to adolescents, children reported liking school more, felt

less pressured by school and perceived more support from their teachers. Also, girls tend to like school more than boys but feel more pressured by schoolwork and report lower levels of support from their fellow students (Inchley et al., 2020). Similar results were found in the Spanish HBSC national report (Moreno et al., 2019). However, this last research study highlighted those children belonging to high SES families had better scores in peer-support (66,7%) and teacher support (50%), than low SES (54,7% and 46%) respectively (Moreno et al., 2019).

Despite the shadows of the above data, it seems that there are also lights and the school can still be considered as an ideal setting in which to modify health behaviours through school-based interventions (Bernal et al., 2020; Sallis, 2018), especially targeting at-risk groups (e.g., girls, adolescents and low SES families). In this regard, physical education (PE) sessions (Bernal et al., 2021; Hollis et al., 2017; Sevil-Serrano et al., 2022; Sevil et al., 2019), school recess (Bernal et al., 2021; Reilly et al., 2016; Sevil et al., 2019), interdisciplinary projects (Marttinen et al., 2017; Sevil et al., 2019; Zaragoza et al., 2019), the active travel to school (Corral-Abos et al., 2022; Corral-Abós et al., 2021; Larouche et al., 2018; Villa-González et al., 2018), after-school programs (Mears & Jago, 2016; Tassitano et al., 2020), the tutorial action plan (Corral-Abos et al., 2022; Murillo Pardo et al., 2019; Sevil et al., 2019), teacher training (Abós et al., 2018; C. Bernal et al., 2021; Sevil et al., 2019) and family involvement (Bernal et al., 2021; Corral-Abos et al., 2022; Zaragoza et al., 2019), are some of the components that can be used to promote multiple health-related behaviours among children and adolescents. Thus, school-based interventions which include the combination of previous curricular and non-curricular components, have been considered as one of the most promising strategies to improve children's health behaviours in the school setting (Bernal et al., 2020; Busch et al., 2013; Mura et al., 2015; Sallis, 2018; Sevil et al., 2019).

Moreover, it seems that children and adolescents who enjoy being in school and experience school as a supportive environment are more engaged with the school setting, leading to improved long-term educational outcomes and higher well-being (Chaput et al., 2020; Coppinger et al., 2020; WHO, 2020). Also, the school should try to connect with the spaces of the near environment to facilitate learning and health promotion (Chaput et al., 2020; Saunders et al., 2022). Then, European children aged 9-12 years whose parents perceived a higher presence of recreational facilities in their

neighbourhood, have been found to be more active in these recreational spaces (Aubert et al., 2018; Coppinger et al., 2020). A literature review highlighted that when families engage with schools, children improve their social skills, have less unhealthy behaviours, and higher academic achievement (Kolbe, 2019). Finally, the HBSC study concluded that positive and supportive social connections in family, school and community settings each contribute to better mental and physical health and fewer risk behaviours in children and adolescents worldwide (Aubert et al., 2018; Coppinger et al., 2020).

### 2.5.2. School health promotion

The implementation of school health promotion mainly requires strategic plans, policies and the engagement of local, national, and international organisations (Kolbe, 2019). According to that, this field has received a strong support by the WHO, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Schools for Health in Europe (SHE), which are constantly funding, innovating and researching about health promotion worldwide (Barnekow et al., 1999; Rieckmann et al., 2017; Vilaça et al., 2019; WHO, 2017; WHO, 2018). Moreover, school health promotion aims to improve students' physical and psychological health, but it also aims to develop health education as health literacy among children and adolescents (Kolbe, 2019). In this case, health literacy is known as the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions (Ratzan, 1990). Therefore, to be capable of achieving this goal, health education should be part of the curriculum at all levels of education (Kolbe, 2019; Sallis, 2018).

In terms of improving students' health, promoting healthy lifestyles is essential for contributing sustainable development (Baena-Morales et al., 2021; Rieckmann et al., 2017; WHO, 2017). A healthy life and an improved well-being can only be guaranteed at all ages by promoting health in relation to all Sustainable Development Goals (SDGs) and involving the whole society in the process (Baena-Morales et al., 2021; World Health Organisation (WHO), 2017). There are multiple direct and indirect pathways whereby policies to promote healthy habits will contribute to achieve many of the SDGs of the 2030 Agenda (Baena-Morales et al., 2021; Rieckmann et al., 2017). For example, school health promotion contributes to achieve SDG 3 "Good health and well-being", as well as other objectives, including SDG 4 "Quality education", SDG 5 "Gender equality", SDG



10 “Reduced inequalities”, and SDG 17 “Partnership for the goals”. Also, the “Global Action Plan on Physical Activity (GAPPA) 2018–2030” intends to reduce physical inactivity by 15% in 2030 and described 20 policy recommendations to guide future actions and interventions (WHO, 2018). Nevertheless, the European and North American regions are the most advanced globally in terms of national surveillance, policy development and implementation of PA and its determinants compared with the rest of countries and regions (Breda et al., 2018; Coppinger et al., 2020). Thus, it suggests an important gap and imbalance worldwide in terms of GAPPA 2018–2030, as well as other policies promoted by the WHO or other global organisations.

A recent study found that globally the school-time estimates of MVPA presented 27.8 minutes a day, which are close to the recommendation of 30 minutes of MVPA during school time (Tassitano et al., 2020). Furthermore, the school setting seems to be the most important in terms of promoting daily MVPA for children, nevertheless this does not mean that schools are reaching their potential for promoting PA (Tassitano et al., 2020). According to that issue, the last report “Global Matrix 3.0” conducted in 49 countries representative from all continents (Aubert et al., 2018), found that the degree of school indicators compliance, which is integrated by several specific indicators (e.g., % of schools with active school policies, % of schools where students are taught by a PE specialist, % of schools that offer PA opportunities different from PE, etc.), had a median C level (i.e., 47-53%). Nevertheless, high SES countries had better results than the median C level while low SES countries registered worse results. For example, France scored a B level (67-73%), and Spain a C+ level (54-59%), while South Africa scored a D- level (20-26%). Then, this study found that the quality and quantity of PA opportunities offered by the school are associated with the economic and development status of a given country (Aubert et al., 2018). Therefore, the Global Matrix 3.0 findings suggested that developing interventions or programs targeting schools in low and medium SES countries should be a priority of the international public health agenda (Aubert et al., 2018; Coppinger et al., 2020).

### 2.5.3. School based interventions

The school day is mainly sedentary (i.e., prolonged periods of sitting and screen time), but it can act like a structured environment to provide teachers and administrators an opportunity to influence students’ health behaviours in a positive way (Saunders et al.,

2022). The scientific literature also highlights the school as a privileged environment to implement health promotion interventions (Singh et al., 2017). Therefore, schools have the potential to play a decisive role in health promotion, taking advantage of their organisational, physical and social structures to provide several opportunities to promote healthy environments (Buijs, 2009).

The most frequently reported factor on which the school interventions are based is PE, with most countries considering it as a key component (Coppinger et al., 2020). Then, a European study suggested that whole-school interventions which included multiple components across the whole school day are the most effective for increasing PA levels in the school setting (Coppinger et al., 2020; Ganzar et al., 2019). Furthermore, a literature review conducted in 2018 found that multi-component interventions (i.e., a combination of two or more components like PE, family involvement, etc.) seem to produce at least moderate evidence of effectiveness compared to one component interventions (Kolbe, 2019). Then, another systematic review about school-based interventions found that material and organisational factors were the components most commonly used as well as the most effective (Bernal et al., 2020). In total, 63.6% of studies with one component and 53.3 % multi-component studies reported an increased level of PA in the short term (Bernal et al., 2020). However, multi-component school-based interventions are difficult to evaluate given the complexity of the school setting and the stakeholders (i.e., teachers, students, parents, etc.) involved (Keshavarz et al., 2010; Schneider et al., 2009).

Some research studies have integrated social ecological frameworks to suggest how reciprocal effects of health and education act at individual, community, and social levels regarding policies and environments (Sallis et al., 2006). Meanwhile, others have used similar frameworks to describe how researchers, practitioners, and policy makers might improve such policies and environments (Bandura, 2001; Daly-Smith et al., 2020). One of the earliest frameworks used to provide adequate levels of PA among school-aged children was the socio-ecological framework (Sallis et al., 2006). It held that human behaviour is conditioned by multiple levels of influence (Spence & Lee, 2003). This framework is classified in different levels like intrapersonal (i.e., biological, psychological), interpersonal (i.e., social, cultural), community, physical environment, and public policy levels (Sallis et al., 2006). Moreover, the social-ecological model has

proven to be an appropriate theoretical framework for designing interventions aimed at increasing health behaviours due the ability to generate behavioural changes based on comprehensive approaches and multicomponent interventions (Sallis, 2018). Some reviews also pointed out the importance of other theoretical frameworks such as the Social Cognitive Theory as a commonly used theory to design effective school health interventions (Dobbins et al., 2013; Lambrinou et al., 2020). This theory suggests that motivation and actions are controlled by thought, and for behaviour change to occur, an individual should mainly improve their self-efficacy, which is so very important in child interventions (Bandura, 2001). It must be noted that these theoretical frameworks have been spread among researchers, practitioners, and teachers in the last decades to design and develop school-based interventions.

In this regard, the Health Promoting Schools (HPS) framework supported by the SHE shares common elements with socio-ecological model, and it can provide promising results in terms of children health promotion (Buijs, 2009; Vilaça et al., 2019). This whole-school approach has three main components: (1) health education in the curriculum; (2) changes to the school ethos and physical environment; and (3) involving families and/or communities to support health promotion. Then, some studies remarked HPS can be effective to improve children's health behaviours (e.g., PA, ST and healthy nutrition), however they revealed very low effect sizes (Langford, Bonell, Jones, & Campbell, 2015; Langford, Bonell, Jones, Poulou, et al., 2015). Currently, a growing number of research studies have examined their health program effectiveness (Langford, Bonell, Jones, Poulou, et al., 2015), but few studies described their intervention development process, such as how other stakeholders were involved (McHugh et al., 2020), or how sustainable the interventions were (Herlitz et al., 2020). Yet to date, there is a limited number of children intervention programs which addressed multiple health behaviours attending to multilevel (i.e., individual, social, community and institutional level) and multicomponent (i.e., curricular and non-curricular) approaches (Sallis, 2018). Interventions addressing health promotion among children have been mainly focused on individual-level approaches which often fail to demonstrate large effects. Recent attention has been given to an alternative “whole-school” approach which involves promoting PA and other health behaviours throughout all aspects of the school environment (i.e., individual, organisational and community level) among children and adolescents (Tibbitts et al., 2021). However, the evidence of the school-based interventions seems to be mixed

depending on outcomes and variables analysed (Bernal et al., 2020; Jones et al., 2020; Lambrinou et al., 2020; Love et al., 2019; Sallis, 2018; van Sluijs et al., 2021).

Then, an experience-driven creative consultation between academics and public sector stakeholders led to the creation of the Creating Active Schools (CAS) framework (Daly-Smith et al., 2020). This framework reinforced the need for change at the individual, school environment, and community level, as outlined in the HPS guidelines. This whole-school approach has three main levels: (1) the grand system (i.e., national organisations and policies), which refers to national organisations and policies that drive the educational focus of schools and the training needs of the key stakeholders; (2) the local system, which is composed by the social environment (i.e., it refers the degree to which the stakeholders engage and support each other to provide health behaviours) and the physical environment (e.g., green space, playground, school hall and quality of available resources); and (3) the in-school factors, (e.g., school events, PE classes, school curriculum, active breaks, active commuting, before and after school activities, family and community activities). Therefore, this framework allows to identify the priorities and to modify the existing structures for promoting behavioural change through school-based interventions (Daly-Smith et al., 2020). This is the first framework where all components have been collated and reinforced the need to create systems change through school leadership groups. Nevertheless, due to its recent creation and publication there are not many intervention studies using or implementing it now in our research field.

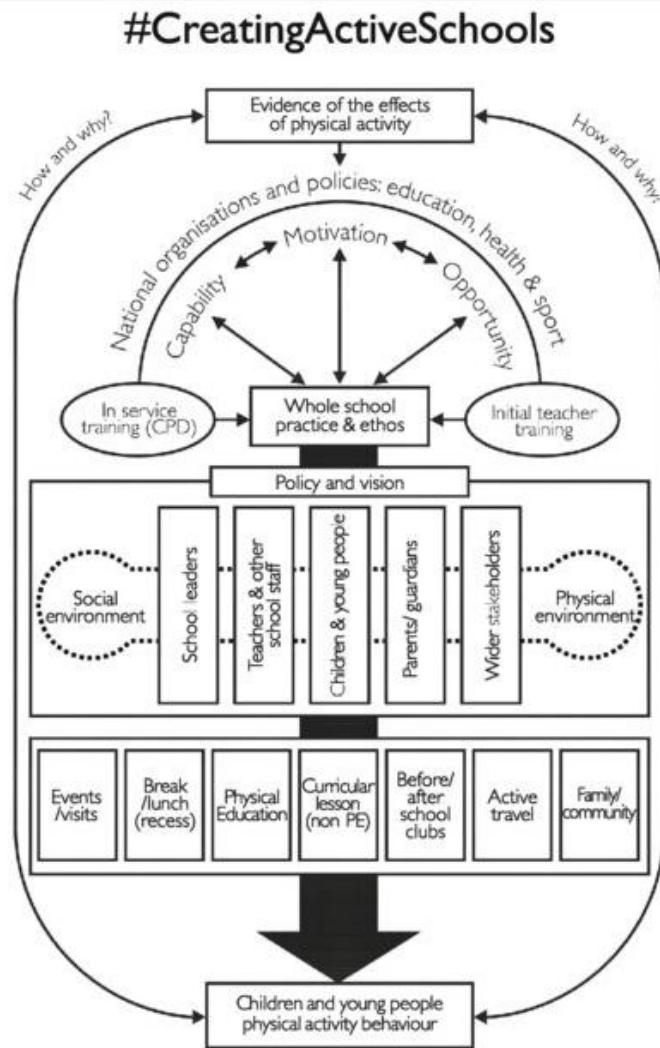


Figure 2. The Creating Active School (CAS) framework (extracted from Daly et al., 2020).

Finally, whilst there are a lot of theoretical frameworks, and different strategies and methods are applied in the literature, it is currently not clear what are the most effective strategies to promote health behaviours in the school setting and further research is therefore necessary (Cassar et al., 2019; Dobbins et al., 2013).

#### 2.5.4. School-based interventions and 24-hour movement behaviours

As previously described, schools are an important setting for promoting healthy behaviours among children, and thereby there is increasing evidence demonstrating the influence of the school setting on their movement behaviour patterns (Bowers & Moyer, 2017; Morton et al., 2016). Moreover, the combination of movement behaviours can impact health in a different way that would not just be explained by the addition of the effect of these individual behaviours studied separately (Chaput et al., 2017; Rollo et al.,

2020). Then, interventions targeting a combination of multiple health behaviours should provide a promising method to improve health outcomes in school-aged children (Prochaska et al., 2008). However, interventions that simultaneously address several health behaviours are usually difficult to implement at schools (Champion et al., 2019), especially due to several barriers and limitations (e.g., lack of teacher's formation in health promotion, a limited school timetable, the school curricula organisation, etc.).

In terms of movement behaviours, school health research has been mainly and exclusively focused on PA or SB (Chaput et al., 2014), with sleep usually treated independently from the other two behaviours (Blunden & Rigney, 2015; Busch et al., 2017). Currently, there are multiple reviews targeting PA (Dobbins et al., 2013; Jones et al., 2013; Love et al., 2019; Love et al., 2017; Metcalf et al., 2012), SB (Altenburg et al., 2016; Biddle et al., 2014; Friedrich et al., 2014; Hegarty et al., 2016; Marsh et al., 2014) and sleep interventions separately (Blunden et al., 2012; S. Blunden & Rigney, 2015; Cassoff et al., 2013; Chung et al., 2017). There are also some reviews targeting children school-based interventions on a combination of movement behaviours (e.g., PA and SB) addressing obesity prevention (Agaronov et al., 2018; Ash et al., 2017; Khambalia et al., 2012; Lambrinou et al., 2020), weight gain prevention (Goldthorpe et al., 2020), and energy-balance (Anselma et al., 2020). While other reviews have been focused on examining the effectiveness of school-based interventions about PA and SB among children (Jones et al., 2020; Lambrinou et al., 2020; Love et al., 2019; Nally et al., 2021).

However, the only two systematic reviews and meta-analysis focused on all 24-hour movement behaviours in children and adolescents only measured the prevalence of meeting the guidelines, they were integrated by cross-sectional studies and both concluded the need for conducting intervention and longitudinal studies about this topic (Rollo et al., 2020; Tapia-Serrano et al., 2022). Then, even though some previous studies targeted two movement behaviour interventions, there is not any review about school-based interventions targeting this whole approach in the literature. Hence, it is difficult to analyse and figure out which is the actual degree of acceptance and implementation of 24-hour movement behaviours, as well as their effectiveness in the school setting.

## **2.6. Research gaps**

Currently, this doctoral thesis has identified several research gaps in the literature that need to be addressed to better understand the school-based interventions targeting 24-hour movement behaviours among school-aged children. The research gaps, objectives and thesis studies are presented together in Table 1.

First, as it was discussed in Section 2.4, the prevalence of reaching PA, SB and sleep recommendations is a concern of paramount importance for children and adolescents, being especially low the prevalence of all 24-hour movement behaviours worldwide. However, there is a lack of information about school-based interventions targeting all 24-hour movement behaviours among children (Rollo et al., 2020; Saunders et al., 2022; Tapia-Serrano et al., 2022).

Second, it is not clear enough if school-based interventions are effective at improving MVPA and reducing ST among children (Dobbins et al., 2013; Jones et al., 2020; Love et al., 2019; Nally et al., 2021). Furthermore, as it was highlighted in section 2.5, there is not enough evidence about which are the most effective strategies, theoretical frameworks, or intervention components to effectively improve health behaviours (Cassar et al., 2019; Dobbins et al., 2013; van Sluijs et al., 2021).

Third, whereas little is known about the inter-relationship between the different school elements, the CAS framework tries to establish whole-school ethos and practice about health behaviours promotion (Daly-Smith et al., 2020). Thus, the CAS framework allows to identify and activate levers at the different levels of the model to be more efficient (i.e., not only focusing on children, but also on teachers, parents, other stakeholders, etc.). Then, there have been conducted only a few studies considering this framework, and our study may be the first Spanish intervention which has been designed based on the CAS framework.

Fourth, as it was highlighted in section 2.5, most research and studies conducted to date about 24-hour movement behaviours have been focused on cross-sectional studies, forgetting intervention and longitudinal studies (Rollo et al., 2020; Tapia-Serrano et al., 2022). Thus, the effect of school-based interventions targeting 24-hour movement behaviours among children as well as its effects on meeting the guidelines seems to be

unexplored (Rollo et al., 2020; Tapia-Serrano et al., 2022).

Table 1. Research gaps, objectives and thesis studies.

Research gaps	Objectives	Studies
There is a lack of information about school-based interventions targeting all 24-hour movement behaviours among children.	To provide an overview of school-based interventions targeting PA, SB, and sleep among children aged 5-12 years.	1. Identifying Promising School-Based Intervention Programs to Promote 24-Hour Movement Guidelines among Children: Protocol for a Systematic Review. 2. Are school-based interventions promoting the 24-hour movement guidelines among children? A scoping review
It is not clear if school-based interventions are effective at improving MVPA and reducing ST among children.	To evaluate the overall effectiveness of school-based interventions assessed with accelerometer devices (i.e., daily MVPA and ST), among children aged 5-12 years.	3. Effectiveness of school-based interventions targeting physical activity and sedentary time among children: a meta-analysis
There is not enough evidence about which are the most effective strategies, theoretical frameworks, or intervention components to effectively increase PA, reduce SB.	To investigate the moderating actions of intervention components, design, duration, quality of the intervention and theoretical framework on these MVPA and ST effectiveness rates.	
Whereas little is known about the inter-relationship between the different school elements, the CAS framework tries to establish whole-school ethos and practice about health behaviours promotion.	To describe the rationale, the methods, and the evaluation process of a multi-component school-based intervention to improve health promotion in the whole school setting (i.e., among children, teachers, and families), using the CAS framework.	4. Promoting health in Spanish children applying CAS Framework: A system approach
Most research to date about the 24-hour movement behaviours has been focused on cross-sectional studies, and the effect of school-based interventions seems to be unexplored.	To examine the effects of a school-based intervention on children's movement behaviours (e.g., MVPA, ST, screen time and sleep outcomes).	5. Effects of a multicomponent intervention to improve movement behaviours and compliance of the 24-Hour Movement Guidelines among 3- to 9-Year-Old Spanish Children.
There has not yet been analysed the effect of a school-based intervention on the percentage of children meeting or not the 24-hour movement guidelines.	To describe the proportion of 3 to 9-year-old children meeting the 24-h movement guidelines measured with both self-reported and accelerometer assessments.	

Finally, given these current knowledge gaps and limitations in our research field, we suggest addressing them through the research studies of this doctoral thesis described in the following section II.



## **SECTION II. THESIS STUDIES**

## **Chapter 3. Identifying Promising School-Based Intervention Programs to Promote 24-Hour Movement Guidelines among Children: Protocol for a Systematic Review**

Chapter 1 and 2 provided a general overview of the research field and highlighted the gaps explored during this thesis. Then, a systematic review protocol was performed to identify and review school-based intervention studies about physical activity, sedentary behaviour, and sleep among primary school students. The main reason to detail and describe a systematic review protocol is to be transparent about our research topic as well as about the method and instruments used. Furthermore, another reason to publish the protocol was to detail a research guide (i.e., eligibility criteria and search strategy exposed) that will help future researchers to conduct other valid and reliable systematic reviews related to 24-hour movement behaviour interventions. Thus, this chapter contains the published systematic review protocol which addressed the following research questions:

- Are school-based interventions implementing the 24-hour movement guidelines among children?
- Are school-based interventions effective promoting movement behaviours among children?

This chapter has been published as:

Rodrigo-Sanjoaquín J, Bois JE, Aibar Solana A, Lhuisset L, Zaragoza Casterad J. Identifying Promising School-Based Intervention Programs to Promote 24-Hour Movement Guidelines among Children: Protocol for a Systematic Review. *Sustainability*. 2020; 12(22):9436. <https://doi.org/10.3390/su12229436>

### **3.1. Introduction**

Public health concern has increased over the past decade due to the rise of non-communicable diseases as the first cause of death worldwide (WHO, 2014). It is known that insufficient physical activity (PA) is one of the most important health behavioural risks for non-communicable diseases in children, youths, and especially in adults (Ding et al., 2016; Ezzati & Riboli, 2013; WHO, 2014). Sedentary behaviours (SB) such as sedentary screen-time behaviours (i.e., TV viewing, computer use, playing videogames,

or smartphone use), and sitting time (i.e., leisure and occupational sedentary time) are behaviours closely related to physical inactivity in children, but must be considered separately (Ding et al., 2015; Lynch & Owen, 2015). Related to sleep (SLP) behaviour, some studies have shown that unhealthy SLP (i.e., irregular sleep patterns, poor sleep quality and short sleep duration) is associated with a higher risk of obesity and a lack of health outcomes (e.g., good physical shape, physical and psychological well-being, healthy dietary patterns, and cognitive performance) among children and adolescents worldwide (Cappuccio et al., 2011; Chaput & Dutil, 2016; Golley et al., 2013). For convenience only the acronyms PA, SB and SLP instead of their full expressions will be used throughout the manuscript.

Some research studies indicated that the adoption of a healthy lifestyle during childhood can have protective effects against the onset of chronic disease (Gore et al., 2011), and health-related behaviours acquired at this age usually tend to persist into adulthood (Telama et al., 2014), so it can influence sustainable long term health behaviours. PA, SB and SLP, separately and combined, can influence and increase health benefits in children (Chaput et al., 2014; Saunders et al., 2016). These three health behaviours are correlated (Salmon et al., 2011; Tremblay et al., 2011; Uijtewilligen et al., 2011; Wu et al., 2017), and can interact among them to increase healthy outcomes (e.g., high PA/low SB/improve SLP) in children and youths (Tremblay et al., 2016). Traditionally, school health research has been mainly focused on promoting PA and reducing SB in children (Chaput et al., 2014), but SLP research has usually been treated independently and separately (Blunden & Rigney, 2015). Although this approach has been very important to the field so far, emerging evidence indicates that today another integrated approach is necessary to understand and promote school health behaviours in children (Sallis et al., 2018; Tremblay et al., 2016). PA is an important health behaviour, but only accounts for a small part of daily time, however SB and SLP make up the majority of a 24-hour period (Carson et al., 2016).

As a consequence, a new paradigm was developed in 2016, called the 24-hour Movement Guidelines (Department of Health, 2017; Tremblay et al., 2016). This framework recognizes and integrates the importance of correctly combining PA, SB and SLP to reach and improve health outcomes in children (Saunders et al., 2016). According to the recommendations provided by the 24-h Movement Guidelines (Tremblay et al.,

2016) and the WHO (WHO, 2010), children aged 5–12 years should accumulate >60 minutes of daily moderate-to-vigorous physical activity (MVPA), spend several hours in a day doing Light Physical Activity (LPA), sleep more than 9 hours per night and dedicate less than 2 hours each day to sedentary screen-time behaviours.

Previous studies suggested that combinations of behaviours (e.g., increase PA, reduce SB and improve SLP quality) can impact health in a different way that would not be explained by the effect of individual behaviours studied separately (Chaput et al., 2017; Chastin et al., 2015). Interventions targeting a combination of multiple health behaviours are a promising method to improve several health outcomes (Prochaska et al., 2008). This approach evidence that changing one health behaviour could affect or improve others (Champion et al., 2019; Prochaska et al., 2008). However, interventions that simultaneously address several health behaviours are usually difficult to implement at schools (Champion et al., 2019), especially due to various barriers and limitations (e.g., lack of teacher's formation in health promotion, a limited school timetable, the school curricula organization, etc.). On the other hand, interventions that combine PA (e.g., MVPA, LPA), SB (e.g., short sitting time, low screen-time) and SLP (e.g., high sleep quality, high sleep duration) have shown more beneficial outcomes compared with interventions that do not combine these behaviours (Carson et al., 2016; Saunders et al., 2016). School is an ideal setting for health promotion behaviours in children because most of the population stay there for a long period of their lifetime, and children spend approximately 50% of their daily waking time at school (Hegarty et al., 2016). Today, school children spend approximately 6–8 hours per day at school, being sedentary (Rush et al., 2012; Van Stralen et al., 2014), so it is even more important to target school interventions that can increase PA (i.e. MVPA and LPA) and reduce SB (i.e., sitting time and screen time). Considering the 24-h movement guidelines framework, SLP should also be considered.

There are multiple reviews targeting PA (Dobbins et al., 2013; Jones et al., 2013; Love et al., 2017; Metcalf et al., 2012), SB (Altenburg et al., 2016; Biddle et al., 2014; Friedrich et al., 2014; Hegarty et al., 2016; Marsh et al., 2014) and SLP (Blunden & Rigney, 2015; Blunden et al., 2012; Cassoff et al., 2013; Chung et al., 2017) interventions separately, but there is a lack of reviews about multiple health behaviour (i.e., 3 or more health behaviours) interventions. We have only found some reviews that target combined

health behaviour interventions (e.g., PA and SB, PA and SLP) in children that address issues such as obesity prevention (Agaronov et al., 2018; Ash et al., 2017; Khambalia et al., 2012; Lambrinou et al., 2020), weight gain prevention (Goldthorpe et al., 2020), energy-balance (Anselma et al., 2020), and pre-schoolers aged 0–4 years (Kuzik et al., 2017). Other reviews related to multiple health behaviour interventions (e.g., PA and SB, PA and SLP) have mainly focused on adolescents (Champion et al., 2019; Hale et al., 2014; Hynynen et al., 2016; MacArthur et al., 2018; Jackson et al., 2012; Prochaska et al., 2011) and suggested that although they were effective in terms of PA outcomes, more evidence and high-quality studies are required to determine their effectiveness related to other health behaviours such as SB or SLP.

Some recent reviews have focused on examining effective PA and SB strategies (Jones et al., 2020; Lambrinou et al., 2020), and a recent umbrella review about school-based interventions to prevent weight gain in children has been published (Goldthorpe et al., 2020). However, to the authors' knowledge, none of the previously published systematic reviews have exclusively dealt with the effectiveness of strategies related to movement behaviours (i.e., PA, SB and SLP) from multiple health behaviour interventions in school children. As a consequence, to fill this gap in literature, this systematic review will aim to: 1) Summarize and classify movement behaviour strategies used in literature to improve PA, SB and SLP in/from school in children; and 2) measure the effect of movement behaviour strategies used in literature to improve PA, SB and SLP in children.

### **3.2. Methods**

The protocol for this systematic review was conducted by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines (Moher et al., 2015), and it is available in Annexes of Chapter 3. This systematic review protocol was registered in PROSPERO (CRD42020199154), International Prospective Register of Systematic Reviews, and the report of this systematic review will be informed by PRISMA guidance (Moher et al., 2009). Relevant modifications to this protocol will be indicated and published in the corresponding final systematic review.

#### *Eligibility Criteria*

To be eligible for the current systematic review, studies will be selected based on

the following criteria. Studies must be published in a peer-reviewed English language journal and target healthy schoolchildren aged 5–12 years (i.e., primary school) without mental disabilities. Study participants are required to have a mean age of 5–11.99 years with at least two exposure measurement points, although follow-up measures of movement behaviours could happen past this age limit. The proposed systematic review will include interventional designs (i.e., randomized controlled trials, cluster randomized controlled trials and non-randomized studies [e.g., quasi-experimental studies, pilot studies and single group]) examining the influence of school-based interventions on movement behaviours. To be included in this systematic review, studies will be required to incorporate at least two movement behaviours from the three 24h movement behaviours (i.e., PA and SB and SLP; PA and SB; PA and SLP; SB and SLP). These behaviours could be assessed by self-report (e.g. questionnaires) or device-based measures (e.g. accelerometer data, pedometers, etc.). According to the eligibility criteria of the recent SB review and meta-analysis conducted by Blackburn et al., (2020), all outcomes relating to SB (i.e., leisure or occupational sitting time and sedentary screen-time behaviours) will be included. Furthermore, in line with another review protocol (Champion et al., 2017) and meta-analysis (Champion et al., 2019), studies addressing other health behaviours (e.g., dietary patterns, healthy nutrition, well-being, etc.), in addition to our movement behaviours of interest, will not be excluded for the review. Thus, in Figure 1, we show the logic model, as recommended in literature (Anderson et al., 2011; Rehfuess et al., 2018) to map, inform, make more transparent, and ultimately describe the conceptualization of the protocol review. Finally, according to these recommendations (Gunnell et al., 2020), grey literature (e.g., book chapters, editorials, pre-prints, abstracts, congress communications, etc.) will not be included in the search strategy because grey literature is typically not published in peer-reviewed scholarly resources (i.e., journals), and could result in a large increase in the number of records to screen, with little added value for those that have already been identified.

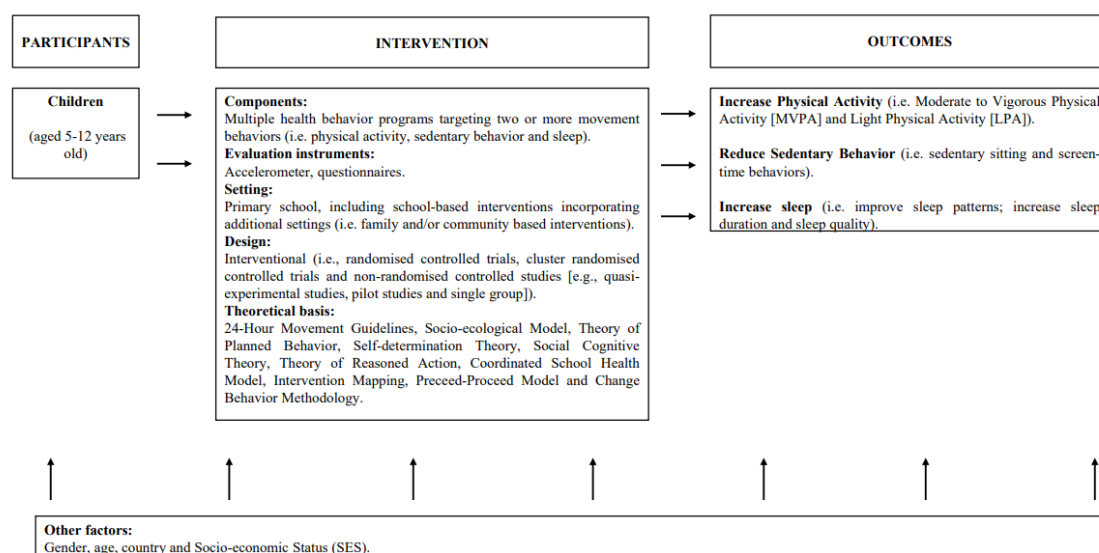


Figure 1. Logic model: School-based interventions targeting movement behaviours.

### Search Strategy

This systematic search will be conducted using the following electronic databases of peer-reviewed journal articles and online research registers: Pubmed, Scopus, SPORTDiscuss, The Cochrane Library and Web of Science, following the recommendations to conduct academic search systems for systematic reviews and meta-analyses (Gusenbauer et al., 2020). The expected school-based strategies to be found in the intervention studies extracted across these databases search, will belong to specific theoretical frameworks (i.e., Socio-ecological Model, Theory of Planned Behaviour, Self-determination Theory, Social Cognitive Theory, Theory of Reasoned Action, Coordinated School Health Model, Intervention Mapping, Preceed-Proceed Model and Behaviour Change Methodology) according to what is shown in Figure 1. Searches will be conducted for studies published between 2010 and October 2020, coinciding with the last decade. Eligible papers will be reviewed to identify other relevant potential studies that could be selected. Similarly, recent related systematic reviews will be consulted to identify any additional studies. The Population, Interventions, Comparisons, Outcomes and Study design (PICOS) framework (Schardt et al., 2007) was followed to conduct the literature search (see Table 1). This strategy allows to identify key study concepts in the research question, like the logic model presented previously in Figure 1, and facilitate the search process (Eriksen et al., 2018). Described search keywords are related to the following topics: target population (i.e., children), intervention (i.e., different strategies,

techniques and health programs), and movement behaviours outcomes (i.e., PA, SB and SLP) in/from school. Search keywords will be combined with different Boolean operators (e.g., “AND”, “OR”, “NOT”). Selected keywords are based on previous systematic reviews that include some movement behaviours (Anselma et al., 2020; Chong et al., 2019; Hynynen et al., 2016; Jones et al., 2020; Saunders et al., 2016). More detailed information about search strategy is available in Annexes of Chapter 3.

Table 1. PICO strategy: category, definition, and search terms.

Category	Definition	Search terms
Population	Children (from 5 to 12 years old).	Child* OR student OR pupil OR infant OR childhood OR school* OR schoolchildren OR school children OR schoolage* OR school-age* OR school age* OR primary school OR elementary school OR basic school NOT adolescent*.
Intervention	Health intervention studies which use different strategies in/from school.	strategy* OR technique* OR intervention* OR program* OR health prevention OR health prevention program* OR health program* OR health promotion program* OR health promotion intervention OR health education OR health intervention OR school setting OR school based intervention OR school-based intervention OR school based program* OR school-based program* OR school program* OR school health program OR school intervention OR school health intervention.
Comparisons	Not applicable.	Not applicable.
Outcomes	Movement behaviors: increase PA, reduce SB, improve SLP.	(PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activity* OR sport* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise* OR motor behavior* OR movement) AND (sedentart* OR sedentary behavior* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavior* OR sitting time OR prolonged sitting OR domestic activities OR computer use OR computer time OR media use OR video games OR tablet use OR smartphone use OR mobile phone use OR computer time OR television time OR TV time OR gaming OR screen time OR screen-time OR reading OR TV viewing OR TV child room OR television viewing OR video viewing) AND (sleep* OR sleep behavior* OR sleep duration OR sleep quality OR sleep pattern* OR bedtime OR sleep disturbance OR insomnia).

### Study Selection

All identified studies from the literature search will be selected by two review authors in three steps as recommended in literature (Gunnell et al., 2020). First, the titles and abstracts of the articles returned from the initial search will be screened and selected based on previous broken-down eligibility criteria. Second, full-text articles will be analysed in detail and selected for eligibility. Third, the bibliographic references of all articles considered will be manually searched to identify relevant articles lost in the initial search strategy. If necessary, disagreements between the authors will be resolved by face-



to-face discussion with the rest of authors to reach a consensus. Mendeley Citation Manager software will be used to store search results as well as to remove duplicate studies.

### *Data Extraction*

Two review authors will independently and systematically extract data from included studies. The PRISMA guidance (Moher et al., 2009) will be used as a reference framework. Authors will identify the required information (i.e., publication details [i.e., authors, year], study characteristics [i.e., design, country, sample size, socio-economic status (SES), age and gender], movement behaviours targeted [i.e., PA, SB and SLP], theoretical framework [e.g., socio-ecological model, theory of planned behaviour, etc.], intervention characteristics [i.e., delivery method, content and components], intervention frequency and duration [e.g., 3 intervention sessions/week during 14 weeks], stakeholders involved [i.e., teachers, families, community members, etc.], measurement tools [i.e., questionnaires, accelerometer data], main findings [related to outcomes measured] and follow-up if available). Possible future discrepancies between the authors will be solved by a consensus-based decision, or if necessary, a discussion with a third reviewer. If data clarifications are needed, authors of the original studies will be contacted. If necessary, authors from this protocol will make a maximum of two attempts of contact. All the extracted data will be synthesized using tables created with Microsoft Excel.

### *Risk of Bias and Quality Assessment*

Some reviews (Gunnell et al., 2020; Higgins et al., 2011) indicated that literature generally failed to correctly identify and differentiate risk of bias from quality assessment. Thus, risk of bias refers to potential systematic errors that produce bias in results. Quality assessment is the rigor and quality control in the research methodology and findings, which gives confidence in the results (Boutron et al., 2019). In that sense, two authors will independently assess the risk of bias of the selected studies using the "The Cochrane Risk of Bias Tool 2" (RoB-2; Sterne et al., 2019) for randomized studies, and "ROBINS-I" (Sterne et al., 2016) for non-randomized studies. These tools cover a range of domains of potential bias, and any discrepancies between the raters will be resolved by a third reviewer. Scores will be summed across the domains evaluated to give a final total score of the risk of bias for each study. According to the aforementioned risk of bias tools (Sterne et al., 2019; Sterne et al., 2016), studies will be classified as "high risk" (i.e., if

most items are rated with “some concerns”, or at least one item is rated with “high risk”); as “some concerns” (i.e., if at least one item is rated with “some concerns”), and finally, as “low risk” (i.e., if all the items are rated as “low risk”). Related to quality assessment, the “Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group” will be used to evaluate intervention studies without control group, and the “Quality Assessment of Controlled Intervention Studies” will be used (Gunnell et al., 2020) to evaluate intervention studies with control group. The “Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group” integrates 12 items (NIH; <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>) having the option to obtain a maximum score of 12 points. The “Quality Assessment Tool of Controlled Intervention Studies” integrates 14 items (NIH; <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>) having the option to obtain a maximum score of 14 points. Each item will be rated as “1” when the information is reported or moderately reported, or “0” when the information is unclear or not reported. Intervention studies with no control group will be classified into “high quality” (>8 points), “medium quality” (4–7 points), and “low quality” (<3 points). Intervention studies with control group will be classified into “high quality” (>10 points), “medium quality” (5–9 points), and “low quality” (<4 points). Two authors will independently assess each study, and discrepancies will be resolved by a third reviewer. We will not exclude studies based on findings from the quality assessment.

### *Data Synthesis*

A narrative synthesis on all available data will be conducted. Depending on the results, authors will decide to conduct a meta-analysis or simply a qualitative synthesis. If only a qualitative synthesis is finally carried out, summary tables describing studies will be performed. Qualitative analysis will answer our first goal referenced in the background: “to summarize and classify movement behaviour strategies used in the literature to improve PA, SB and SLP in/from school in children”. These tables will include the general details of the studies, the intervention content (i.e., movement behaviours targeted and theoretical framework), the delivery method (i.e., school, family, teacher or children’s strategies and stakeholders involved), and the socio-ecological level stage (i.e., individual, interpersonal, organizational, community or policy). A second table will include methodological quality of studies (i.e., risk of bias and quality of assessment). If possible, a quantitative analysis (i.e., meta-analysis) of all defined movement behaviour

effects (i.e., pre-post, follow-up), where enough data is available, will also be conducted. Quantitative analysis will answer our second goal referenced in the background: “to measure the effect of movement behaviour strategies used in literature to improve PA, SB and SLP in children”. We anticipate a high degree of heterogeneity with respect to intervention types/lengths, reporting of outcomes and outcome measurements.

### **3.3. Discussion**

The proposed systematic review will be the first to evaluate the school-based movement behaviour interventions designed to promote healthy outcomes among children and their efficacy: Increase PA (i.e., MVPA, LPA), reduce SB (e.g., sitting and screen-time) and improve SLP (i.e., sleep patterns, duration and quality). This systematic review of recent and older studies will also allow us to obtain information about the degree of development and sustainability of interventions addressing movement behaviours among primary school students. Although there are some recent systematic reviews, which have examined health behaviour interventions in children and adolescents, these were focused on preventing diseases or unhealthy behaviours (e.g., overweight, obesity, physical inactivity, alcohol and smoke consumption, etc.), instead of promoting health behaviours (Champion et al., 2019; Goldthorpe et al., 2020; Jones et al., 2020; Lambrinou et al., 2020). Consequently, there is a lack of reviews focused on targeting movement behaviour interventions in children. Thus, this protocol provides a description of the future systematic review to be carried out, exploring this literature gap.

According to our task to find multiple health behaviour intervention studies, previous reviews (Champion et al., 2019; Lambrinou et al., 2020) found that studies usually do not detail their strategies or methods of intervention, and further high-quality research is needed. In order to do that, an important number of methodological unclear studies is expected to be found in our future search. In addition, a review and meta-analysis carried by Champion et al., (2019) found that school-based multiple health behaviour interventions were beneficial in increasing PA, and reducing screen time (i.e., SB), but concluded that effects were small, and the overall quality of evidence was low (measured by GRADE [Grading of Recommendations Assessment, Development and Evaluation] framework). As mentioned in the introduction, combinations of health behaviours can impact health in a different way, which would be not explained by the effect of individual behaviours separately (Chaput et al., 2017; Chastin et al., 2015).

However, recent reviews have found that benefits of single health behaviour interventions versus multiple health behaviour interventions remained unclear (James et al., 2016; Lambrinou et al., 2020). Nevertheless, although there is no consensus in this regard, the present review will only include school interventions targeting at least two movement behaviours simultaneously to further study this topic.

Strengths of this review protocol come firstly from the detailed research guide (i.e., eligibility criteria and search strategy exposed) that will help future researchers to conduct other valid and reliable systematic reviews related to movement behaviour interventions. Another methodological strength that should be highlighted in the current review is the detailed quality assessment and risk of bias procedure, according to recent recommendations to conduct systematic reviews (Gunnell et al., 2020). Related to the limitations of this review, language restriction of published English written studies could limit the generalization of future results. Another limitation is that authors could be ignoring other databases (Gusenbauer et al., 2020) and do not identify more studies in the present systematic review.

### **3.4. Conclusions**

The systematic review to be carried out will provide information about existing studies that have implemented school-based intervention programs targeting movement behaviours to increase health outcomes in children. It is expected that data extracted will be able to identify the most effective strategies and measure the intervention program effect according to our aim. Moreover, results of the present study will show a deeper understanding of which are the most effective and sustainable intervention programs to improve movement behaviours (i.e., PA, SB and SLP) in school-aged children. Finally, reviewing a broad range of adequate intervention programs to improve movement behaviours in/from school will provide information to researchers and practitioners of our field about which kind of interventions and strategies are the best to implement, related to each study design and program objectives.

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## **Chapter 4. Are school-based interventions promoting the 24-hour movement guidelines among children? A scoping review**

Chapter 3 provided in protocol format the whole process needed to conduct a systematic review about school-based interventions targeting 24-hour movement behaviours. Then, a systematic review was performed to identify and review school-based intervention studies about physical activity, sedentary behaviour, and sleep among primary school students. However, results of this systematic review resulted too small for publication, and we resorted to adapt it into a scoping review format. The main reason to take this decision was the lack of school-based interventions targeting the three movement behaviours, which was in fact the detection of an important gap in our research field. Therefore, this chapter contains the scoping review which addressed the same research questions provided previously in chapter 3:

- Are school-based interventions implementing the 24-hour movement guidelines among children?
- Are school-based interventions effective promoting movement behaviours among children?

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### **4.1. Introduction**

The prevalence of non-communicable diseases has increased over the last decades, becoming an important public health problem and the first cause of death worldwide (World Health Organization, 2014). Insufficient physical activity (PA), as well as high levels of sedentary behaviours (SB), are two of the most important health behavioural risks for non-communicable diseases (Ding et al., 2016; WHO, 2014). Additionally, 80% of the world's children and youths do not meet the PA recommendations (Guthold et al., 2020). Moreover, sedentary screen-time behaviours (i.e., playing videogames, TV viewing, smartphone use or computer use), and sedentary time (ST; i.e., leisure and occupational sitting time) take up over 50% of the waking day for 7 year-old children, and 75% of the waking day for 15 year-old adolescents (Janssen et al., 2016). Some studies have shown that unhealthy sleep (i.e., irregular sleep patterns,

poor sleep quality, and short sleep duration), is associated with a lack of healthy outcomes (e.g., good physical shape, physical and psychological well-being, healthy dietary patterns and cognitive performance) among youths (Chaput and Dutil, 2016; Golley et al., 2013). In addition, children today sleep less and less, with only 60% of them meeting the sleep recommendations (Chaput et al., 2015; Matricciani et al., 2012). Overall, low PA, high SB levels and short sleep duration have been linked to various adverse health outcomes including overweight and obesity in children (Chaput et al., 2017; Rollo et al., 2020).

These three behaviours, also called movement behaviours, can influence sustainable long-term benefits in children (Chaput et al., 2014; Rollo et al., 2020; Saunders et al., 2016). Due to the lack of a common research approach to these three behaviours, in 2016 an integrated theoretical framework was developed in Canada, named the 24-Hour Movement Guidelines, integrating the recommendations for PA, SB, and sleep (Tremblay et al., 2016). This model recognized the importance of movement behaviours to improve health outcomes in children and adolescents from an integrated perspective (Rollo et al., 2020; Saunders et al., 2016). The combination of these movement behaviours can impact health in a different way that would not just be explained by the addition of the effect of these individual behaviours studied separately (Chaput et al., 2017; Rollo et al., 2020). Nevertheless, school health research has been mainly and exclusively focused on PA or SB (Chaput et al., 2014), with sleep usually treated independently from the other two behaviours (Blunden and Rigney, 2015; Busch et al., 2017). Due to the recent 24-hour movement guidelines, sleep should also be considered in school health interventions.

Then, school is a decisive place to promote health behaviours in children, as the majority of the population stay there for a given period of their lifetime, and children spend half of their daily waking time there (Hegarty et al., 2016). Besides that, schools offer a context to reach the majority of children, and they provide an obvious intervention setting irrespective of their background characteristics, sex, socio-economic status (SES) and ethnicity (Åvitsland et al., 2020). Moreover, schools are an ideal health promotion setting because they can reach several other target groups other than children and adolescents, such as school staff, teachers, families and even members of the community (Gugglberger, 2021).

Even though some studies used multiple movement behaviour interventions, no review of this whole approach exists in the school setting. We have only found some reviews that targeted a combination of two movement behaviours in children (i.e., PA and SB) or a single movement behaviour (i.e., sleep), which addressed issues and outcomes such as obesity prevention (Agaronov et al., 2018; Ash et al., 2017; Lambrinou et al., 2020), weight gain prevention (Goldthorpe et al., 2020; Nooijen et al., 2017), and energy-balance (Anselma et al., 2020). Finally, only two meta-analyses focused on examining PA and SB in school children (Jones et al., 2020; Love et al., 2019).

### *Aim*

None of the previously published systematic reviews have dealt with the effectiveness and implementation of school-based interventions related to PA, SB, and sleep together in children. Therefore, to fill this gap in the literature, we aimed to systematically review and summarise the implementation and effectiveness of school-based interventions targeting movement behaviours in 5-12 years-old children.

## **4.2. Methods**

This scoping review has been written following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Extension for Scoping Reviews (Tricco et al., 2018). The PRISMA checklist is available in Annexes of Chapter 4. Moreover, the present review study was registered in the International Prospective Register of Systematic Reviews (PROSPERO), ID: CRD42020199154.

### *Information sources and search strategy*

A structured electronic bibliographic search of 5 databases (Pubmed, Scopus, SPORTDiscuss, The Cochrane Library and Web of Science) was conducted to retrieve peer-reviewed intervention articles published in English language, from January 2010 through December 2020, coinciding with the last decade of research and the consolidation of the 24-hour movement guidelines. We selected these databases following the recommendations to conduct academic searches for systematic reviews and meta-analyses

(Gusenbauer and Haddaway, 2020). The search strategy combined multiple previously agreed keywords, which were developed by breaking down the aim. The Population, Interventions, Comparisons and Outcomes (PICO) framework was followed to conduct the literature search (Schardt et al., 2007). We give an example of the keywords selected to make the database searches in Table 1. More detailed information about the search strategy is available in Annexes of Chapter 4.

**Table 1.** PICO strategy

Category	Definition	Search terms
Population	Children (from 5 to 12 years old).	Child* OR student OR pupil OR infant OR childhood OR school* OR schoolchildren OR school children OR schoolage* OR school-age* OR school age* OR primary school OR elementary school OR basic school NOT adolescent*.
Intervention	Health promotion intervention studies that implement different strategies in/from school.	Strategy* OR technique* OR intervention* OR program* OR health prevention OR health prevention program* OR health program* OR health promotion program* OR health promotion intervention OR health education OR health intervention OR school setting OR school based intervention OR school-based intervention OR school based program* OR school-based program* OR school program* OR school health program OR school intervention OR school health intervention.
Comparisons	Between intervention and control group.	Not applicable.
Outcomes	Movement behaviours: increase PA, reduce SB, improve sleep.	(PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit* OR sport* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercis* OR motor behavio* OR movement) AND (sedentar* OR sedentary behavio* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio* OR sitting time OR prolonged sitting OR domestic activities OR computer use OR computer time OR media use OR video games OR tablet use OR smartphone use OR mobile phone use OR computer time OR television time OR TV time OR gaming OR screen time OR screen-time OR reading OR TV viewing OR TV child room OR television viewing OR video viewing) AND (sleep* OR sleep behavio* OR sleep duration OR sleep quality OR sleep pattern* OR bedtime OR sleep disturbance OR insomnia).

### *Eligibility criteria*

Two review authors assessed the studies that met the following eligibility criteria in the initial search processes. Studies were included if they targeted healthy primary

school children without mental disabilities. Study participants were required to have a mean age between 5 and 11.99 years old with at least two exposure measurement points (i.e., baseline and post-test), although follow-up measures of movement behaviours were acceptable beyond this age limit. Only interventional designs with control group measure (i.e., randomized controlled trials [RCT], cluster randomized controlled trials, grouped randomized controlled trials, pilot randomized controlled trials, and non-randomized studies [e.g., quasi-experimental controlled studies and pilot quasi-experimental controlled studies]) have been included. Studies that exclusively used a qualitative approach, and therefore did not include any quantitative data, were excluded from this review. Finally, studies were required to incorporate at least two movement behaviours from the three behaviours of the 24-hour movement guidelines. The behaviours could have been assessed indifferently by self-report (e.g., questionnaires), or by device-based measures (e.g., accelerometer data and/or pedometers).

### *Study selection*

Two review authors identified the searched studies in three steps according to the literature (Gunnell et al., 2020). First, titles and abstracts of the articles returned from the initial search were screened and selected based on previous broken-down eligibility criteria. Second, full-text articles were analysed in detail and selected for eligibility. Third and finally, bibliographic references of all articles selected were manually analysed to identify relevant articles lost in the initial search strategy.

### *Data extraction*

Two review authors independently and systematically extracted the data from the final list of included studies. The following categories were identified and considered from the manuscripts: publication details (i.e., authors, year); study characteristics (i.e., design, country, sample size, SES, age and gender); movement behaviours targeted (i.e., PA, SB and sleep); other health-related behaviours (e.g., nutrition); intervention duration (e.g., three months); measurement tools (i.e., questionnaires, accelerometer data); main findings (related to movement behaviours measured), and follow-up measurements if available. Discrepancies between the authors were solved by a consensus-based decision.



All the extracted data were synthesized and pooled together using tables created with Microsoft Excel.

### 4.3. Results

Using the search strategy described above, 11,432 records were identified. After removing 3,542 duplicates, 7,890 articles remained for screening. These 7,890 manuscripts were screened by the abstract and 7,761 were excluded based on eligibility criteria. Then, 129 full-text articles were screened, of which 37 publications fulfilled the criteria and were deemed eligible (see Figure 1).

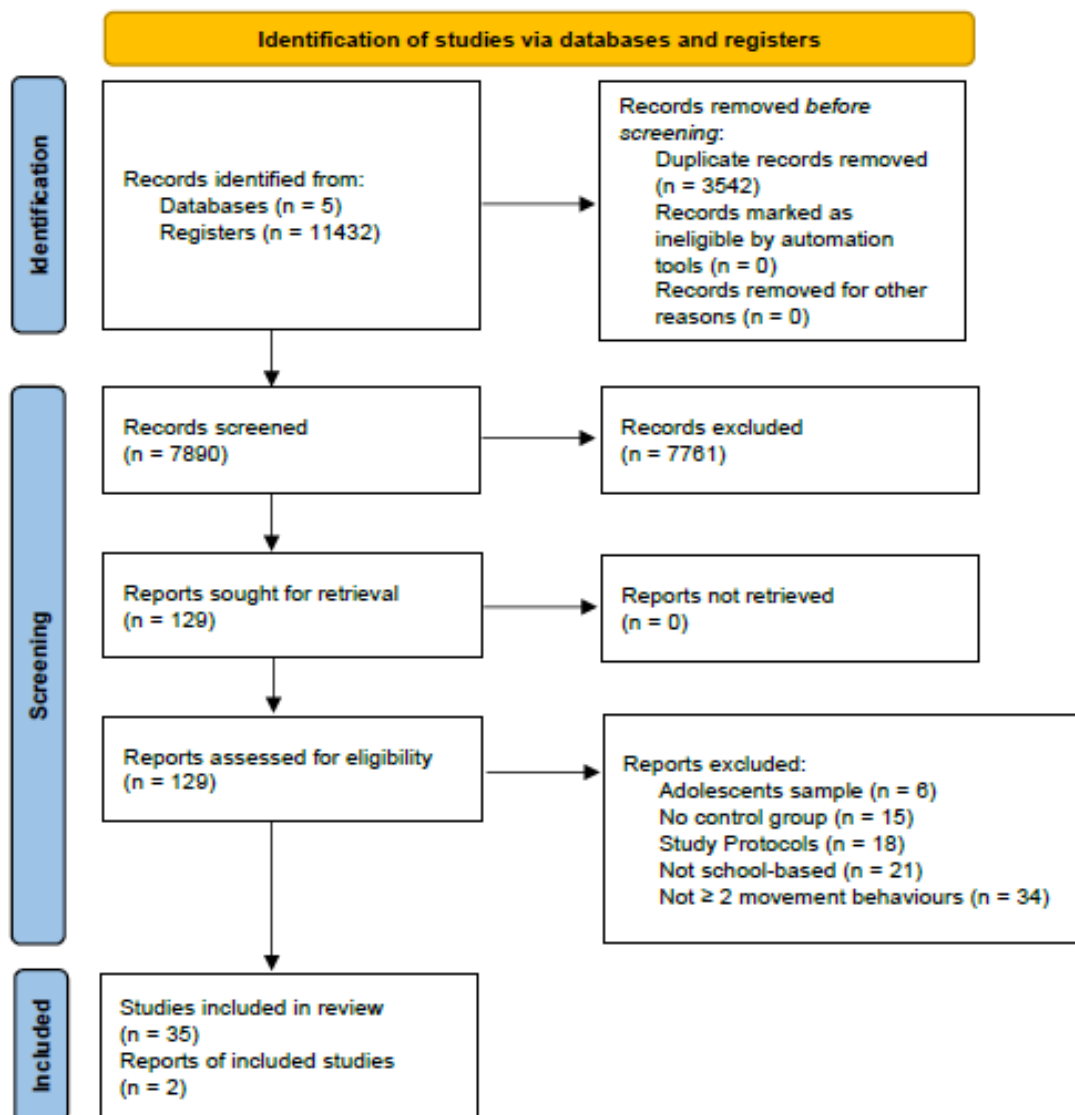


Figure 1. Scoping review Flow diagram.

### *Description of the studies included*

Table 2 shows the general characteristics of the studies that make up this scoping review. From the 37 studies included, there were 28 RCT studies (i.e., RCT, Cluster RCT, Pilot RCT and Group RCT) and 9 non-Randomised studies (i.e., Quasiexperimental studies). The studies were conducted in 6 European countries (n=12, 32%), in the United Kingdom (n=10, 28%), in 4 Asian countries (n=5, 13%), and in 2 Oceanian countries (n=4, 11%). The remaining 6 studies were conducted in the United States of America (n=4, 11%), and Mexico (n=2, 5%). The SES has not been detailed in 14 studies. The total sample size of this scoping review was 27145 primary school children. The sample size of school-based interventions was less than 250 students in 6 studies, between 250 and 999 students in 24 studies, and more than 1000 students in 7 studies. Children's mean age varied between 5 and 9 years old in 40% of the studies, and between 9 and 12 years old in the remaining studies. All studies included both male and female child participants (n=37), and the percentage of male children ranged between a minimum of 40%, and a maximum of 58%. All but one study detailed male/female participation percentages (Fairclough et al., 2013). Regarding the other health-related behaviours measured, 23 studies measured nutrition outcomes (i.e., dietary patterns, daily food, and beverage intake, etc.), only 1 study measured nutrition and health-related quality of life, while 13 studies did not measure any other health behaviour (see Table 1).

Table 2. Summary of the studies included.

<b>STUDY</b>	<b>CHARACTERISTICS</b> (Design; Country)	<b>SAMPLE</b> (Sample; mean age; % male)	<b>SES</b>	<b>TARGET BEHAVIOURS</b>	<b>OTHER HEALTH BEHAVIOURS</b>	<b>DURATION</b>
Colín-Ramírez et al., 2010	RCT; Mexico	10 schools/498 children; 9.4; SD: 0.71; 8-10 Y.O; 56% male	Low	PA & SB (screen-time)	Not applicable	12 Months
Hands et al., 2011	RCT; Australia	27 schools/305 children; 7.2; SD: 0.1; 7-8 Y.O; 54% male	Low-Medium- High	PA & SB (screen-time)	Not applicable	6 Months
Salmon et al., 2011	RCT; Australia	15 schools/ 957 children; 10.3; SD: 0.62; 9-12 Y.O; 42% male	Low	PA & SB (screen-time)	Not applicable	3 Months
Bacardí-Gascón et al., 2012	RCT; Mexico	4 schools/532 children; 8.5; SD: 0.73; 8-9 Y.O; 52% male	Not detailed	PA & SB (screen-time)	Nutrition	6 Months
Brandstetter et al., 2012	RCT; Germany	32 schools/945 children; 7.57; SD: 0.42; 7-8 Y.O: 53% male	Not detailed	PA & SB (screen-time)	Nutrition	9 Months
Breslin et al., 2012	Non RCT; Northern Ireland	24 schools/416 children; 9.1; SD: 0.36; 8-9 Y.O; 48% male	Low	PA & SB (screen-time)	Nutrition	3 Months
Lloyd et al., 2012	Cluster RCT; England	4 schools/202 children; 9.69; SD: 0.3; 9-10 Y.O; 50% male	High	PA & SB (screen-time)	Nutrition	6 Months
van Stralen et al., 2012	Non RCT; Netherlands	19 schools/600 children; 9.8; SD: 0.7; 8-12 Y.O; 49% male	Low	PA & SB (screen-time)	Not applicable	8 Months (2 years)
Verloigne et al, 2012	Pilot RCT; Belgium	10 schools/372 children; 10.9; SD: 0.7; 10-12 Y.O; 40% male	Not detailed	PA & SB (ST)	Not applicable	2 Months
Carson et al., 2013	Cluster RCT; Australia	20 schools/293 children; 8.0; SD: 1.3; 7-10 Y.O; 44% male	Low-Medium- High	PA & SB (ST)	Not applicable	7 Months (2 years)
Fairclough et al., 2013	RCT; England	12 schools/318 children; 10.6; SD: 0.3; 10-11 Y.O; % Not detailed	High & Low	PA & SB (ST)	Nutrition	5 Months
Habib-Mourad et al., 2014	RCT; Lebanon	8 schools/387 children; 10.2; SD: 0.9; 9-11 Y.O; 55% male	Not detailed	PA & SB (screen-time)	Nutrition	3 Months
Huberty et al., 2014	Group RCT; USA	12 schools/667 children;	Not detailed	PA & SB (ST)	Not applicable	9 Months

		9,7; SD: 1,2; 7-11 Y.O; 46% male				
Kipping et al., 2014	RCT; England	60 schools/2221 children; 9,5; SD: 0,3; 9-10 Y.O; 49% male	Low-Medium-High	PA & SB (screen-time)	Nutrition	5 Months
Kobel et al., 2014	RCT; Germany	1943 children; 7,1; SD: 0,6; 7-8 Y.O; 51% male	Not detailed	PA & SB (screen-time)	Nutrition	12 Months
Bhave et al., 2015	Quasi-experimental; India	3 schools/865 children; 9,5; SD: 1,1; 9-10 Y.O; 52% male	High	PA & SB (ST and screen-time)	Nutrition	12 Months (For 5 years)
Madsen et al., 2015	RCT; USA	6 schools/879 children; 9-11 Y.O; 48% male	Not detailed	PA & SB (ST)	Nutrition	10 Months (For 2 years)
Xu et al., 2015	RCT; China	8 schools/1108 children; 10,2; SD: 0,5; 9-10 Y.O; 56% male	Not detailed	PA & SB (screen-time)	Nutrition	8 Months
Amini et al, 2016	RCT; Iran	12 schools/ 334 children; 10,8; SD: 0,9; 10-12 Y.O; 51% male	Medium-Low	PA & SB (screen-time)	Nutrition	5 Months
Anderson et al., 2016	RCT; England	60 schools/2221 children; 9,5; SD: 0,3; 9-10 Y.O; 49% male	Low-Medium-High	PA & SB (screen-time)	Nutrition	7 Months
Efstathiou et al., 2016	RCT; Greece	30 schools/729 children; 8-10 Y.O; 46% male	Low-Medium-High	PA & SB (screen-time)	Nutrition	5 Months
Gallotta et al., 2016	RCT; Italy	3 schools/230 children; 9,3; SD: 0,8; 8-11 Y.O; 45% male	Not detailed	PA & SB (screen-time)	Nutrition	5 Months
Kobel et al., 2016	RCT; Germany	525 children; 7,1; SD: 0,7; 7-8 Y.O; 49% male	Low	PA & SB (screen-time)	Nutrition	10 Months
Lynch et al., 2016	Pilot RCT; USA	1 school/51 children; 7,8; SD: 0,2; 7-8 Y.O; 45% male	Not detailed	PA; SB (screen-time) & SLP	Nutrition	2 Months
Nyberg et al., 2016	RCT; Sweden	13 schools/378 children; 6,3; SD: 0,3; 6 Y.O; 51% male	Medium-Low	PA & SB (screen-time)	Nutrition	6 Months
van Kann et al., 2016	Quasi-experimental; Netherlands	18 schools/520 children; 10,1; SD: 0,7; 8-11 Y.O; 44% male	Low	PA & SB (ST)	Not applicable	12 Months
Brittin et al., 2017	Quasi-experimental; USA	2 schools/41 children; 9,3; SD: 1,2; 8-11 Y.O; 58% male	Not detailed	PA & SB (ST)	Not applicable	12 Months

Hamer et al., 2017	Quasi-experimental; England	7 schools/347 children; 8,8; SD: 0,7; 8-10 Y.O; 55% male	Low	PA & SB (ST)	Not applicable	12 Months
Lloyd et al., 2017	RCT; England	32 schools/1244 children; 9,8; SD: 0,3; 9-10 Y.O; 48% male	Not detailed	PA & SB (ST)	Nutrition	12 Months
Chesham et al., 2018	Quasi-experimental; Scotland	2 schools/379 children; 8,4; SD: 2,0; 6-10 Y.O; 51% male	Not detailed	PA & SB (ST)	Not applicable	10 Months
Morris et al., 2018	Pilot RCT; England	6 schools/154 children; 9,9; SD: 0,3; 9-10 Y.O; 40% male	Not detailed	PA & SB (ST)	Not applicable	2 Months
Taylor et al., 2018	RCT; England	7 schools/114 children; 9-10 Y.O; 48% male	Low	PA & SB (ST)	Not applicable	2 Months
Bartelink et al., 2019	Quasi-experimental; Netherlands	8 schools/ 1676 children; 7,5; SD: 1,3; 5-12 Y.O; 47% male	Low	PA & SB (screen-time)	Nutrition	10 Months (4 years)
Duncan et al., 2019	RCT; New Zealand	16 schools/675 children; 8,72; SD: 1,0; 7-10 Y.O; 48% male	Low, Medium- High	PA & SB (screen-time)	Nutrition	2 Months
Li et al., 2019	RCT; China	40 schools/ 1641 children; 6,15; SD: 0,35; 6-7 Y.O; 54% male	Medium-High	PA & SB (screen-time)	Nutrition and Health Related Quality of Life	12 Months
Norman et al., 2019	RCT; Sweden	13 schools/378 children; 6,3; SD: 0,3; 6 Y.O; 51% male	Medium-Low	PA & SB (screen-time)	Nutrition	12 Months
Verjans-Janssen et al., 2020	Quasi-experimental; Netherlands	11 schools/ 523 children; 8,5; SD: 1,06; 7-10 Y.O; 46% male	Low	PA & SB (ST)	Nutrition	10 Months (2 years)

Abbreviations: RCT = Randomised-Controlled-Trial; Y.O. = Year-old; PA = Physical activity; SLP = Sleep; SB = Sedentary behaviour; ST = Sedentary time.

### *Outcome measure and effectiveness of school-based interventions*

Table 3 presents the measurement tools, the outcome results, and the follow-up measures of the included studies. Regarding the measurement tools, 12 studies were exclusively measured with accelerometry devices (Brittin et al., 2017; Carson et al., 2013; Chesham et al., 2018; Fairclough et al., 2013; Hamer et al., 2017; Huberty et al., 2014; Lloyd et al., 2018; Madsen et al., 2015; Morris et al., 2019; Taylor et al., 2018; Van Kann et al., 2016; Verloigne et al., 2012), 9 studies only used children self-reported questionnaires (Amini et al., 2016; Bacardí-Gascon et al., 2012; Colín-Ramírez et al., 2010; Efstathiou et al., 2016; Habib-Mourad et al., 2014; Lloyd et al., 2012; Salmon et al., 2011; van Stralen et al., 2012; Xu et al., 2015), 6 studies used a combination of self-reported questionnaires for children and device-based measures such as pedometers or accelerometers (Anderson et al., 2016; Breslin et al., 2012; Kipping et al., 2014; Li et al., 2019; Lynch et al., 2016; Verjans-Janssen et al., 2020), 4 studies used parental-reported questionnaires (Brandstetter et al., 2012; Kobel et al., 2014, 2017; Norman et al., 2019), 3 studies used a combination of parental-reported questionnaires and device-based measures in children (Duncan et al., 2019; Hands et al., 2011; Nyberg et al., 2015), 2 studies used parental-reported and self-reported questionnaires for children (Bhave et al., 2016; Gallotta et al., 2016), and only one study used a combination of parental-reported, children self-reported questionnaires and device-based measures in children (Bartelink et al., 2019). The three movement behaviours were measured together in only one study (Lynch et al., 2016), but without sleep post-test measure, and reported no significant intervention effect in any of the three behaviours.

The remaining 36 studies only measured PA and SB. Out of these 36 intervention studies, there was no overall evidence of significant effects on PA and SB outcomes after the intervention in 36% of the studies (Anderson et al., 2016; Bartelink et al., 2019; Brandstetter et al., 2012; Efstathiou et al., 2016; Fairclough et al., 2013; Habib-Mourad et al., 2014; Hamer et al., 2017; Huberty et al., 2014; Kobel et al., 2017; Lloyd et al., 2018; Madsen et al., 2015; Norman et al., 2019; Nyberg et al., 2015). 25% reported significant effects on both PA and SB outcomes (Bacardí-Gascon et al., 2012; Bhave et al., 2016; Breslin et al., 2012; Brittin et al., 2017; Chesham et al., 2018; Gallotta et al., 2016; Li et al., 2019; Verloigne et al., 2012; Xu et al., 2015), 22% reported significant effects only on PA outcomes (Amini et al., 2016; Colín-Ramírez et al., 2010; Duncan et al., 2019; Hands et al., 2011; Morris et al., 2019; Van Kann et al., 2016; van Stralen et

al., 2012; Verjans-Janssen et al., 2020), and finally, 17% reported significant effects on SB alone, of which 11% in sedentary screen-time (Kipping et al., 2014; Kobel et al., 2014; Lloyd et al., 2012; Salmon et al., 2011), and 6% on ST (Carson et al., 2013; Taylor et al., 2018).

Significant changes between baseline time and post-test in at least one of the targeted behaviours were found in 17 studies for PA and 15 for SB, from the intervention group compared to the control group. The duration of effective studies varied from 6 weeks (Morris et al., 2019; Verloigne et al., 2012), to 5 years, with 3 studies reporting intervention durations of 2 years or longer (Bhave et al., 2016; Carson et al., 2013; Verjans-Janssen et al., 2020). The average duration of the interventions was between 7 to 10 months, the most repeated duration was 12 months, and 75% of the effective studies had an intervention duration of at least 5 to 12 months (Amini et al., 2016; Bacardí-Gascon et al., 2012; Bhave et al., 2016; Brittin et al., 2017; Carson et al., 2013; Chesham et al., 2018; Colín-Ramírez et al., 2010; Gallotta et al., 2016; Hands et al., 2011; Kipping et al., 2014; Kobel et al., 2014; Li et al., 2019; Lloyd et al., 2012; Van Kann et al., 2016; van Stralen et al., 2012; Verjans-Janssen et al., 2020; Xu et al., 2015).

In terms of follow-up measures, 29 studies did not report or indicated any measure of the 24-hour movement guidelines, 2 studies reported non-significant effects (Madsen et al., 2015; Norman et al., 2019), 2 studies reported a significant effect on both PA and SB outcomes (Bartelink et al., 2019; Verjans-Janssen et al., 2020), 2 studies reported a significant reduction only in sedentary screen-time or ST (Colín-Ramírez et al., 2010; Nyberg et al., 2015), and 2 other studies reported a significant improvement only in PA outcomes (Duncan et al., 2019; Fairclough et al., 2013). There were no studies with positive effects in either post-test or follow-up for PA and SB outcomes. There were 3 studies with non-significant effects in the post-test but which reported positive effects in the follow-up measure (Bartelink et al., 2019; Fairclough et al., 2013; Nyberg et al., 2015). Further details about the results and follow-up of the 37 studies are available in Annexes of Chapter 4.

Table 3. Measurement tools and outcome results.

Intervention studies	Numbers of studies	Studies with significant effects in PA	Studies with significant effects in SB	Percentage of effectiveness
<b>Outcomes</b>				
Sleep + PA + SB	1	0	0	0 %
PA + SB	36	17	15	44%
<b>Measurement tools</b>				
Self-reported	14	7	6	46%
Device-based	12	5	5	41%
Self-reported+ device-based	11	5	4	38%
<b>Studies with Follow-up</b>				
PA+ SB	8	4	4	50%

Abbreviations: PA = Physical activity; SB = Sedentary behaviour.

#### 4.4. Discussion

Overall, the purpose of this scoping review was to identify existing intervention studies about 24-hour movement behaviours that were delivered in the school setting. This scoping review allowed us to identify that there is a lack of school-based interventions targeting the three 24-hour movement behaviours in 5-12 years old children.

Among the 37 studies included, 62% (i.e., 23 intervention studies of which 18 were RCT) effectively improved PA and/or SB outcomes. Out of the three movement behaviours, PA was the most improved outcome, reporting positive effects in 17 out of the 23 effective studies. Regarding SB, 15 out of the 23 effective studies reported positive effects (i.e., screen-time and/or ST reduction). A recent study about the contribution of different settings to youths' daily PA accumulation suggested that the school setting was the preferred environment to promote PA and reduce ST (Tassitano et al., 2020). Although schools are close to providing the expected amount of MVPA during school-time, this study also highlighted that school-based interventions might produce better results if they were to focus on reducing ST rather than promoting PA (Tassitano et al., 2020).

Then, school-based interventions such as those targeting PA, SB and/or diet are very common in our field as we have shown in Table 2. However, as a main finding of our review, we reported that there is a lack of primary school-based intervention studies that include sleep. We expected to find in the literature several intervention studies



targeting the three movements behaviours, but we only identified one study (Lynch et al., 2016), with just a baseline measure (i.e., without post-test) of sleep. This lack of studies did not allow us to conduct a systematic review or meta-analysis, but it enabled us to detect an important gap in our research field. The absence of school-based interventions about this outcome in our review does not mean that no sleep research studies had been carried out independently in the literature (Ávila-García et al., 2021; Gruber et al., 2016). However, what we have noticed is the scarcity of school-based interventions that include sleep with at least one of the other two movement behaviours simultaneously (i.e., PA and SB). Most interventions that aimed to improve sleep among children have focused on specific or clinical subgroups, and are not applicable to school-aged children (Busch et al., 2017). A recent study (Ávila-García et al., 2021), found that only four sleep education programmes have been carried out in primary schools to improve children's sleep in the last 5 years (Ashton, 2017; Ávila-García et al., 2021; Gruber et al., 2016; Rigney et al., 2015). Integrating sleep interventions into primary schools has the potential of promoting knowledge about the importance of sleep, and involving families to consolidate good sleep habits prior to adolescence and adulthood (Agaronov et al., 2018; Gruber et al., 2014). Since adequate sleep is a core foundation of good health and is reportedly decreasing in children (Chaput et al., 2015; Matricciani et al., 2012), sleep education should be an important consideration for school-aged children. Moreover, as movement behaviours must be combined together to maximise their benefits throughout the whole day (Rollo et al., 2020), sleep should be included in future school-based interventions. Due to these findings, we consider that the school health research is still mainly focused on PA and SB (Chaput et al., 2015; Rigney et al., 2015), and the study of the three movement behaviours has not been fully integrated into primary school interventions.

We have pointed out that the percentage of the age range from the eligible studies is nearly the same between 5 to 9 years-old and 9 to 12 years-old, as well as for the gender of participants. Thus, we can assume that our results are representative for the entire childhood stage (i.e., 5-12 years) in both male and female children. On the other hand, the mean value of the SES in this scoping review was medium-low, but most of the countries where eligible studies were developed belonged to high income regions (i.e., countries from Europe, Oceania, and North America). The same concerns about the SES were found in a previous systematic review (Dobbins et al., 2013), although it is not clear

if these findings are applicable to low and medium SES countries, since cultural differences and the school system may be different and should be considered with caution. Due to this confrontation and the lack of details, we cannot draw sound conclusions about the SES relevance in the current review. Nevertheless, primary school-based interventions in high income countries seem to show an acceptable degree of effectiveness, especially in PA outcomes.

### *Limitations*

The originality of this study is that it focuses on the three movement behaviours in primary school-based interventions, which has not been reviewed before. However, our study has some limitations that should be noted. First, it is possible that we have overestimated the treatment effects when interpreting the results across studies, since we could not conduct a meta-analysis. Second, we found a lack of transparency in some studies about their intervention details that made it difficult to extract specific data. Finally, we restricted our search strategy to five databases, English language studies, and only peer-reviewed articles, avoiding the grey literature. This search procedure could have introduced some publication bias.

### *Implications for School Health Policy and Practice*

This article highlights some recommendations for future research. First, the school is an ideal setting to increase PA and reduce SB. Furthermore, incorporating sleep behaviour within school-based interventions to improve children's health should be considered from the 24-hour movement guidelines perspective. Second, 29 studies did not report or indicate any follow-up measure of the 24-hour movement behaviours, so we encourage researchers to, if possible, include follow-up measures in their school-based interventions to interpret their sustainability. Third, we detected misleading information about the intervention details in several studies. Thus, researchers should try to correctly indicate their intervention details and components in any future studies or in their protocols to favour transparency.

#### 4.5. Conclusion

This is the first scoping review about school-based intervention studies targeting 24-hour movement behaviours in children aged 5–12 years old. As a main result, we found a lack of primary school-based interventions that include sleep in their intervention programmes. Then, further research and more studies are needed to explore this gap and the effectiveness of the 24-hour movement behaviours in the school setting. Also, we detected that only a few studies included follow-up measures about the movement behaviours targeted, being difficult to interpretate the sustainability of interventions. Finally, we encourage researchers to consider the recommendations provided in this paper before designing future school-based interventions, especially if they are going to target 24-hour movement behaviours among 5-12 years-old children.

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## **Chapter 5. Effectiveness of school-based interventions targeting physical activity and sedentary time among children: a meta-analysis**

Chapter 4 presented a scoping review of school-based interventions about physical activity, sedentary behaviour, and sleep among 5-12 years-old children. The review highlighted that 24-hour movement behaviours are not yet fully integrated in primary school-based interventions, with only one study addressing physical activity, sedentary behaviour, and sleep. Thus, detecting an important gap in the literature regarding school-based interventions in children, and justifying the aim and research questions of this thesis. Nevertheless, due to a lack of research studies about the three movement behaviours together, we could not conduct a meta-analysis exploring their effectiveness. Then, as we detected that there is unclear evidence in the literature about the effectiveness of school-based interventions targeting PA and SB, we decided to conduct a meta-analysis addressing that issue. Thus, this chapter provides a systematic review and meta-analysis about the following research question:

- Are school-based interventions effective promoting movement behaviours among children?

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### **5.1.Introduction**

Physical activity (PA) engagement and sedentary time (ST) reduction are both associated with numerous positive outcomes and health benefits (i.e., self-esteem, well-being, fitness and cardiometabolic health, better sleep, etc.) in children (Carson et al., 2016; Poitras et al., 2016). However, most children do not meet the 60 minutes of moderate to vigorous physical activity (MVPA) recommendations (Guthold et al., 2020), and they accumulate several hours of sedentary time across the week that are highly

concerning (Bull et al., 2020). Therefore, promoting regular opportunities for daily MVPA engagement and ST reduction during childhood continues to be a significant public health challenge (Bull et al., 2020; Dobbins et al., 2013; Guthold et al., 2020). In fact, most school-based interventions are more focused on increasing PA levels, although it seems easier to decrease ST in comparison to increase MVPA, especially in the school setting (Tassitano et al., 2020).

Furthermore, the school is an ideal setting to promote healthy behaviours in children, as children spend more than half of their daily waking time here (M. Hegarty et al., 2016), and schools offer a context to reach most children irrespective of their socio-economic status (SES), sex and ethnicity (Åvitsland et al., 2020). Although there are many theoretical frameworks (e.g., socio-ecological model, social-cognitive theory, etc.) and strategies (e.g., behaviour change techniques, motivational strategies, etc.) in the literature, it is currently not clear which are the most effective variables to be used to promote healthy behaviours in the school setting. Indeed, effective health behaviour interventions that act at multiple levels and use multiple components are still challenging in terms of development and implementation (Sallis, 2018). While school-based interventions can include several intervention components like active breaks, family involvement and teacher's training, interventions targeting several health behaviours are usually difficult to implement due to several barriers and limitations (e.g., lack of teacher's formation in health promotion, a limited school timetable, the school curriculum organization, etc.; Champion et al., 2019). Thus, understanding how much children improve their PA and reduce ST levels after attending a school-based intervention is a crucial factor for designing effective multicomponent interventions that needs to be better understood.

Overall, there is a lack of evidence about the effectiveness of school-based PA and ST interventions in the literature, with some researchers reporting positive and negative effects after the intervention and over the long term (Dobbins et al., 2013; Jones et al., 2020; Love et al., 2019; Nally et al., 2021). It must be noted that these studies are not homogeneous, with large disparities between them. In this regard, Dobbins et al., (2013) did not conduct a meta-analysis and mixed self-reported and device-based measures in their overall results. Furthermore, a meta-analysis by Love et al., (2019) only measured MVPA and mixed children and adolescent samples. Two meta-analyses (Jones et al., 2020; Nally et al., 2021) included after-school intervention studies as well as pedometer

and self-reported measures, which reduced the sample size of the studies using accelerometers, especially for ST. In fact, some of these reviews showed positive effects in PA and ST using self-reported measures (i.e., validated questionnaires and ad-hoc questionnaires), mixed-methods and pedometer devices, which have limited validity and differential bias, such as over-estimating PA or under-estimating ST (Ekelund et al., 2019; Tassitano et al., 2020). Given that most school-based interventions in the last decade were designed to increase total activity and decrease inactivity across the whole day, and total MVPA and ST are strongly associated with different health benefits (Bull et al., 2020; Ekelund et al., 2020), it must be required to assess these outcomes objectively if it is intended to draw sound conclusions. Thus, as it was highlighted in the literature, the most accurate and less biased evaluation of MVPA and ST requires an accelerometer assessment (DiPietro et al., 2020; Ekelund et al., 2020; Tassitano et al., 2020).

A scoping review about school-based interventions in children remarked on an overall scarcity of sleep assessment but revealed most interventions assessed both PA and ST together. However, we identified that recent systematic reviews and meta-analyses did not include an important number of studies assessed with accelerometer devices in children (Jones et al., 2020; Love et al., 2019; Nally et al., 2021). Also, we identified that there is a lack of meta-analyses that assessed associations between school-based intervention characteristics and MVPA or ST in children. Moreover, little is known about the social and intervention determinants that drive children PA adoption and maintenance (DiPietro et al., 2020), being a challenge to evaluate their effectiveness, especially in the school setting.

To date, no meta-analysis has examined the influence of specific intervention characteristics in the overall effectiveness of school-based interventions measured only with accelerometer devices. The aforementioned meta-analyses shared some common characteristics with this study, but they were not as specific in terms of assessment procedures, designs and children sample. Therefore, a more fine-grained picture of the overall effectiveness of school-based interventions according to these variables (i.e., components, design, duration, quality and theoretical framework), and outcomes (i.e., MVPA and ST), are required to design future intervention studies. To fill these gaps in the scientific literature, the present systematic review and meta-analysis aimed to: 1) evaluate the overall effectiveness of school-based interventions assessed with accelerometer devices (i.e., daily MVPA and ST), among children aged 5-12 years-old;

and 2) investigate the moderating actions of intervention components, design, duration, quality of the intervention and theoretical framework on these effectiveness rates.

## 5.2.Methods

This systematic review follows the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (Page et al., 2021), and it was registered in the International Prospective Register of Systematic Reviews (PROSPERO), ID: CRD42022326859. The PRISMA checklist is available in Annexes of Chapter 5.

### *Information sources and search strategy*

A structured electronic bibliographic search of 5 databases (Web of Science, Scopus, Pubmed, SPORTDiscuss and Cochrane Library) was conducted to retrieve peer-reviewed intervention articles published in English, French and Spanish language, from January 2010 through December 2021, coinciding with the last decade of research in PA and ST school-based interventions. We selected these databases following the recommendations to conduct academic searches for systematic reviews and meta-analyses (Gusenbauer & Haddaway, 2020). The Population, Interventions, Comparisons and Outcomes (PICO) framework was followed to conduct the literature search (Schardt et al., 2007), and we selected keywords based on previous similar review studies and protocols (Jones et al., 2020; Love et al., 2019; Rodrigo-Sanjoaquín et al., 2020). We provide an example of one of the database searches in Table 1. All other search strategy databases are available in Annexes of Chapter 5.

Table 1. PICO strategy.

Category	Definition	Search terms
Population	Children (from 5 to 12 years old).	Child* OR student OR pupil OR infant OR childhood OR school* OR schoolchildren OR school children OR schoolage* OR school-age* OR school age* OR primary school OR elementary school OR basic school NOT adolescent*.



Intervention	Health promotion intervention studies	Strategy* OR technique* OR intervention* OR program* OR health prevention OR health prevention program* OR health program* OR health promotion program* OR health promotion intervention OR health education OR health intervention OR school setting OR school based intervention OR school-based intervention OR school based program* OR school-based program* OR school program* OR school health program OR school intervention OR school health intervention.
Comparisons	Between intervention and control group.	Not applicable these keywords in search strategy.
Outcomes	Increase PA, reduce ST.	(PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit* OR sport* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercis* OR motor behavio* OR movement) AND (sedentar* OR sedentary behavio* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio* OR sitting time OR prolonged sitting OR domestic activities).

### *Eligibility criteria*

Two review authors identified the searched studies in three steps according to the literature (Gunnell et al., 2020). First, titles and abstracts of the articles returned from the initial search were screened and selected based on eligibility criteria. Second, full-text articles were analysed in detail and selected for eligibility. Finally, bibliographic references of all articles selected were manually analysed to identify relevant articles lost in the initial search strategy. Thus, eligible studies were included if they targeted healthy primary school children without mental disabilities. Study participants were required to have a mean age between 5 and 12 years old with two exposure measurement points (i.e., baseline and post-test). Only interventional designs with a control group measure (i.e., randomised controlled trials [RCT] and quasi-experimental controlled studies) were included. Studies that exclusively used a qualitative approach, and therefore did not include any quantitative data, were excluded from this review. Finally, studies were required to incorporate both daily MVPA and ST measures. The behaviours must have been assessed by accelerometer-devices.

### *Data extraction*

Two review authors independently and systematically extracted the data from the final list of included studies. The following categories were identified and considered

from the manuscripts: publication details (i.e., authors, year); study characteristics (i.e., design, country, sample size, SES, age, and gender); theoretical framework used (e.g., Socio-Ecological Model); intervention components (i.e., school curriculum, family involvement); intervention duration (e.g., three months); and main findings (related to pre-post measures). Discrepancies between the authors were solved by a consensus-based decision. All the extracted data were synthesised and pooled together using tables created with Microsoft Excel.

### *Risk of bias and quality assessment*

The risk of bias and the quality assessment were both assessed independently by two review authors. For the risk of bias, we selected the Cochrane “Risk of Bias Tool 2” (RoB-2) for randomised studies (Sterne et al., 2019), and the “Risk of Bias in Non-randomised Studies - of Interventions” (ROBINS-I) for non-randomised studies (Sterne et al., 2016). These two tools cover a wide range of domains of potential bias, and both instruments focus on the study’s internal validity. Studies were categorised as low, medium, high, and serious risk, as well as with some concerns. To analyse the quality assessment, we selected the “Quality Assessment of Controlled Intervention Studies” tool of the National Institutes of Health (NIH; for further information see <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>). This tool allows to categorise the selected studies in low, medium, or high-quality studies.

### *Meta-analysis*

A meta-analysis was conducted for both daily minutes of MVPA and ST, since these variables are most strongly associated with health-related outcomes (Bull et al., 2020; Ekelund et al., 2019, 2020). When the reporting data in the studies was insufficient (i.e., only school day minutes of MVPA and ST), the corresponding authors were contacted to request additional information. All analyses were performed using Stata software (v16.1; Stata Corp, College Station, TX, USA).

We analysed effects using the DerSimonian-Laird random effects inverse-variance model because heterogeneity was expected in different school-based interventions (Cooper et al., 2019). Study effect sizes (ES) were calculated by subtracting change

differences between the intervention and control groups, using the pooled standard deviation (SD) of change in both groups, as well as pre-SD and post-SD values, assuming a correlation of  $r = 0.5$  between baseline and postintervention (Morris, 2008). If a study had 2 or more intervention groups, their data were analysed independently, with the control group thus yielding multiple ES for that study and outcome. According to Cooper et al., (2019), the magnitude using Hedges'  $g$  was classified as small ( $0 \leq g \leq 0.50$ ), medium ( $0.50 < g \leq 0.80$ ) and large ( $g > 0.80$ ) ES. For MVPA, positive ES values indicated more minutes of MVPA in favour of the intervention group compared with the control group, whereas for ST, negative ES values indicated fewer minutes of ST in favour of the intervention group compared to the control group. Then, two separate random effects meta-analyses were performed for MVPA and ST outcomes respectively. Pooled ES were estimated using 95% confidence intervals (CI).

Also, sensitivity analyses were performed by removing studies one by one to assess the robustness of the summary estimates (Cooper et al., 2019). This would also indicate whether an individual study accounted for a large proportion of the heterogeneity. Then, heterogeneity across studies was calculated using the Cochran Q statistic and using the tau-squared ( $\tau^2$ ) test (Higgins & Thompson, 2002). Proportion of variation across studies was estimated using the inconsistency index ( $I^2$ ), considering values of 30% (low), 50% (moderate) and 75% (high) heterogeneity. For its part, if  $\tau^2$  is above 1, it suggests substantial heterogeneity between studies. Publication bias was analysed using funnel plots and the Egger regression asymmetry test. Additionally, subgroup analyses were run to investigate if heterogeneity could be explained by several characteristics of interest (i.e., design, theoretical framework, intervention components and quality assessment). Finally, a random-effects meta regression analysis was carried out to evaluate the relation between intervention duration and ES in daily MVPA and ST.

### **5.3.Results**

#### *Study selection*

Using the search strategy described above, 12,761 records were identified. After removing 4,226 duplicates, 8,535 articles remained for screening. These 8,535 manuscripts were screened by the abstract and 8,382 were excluded based on eligibility criteria. Then, 153 full-text articles were screened, of which only 34 publications were

deemed valid based on eligibility criteria. Finally, a total of 24 intervention studies provided necessary data and were then included in the meta-analysis (see Figure 1).

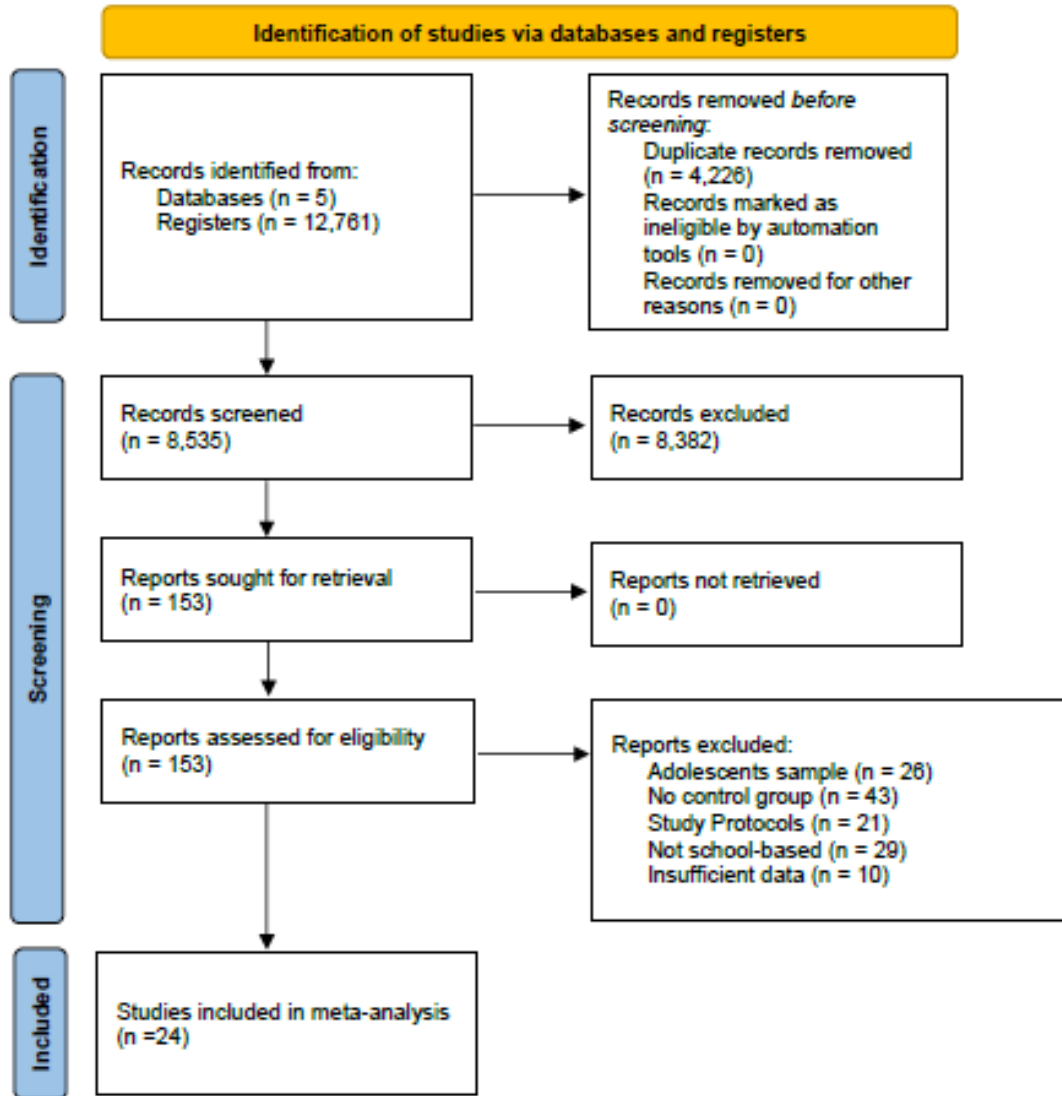


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

### *Study characteristics*

The study characteristics are summarized in table 2. The systematic review and meta-analysis included 10 cluster RCTs (Adab et al., 2018; Engelen et al., 2013; Kobel et al., 2017, 2020; Lloyd et al., 2012; Nathan et al., 2020; Resaland et al., 2016; Seljebotn

et al., 2019; Telford et al., 2016; Wells et al., 2014), 10 RCT (Anderson et al., 2016; Bernal et al., 2021; Fairclough et al., 2013; Kipping et al., 2014; Kocken et al., 2016; Li et al., 2019; Lloyd et al., 2018; Madsen et al., 2015; Morris et al., 2019; Verloigne et al., 2012), and 4 quasi-experimental studies (Bartelink et al., 2019; Breslin et al., 2012; Brittin et al., 2017; Verjans-Janssen et al., 2020) with a total of 19,487 healthy children aged 5-12 years-old. All studies included boys and girls (48.7% and 51.3%, respectively), only two studies did not include gender percentage (Engelen et al., 2013; Fairclough et al., 2013). 9 Studies were conducted in Europe (Bartelink et al., 2019; Bernal et al., 2021; Kobel et al., 2017, 2020; Kocken et al., 2016; Resaland et al., 2016; Seljebotn et al., 2019; Verjans-Janssen et al., 2020; Verloigne et al., 2012), 8 in United Kingdom (Adab et al., 2018; Anderson et al., 2016; Breslin et al., 2012; Fairclough et al., 2013; Kipping et al., 2014; J. Lloyd et al., 2018; Lloyd et al., 2012; Morris et al., 2019), 3 in United States of America (Brittin et al., 2017; Madsen et al., 2015; Wells et al., 2014), 3 in Australia (Engelen et al., 2013; Nathan et al., 2020; Telford et al., 2016), and 1 in China (Li et al., 2019). The SES was not detailed in 11 studies (Adab et al., 2018; Bernal et al., 2021; Brittin et al., 2017; Engelen et al., 2013; Kobel et al., 2020; J. Lloyd et al., 2018; Madsen et al., 2015; J. L. Morris et al., 2019; Resaland et al., 2016; Seljebotn et al., 2019; Verloigne et al., 2012). All studies were implemented in high-income countries (n = 24). Kobel et al., (2017), only provided accelerometer data for MVPA, while Kobel et al., (2020) only did it for ST. Nevertheless, both studies included intervention strategies to improve PA and reduce ST. There was only one study that provided data from two intervention groups for both MVPA and ST outcomes (Bartelink et al., 2019).

Table 2. Summary of the studies included.

<b>STUDY</b>	<b>CHARACTERISTICS</b> (Design; Country)	<b>SAMPLE</b> (Sample; SD; mean age; % male)	<b>SES</b>	<b>TEORETICAL FRAMEWORK</b>	<b>INTERVNTION COMPONENTS</b>	<b>INTERVENTION DURATION</b>	<b>QUALITY ASSESSMENT</b>
Breslin et al., 2012	Non RCT; Northern Ireland	416 children; 9,1; SD: 0,36; 8-9 Y.O; 48% male	Low	Social Cognitive Theory	School curriculum and teacher training	3 Months	3 (LQ)
Lloyd et al., 2012	Cluster RCT; England	202 children; 9,69; SD: 0,3; 9-10 Y.O; 50% male	High	Intervention Mapping	School curriculum, school staff and family involvement	6 Months	7 (MQ)
Verloigne et al., 2012	Pilot RCT; Belgium	372 children; 10,9; SD: 0,7; 10-12 Y.O; 40% male	Not detailed	Socio-ecological Model	School curriculum, teacher training and family involvement	2 Months	6 (MQ)
Fairclough et al., 2013	RCT; England	318 children; 10,6; SD: 0,3; 10-11 Y.O; % Not detailed	High & Low	Social Cognitive Theory	School curriculum, teacher training and family involvement	5 Months	8 (MQ)
Engelen et al., 2013	Cluster RCT; Australia	226 children; 5,9; SD: 0,5; 5-7 YO; % Not detailed	Not detailed	Not detailed	Playground intervention, teacher and family involvement	3 Months	10 (HQ)
Kipping et al., 2014	RCT; England	2221 children; 9,5; SD: 0,3; 9-10 Y.O; 49% male	Low- Medium- High	Social Cognitive Theory	School curriculum, teacher training and family involvement	5 Months	7 (MQ)
Wells et al., 2014	Cluster RCT; USA	227 children; 9,3; SD: 0,7; 8-12 YO; 44,6% male	Low	Not detailed	physical environment and school curriculum	12 Months	10 (HQ)
Madsen et al., 2015	RCT; USA	879 children; SD not detailed; 9-11 Y.O; 48% male	Not detailed	Social Cognitive Theory	School curriculum, active breaks and teacher training	10 Months (For 2 years)	6 (MQ)
Anderson et al., 2016	RCT; England	2221 children; 9,5; SD: 0,3; 9-10 Y.O; 49% male	Low- Medium- High	Social Cognitive Theory	School curriculum and teacher training	7 Months	11 (HQ)
Kocken et al., 2016	RCT; Netherlands	1112 children; SD not detailed; 9-11 years old; 49% male	Medium	Intervention Mapping	School curriculum	10 Months (For 2 years)	10 (HQ)
Resaland et al., 2016	Cluster RCT; Norway	1129 children; 10,2; SD: 0,3; 10-11 YO; 52% male	Not detailed	Not detailed	School curriculum, active breaks, homework PA and teacher training	8 Months	11 (HQ)
Telford et al., 2016	Cluster RCT; Australia	853 children; 8,1; SD:0,3; 8-9 YO 51% male	Medium	Not detailed	PE classes	10 months (For 4 years)	10 (HQ)

Brittin et al., 2017	Non-RCT; USA	41 children; 9,3; SD: 1,2; 8-11 Y.O; 58% male	Not detailed	Not detailed	Physical environment modifications	12 Months	4 (MQ)
Kobel et al., 2017	Cluster RCT; Germany	167 children; 8,0; SD: 0,6; 8-9 YO; 46,1% male	Low-Medium-High	Social Cognitive Theory	School curriculum	10 months	6 (MQ)
Lloyd et al., 2017	RCT; England	1244 children; 9,8; SD: 0,3; 9-10 Y.O; 48% male	Not detailed	Social Cognitive Theory	School curriculum and family involvement	12 Months	11 (HQ)
Adab et al., 2018	Cluster RCT; England	1397 children; 6,3; SD: 0,3; 6-7 YO; 51% male	Not detailed	Not detailed	school curriculum, after school activities and family involvement	12 Months	10 (HQ)
Morris et al., 2018	Pilot RCT; England	154 children; 9,9; SD: 0,3; 9-10 Y.O; 40% male	Not detailed	Not detailed	Teacher training	2 Months	6 (MQ)
Bartelink et al., 2019	Non-RCT; Netherlands	1676 children; 7,5; SD: 1,3; 5-12 Y.O; 47% male	Low	Health Promoting Schools (HPS)	PA promotion and lunch breaks	10 Months (For 4 years)	3 (LQ)
Li et al., 2019	RCT; China	1641 children; 6,15; SD: 0,35; 6-7 Y.O; 54% male	Medium-High	Social Cognitive Theory	School curriculum and family involvement	12 Months	10 (HQ)
Seljebotn et al., 2019	Cluster RCT; Norway	447 children; 9,3; SD: 0,4; 9-10 YO 52% male	Not detailed	Not detailed	School curriculum and teacher training	10 Months	8 (MQ)
Kobel et al., 2020	Cluster RCT; Germany	231 children; 7,1; SD: 0,6; 7-8 YO; 46,1% male	Not detailed	Social-ecological Model; Social Cognitive Theory; Implementation Mapping	School curriculum, teacher training, active breaks and family involvement	12 Months	7 (MQ)
Nathan et al., 2020	Cluster RCT; Australia	1502 children; 8,01; SD: 2,04; 6-11 YO; 51% male	High & Low	Theoretical domains framework	Active breaks and lunchbox support	9 Months	11 (HQ)
Verjans-Janssen et al., 2020	Non-RCT; Netherlands	523 children; 8,5; SD: 1,06; 7-10 Y.O; 46% male	Low	Comprehensive School Health	School curriculum and staff involvement	10 Months (For 2 years)	4 (MQ)
Bernal et al., 2021	RCT; France	288 children; 8,76; SD:1,4;6-10 YO; 52% male	Not detailed	Social-ecological Model	School curriculum, active breaks, teacher training, physical environment, and family involvement	10 months (For 2 years)	5 (MQ)

Abbreviations: RCT = Randomised-Controlled-Trial; Y.O. = Year-old; SD = Standard Deviation; LQ = Low Quality; MQ = Medium Quality; HQ = High Quality.

### *Intervention characteristics*

Concerning interventions, 8 studies (i.e., 33%) were based on Social Cognitive Theory (Anderson et al., 2016; Breslin et al., 2012; Fairclough et al., 2013; Kipping et al., 2014; Kobel et al., 2017, 2020; J. Lloyd et al., 2018; Madsen et al., 2015), 3 studies (i.e., 12%), on the Socio-ecological Model (Bernal et al., 2021; Kobel et al., 2020; Verloigne et al., 2012), 5 studies (i.e., 20%), on other theoretical frameworks (Bartelink et al., 2019; Kocken et al., 2016; Lloyd et al., 2012; Nathan et al., 2020; Verjans-Janssen et al., 2020), and 8 (i.e., 33%), did not detail anyone (Adab et al., 2018; Brittin et al., 2017; Engelen et al., 2013; Morris et al., 2019; Resaland et al., 2016; Seljebotn et al., 2019; Telford et al., 2016; Wells et al., 2014). Interventions used a combination of intervention components (i.e., school curriculum, teacher training, family involvement, active breaks, etc.) or at least one component when they were delivered in the school setting. Regarding to that, there were 5 single component interventions (Brittin et al., 2017; Kobel et al., 2017; Kocken et al., 2016; Morris et al., 2019; Telford et al., 2016), 9 two-components interventions (Anderson et al., 2016; Bartelink et al., 2019; Breslin et al., 2012; Li et al., 2019; Lloyd et al., 2018; Nathan et al., 2020; Seljebotn et al., 2019; Verjans-Janssen et al., 2020; Wells et al., 2014), 7 three-components interventions (Adab et al., 2018; Engelen et al., 2013; Fairclough et al., 2013; Kipping et al., 2014; Lloyd et al., 2012; Madsen et al., 2015; Verloigne et al., 2012), and 3 studies with four or more components (Bernal et al., 2021; Kobel et al., 2020; Resaland et al., 2016). The duration of intervention studies varied from 2 months (Morris et al., 2019; Verloigne et al., 2012), to 4 years (Bartelink et al., 2019; Telford et al., 2016), with 13 studies averaging >10 months' duration (Adab et al., 2018; Bartelink et al., 2019; Bernal et al., 2021; Brittin et al., 2017; Kobel et al., 2017; Kocken et al., 2016; Li et al., 2019; Lloyd et al., 2018; Madsen et al., 2015; Seljebotn et al., 2019; Telford et al., 2016; Verjans-Janssen et al., 2020; Wells et al., 2014).

### *Risk of bias and quality assessment*

All studies met criteria on the RoB-2 or ROBINS-I scales, and both are summarized in Annexes of Chapter 5. Low scores in both scales corresponded to studies that had some bias in the measure of the outcome, bias in selection of the reported result, bias from the randomization and allocation process, and due to not blinding participants and study personnel to intervention assignment (i.e., very difficult to do in school-based studies).



Results from quality assessment were shown in table 2. There were 2 studies (i.e., 8%), categorized with low quality (Bartelink et al., 2019; Breslin et al., 2012), 12 studies (i.e., 50%), with medium quality (Bernal et al., 2021; Brittin et al., 2017; Fairclough et al., 2013; Kipping et al., 2014; Kobel et al., 2017, 2020; Lloyd et al., 2012; Madsen et al., 2015; Morris et al., 2019; Seljebotn et al., 2019; Verjans-Janssen et al., 2020; Verloigne et al., 2012), and 10 studies (i.e., 42%), with high quality (Adab et al., 2018; Anderson et al., 2016; Engelen et al., 2013; Kocken et al., 2016; Li et al., 2019; Lloyd et al., 2018; Nathan et al., 2020; Resaland et al., 2016; Telford et al., 2016; Wells et al., 2014).

### Quantitative analysis

The pooled ES estimates for the effects of interventions on MVPA was  $g = 0.07$  (95%CI -0.03 to 0.17), indicating nonsignificant low effect as indicated by the CIs from a negative small effect to a positive small effect. The Cochrane Q showed a significant heterogeneity ( $Q = 151.27, p < .001; \tau^2 = 0.05$ ) and considerable inconsistency measure ( $I^2 = 84.80\%$ ). Sensitivity analysis revealed that only one study (Breslin et al., 2012), was a potential outlier and considered overly influential ( $g = 0.03, 95\%CI -0.06$  to  $0.12, p < .001, Q = 110.96, I^2 = 80.17\%; \tau^2 = 0.03$ ). As shown in Figure 2, the Funnel plot of the observed effect showed small asymmetry in the left side, and the Egger test suggested evidence of publication bias for MVPA ( $Z = 2.06, p = 0.0393$ ). Meta-regression analysis found that duration of the school-based interventions was not associated with changes in daily MVPA ( $\beta = 0.009; p = 0.51$ ).

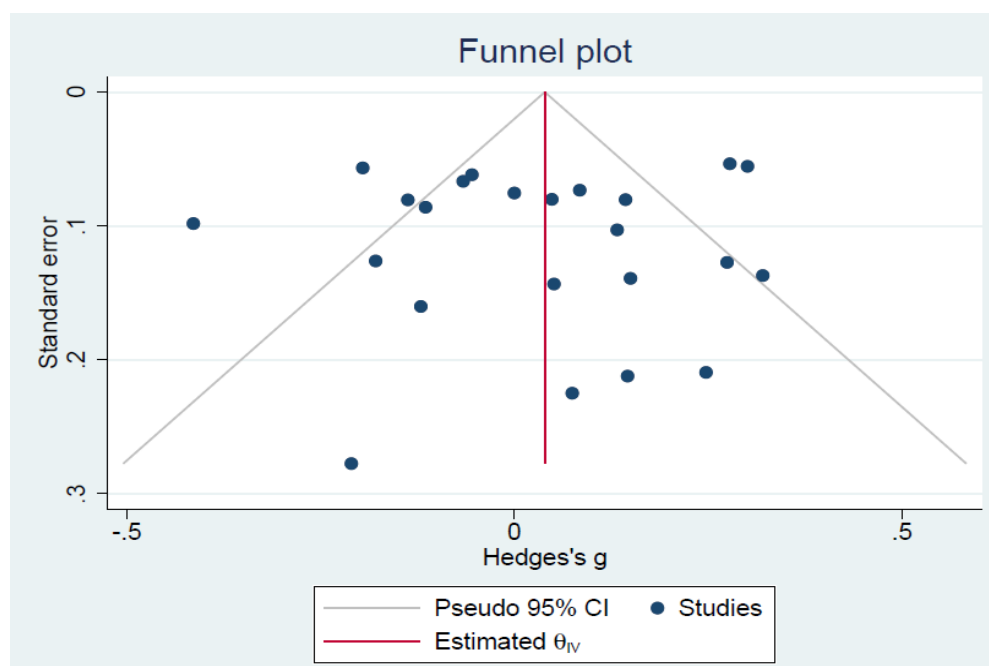


Figure 2. Funnel Plot showing the publication bias of MVPA studies.

Subgroup analyses did not show any significant result with respect to design ( $p = 0.28$ ) and theoretical framework ( $p = 0.77$ ) variables. However, as shown in Table 3, subgroup analysis of intervention components and quality assessment variables demonstrated that daily MVPA differed significantly by school-based interventions, showing better outcomes in those with two intervention components ( $g = 0.21$ , 95% CI 0.06 to 0.36,  $p < .001$ ,  $Q = 44.78$ ,  $I^2 = 77.67\%$ ;  $\tau^2 = 0.02$ ), and labelled with high quality assessment ( $g = 0.12$ , 95% CI 0.01 to 0.22,  $p < .001$ ,  $Q = 76.95$ ,  $I^2 = 88.30\%$ ;  $\tau^2 = 0.05$ ).

Table 3. MVPA subgroup analyses.

Variables	<i>N</i>	Mean difference, 95% CI	<i>p</i> for subgroup analysis
1) Design			0.28
Non-RCT	5	0.30 (-0.10, 0.70)	
RCT	10	-0.02 (-0.17, 0.14)	
Cluster RCT	9	0.09 (-0.03, 0.20)	
2) Intervention components			<b>0.02</b>
1 component	5	-0.07 (-0.20, 0.06)	
2 components	10	<b>0.21 (0.06, 0.36)</b>	
3 components	7	-0.07 (-0.22, 0.08)	
4 components	2	-0.05 (-0.17, 0.08)	
3) Theoretical Framework			0.77
No Theoretical Framework	8	0.05 (-0.05, 0.16)	
With Theoretical Framework	16	0.08 (-0.05, 0.21)	
4) Quality Assessment			<b>0.04</b>
Low Quality	3	0.45 (-0.14, 1.03)	
Medium Quality	10	-0.07 (-0.21, 0.06)	
High Quality	11	<b>0.12 (0.01, 0.22)</b>	

The pooled ES estimates for the effects of interventions on ST was  $g = -0.08$  (95% CI -0.12 to -0.03), indicating significant low effect in the reduction of daily ST (See Figure 3). The Cochran Q showed a nonsignificant heterogeneity ( $Q = 29.09$ ,  $p = 0.18$ ;  $\tau^2 = 0.01$ ) and low inconsistency measure ( $I^2 = 20.94\%$ ). Sensitivity analysis revealed that there was not any potential outlier or influential study. The Funnel plot showed asymmetry in the right side, and the Egger test suggested evidence of publication bias for ST ( $Z = -2.24$ ,  $p = 0.025$ ). Meta-regression analysis found that duration of the school-based interventions was not associated with changes in daily ST ( $\beta = -0.0003$ ;  $p = 0.96$ ).

Finally, subgroup analyses were not conducted due to the lack of heterogeneity detected in the ST forest plot.

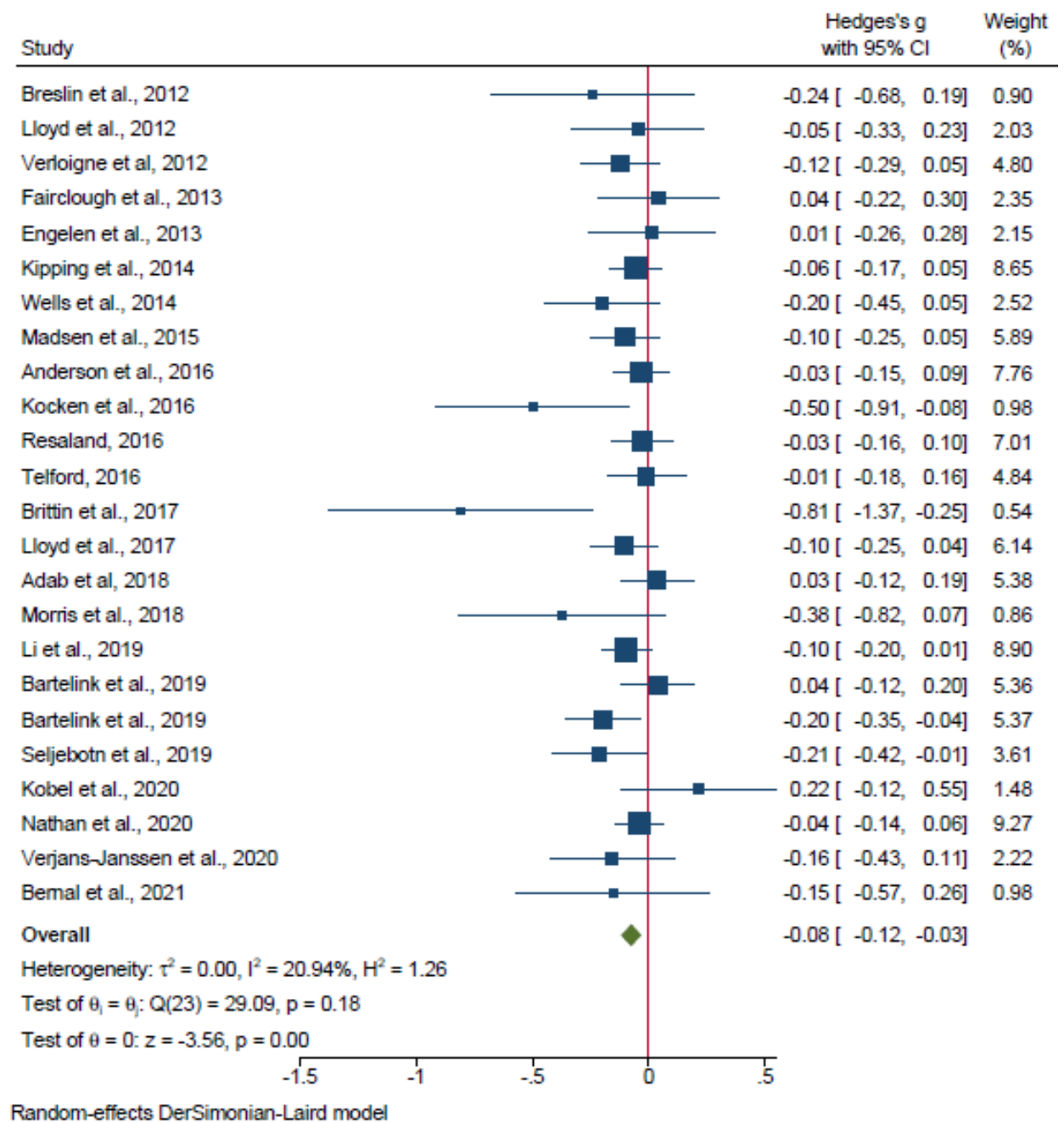


Figure 3. Forest plot showing the effects sizes (Hedge's g) of school-based interventions on daily ST for each study.

## 5.4. Discussion

This is the first meta-analysis that has focused on the overall and specific effects of school-based interventions only assessed with accelerometer devices (i.e., daily minutes of MVPA and ST) among 5-12 years-old children. The main findings of this study are the following: (1) school-based interventions are effective to reduce daily ST in children, but apparently not to improve MVPA; (2) multi-component interventions (i.e., 2 components) significantly improved daily MVPA in children; and (3) high quality interventions also favour a significant increase in daily MVPA.

### *MVPA and ST effectiveness*

In the last few years, developmental evidence has been accumulated regarding the effects of school-based interventions targeting MVPA and ST outcomes (Jones et al., 2020; Love et al., 2019; Nally et al., 2021). Then, in terms of daily MVPA, we found non-significant effects of school-based interventions, being consistent with previous research. For example, a meta-analysis (n=17) by Love et al., (2019), detected a non-significant effect (ES = 0.02, 95% CI -0.07 to 0.11) in children and adolescents. Oppositely, Jones et al., (2020) meta-analysis (n = 11), found a moderate effect (ES = 0.51, 95%CI: 0.02 to 0.99), but it was not supported by the sensitive analysis and they declared no evidence of effect. Finally, a subgroup analysis (n = 16) of device-based (i.e., pedometers and accelerometers) studies in the Nally et al., (2021) meta-analysis, found a strong positive effect (ES = 1.53, 0.49 to 2.57). However, they did not detail the significance ( $p < 0.05$ ) of the subgroups analysis and reported inconclusive effects for daily MVPA. Therefore, this may be interpreted that either the interventions are not effective or that they are not correctly implemented and assessed or that they could be effective in some groups but not others.

The overall daily ST from previous meta-analyses differed significantly from our results since we found a small significant ST reduction in favour of the intervention group. Although other studies have not included ST (Love et al., 2019), Jones et al., (2020), reported a non-significant large effect (ES = 1.15, 95% CI -1.03 to 3.33) with a small study sample (n = 4), and finally, a subgroup analysis (n = 11) of device-based measures in Nally et al., (2021) study found non-significant results (ES = -0.91, -2.30 to 0.48). Then, the significant effect size found in this ST meta-analysis was not very large to draw final

conclusions, however we considerate it another important step in the knowledge of our research field. Thus, our findings support that those interventions delivered during the school day might produce more effective results on reducing ST than promoting MVPA. In this regard, Tassitano et al., (2020) concluded in their study that interventions delivered during the school day might produce better results if they focus on reducing ST rather than promoting PA. The effectiveness in ST reduction but not in MVPA increase may be due to the fact that the school setting is mainly sedentary (i.e., a lot of sitting time during classes), and therefore it could be easier to reduce that level of sedentary with a school-based intervention (e.g., active breaks) than improving the total time of MVPA, which may be a type of activity far away from an standard educational task. Finally, we hypothesise that previous meta-analyses did not find any significant ST reduction because they had a limited sample size as well as mixed self-reported and device-based results in their analyses.

#### *School-based intervention components*

Then, subgroup analyses revealed that all intervention components do not produce similar results, as we highlighted previously. It was difficult to compare our findings with other studies due to different procedures used and only Nally et al., (2021) conducted similar subgroups analysis, without reporting their significance (i.e.,  $p$  value), inferring misleading errors. However, the literature has suggested that PA may be enhanced, and ST reduced by school-based multicomponent interventions and the school setting (Sallis, 2018; Tassitano et al., 2020), and this study found that interventions with two components seems to be more effective than single and more than two component interventions. These findings add to the emerging evidence that multicomponent interventions produce larger improvements in MVPA than single component interventions (Dobbins et al., 2013; Sallis, 2018). Nevertheless, our results seem to suggest that there may be a limited effect in the number of components, without being more effective the addition of extra components. Also, even if the significant effect sizes reported after performing subgroup analyses were not large, they provide new value information about school-based interventions assessed with accelerometer devices targeting MVPA. Thus, future research should be focused on detecting which are the key intervention components (e.g., school curriculum, active breaks, family involvement, etc.), since we could not draw sound

conclusions about them after performing several subgroup analyses. Regarding the duration of school-based interventions and their effectiveness, no differences were observed in our meta-regression analyses for both MVPA and ST outcomes. Also, previous meta-analyses found similar results when they performed meta-regression (Love et al., 2019), or subgroup analyses (Nally et al., 2021). Thus, the intervention duration may not be as determinant as we thought. Probably, it will be more important for future research to focus on detecting effectiveness by other similar factors like frequency of implementation.

In terms of designs and quality of the studies included in this meta-analysis, most of them were RCTs and cluster RCTs with only 4 quasi-experimental studies, being 3 of them categorised as low quality. Also, we found in the subgroup analyses that only high-quality interventions favoured a significant increase in daily MVPA, differing from previous studies which did not find significant results in relation to study quality (Jones et al., 2020; Love et al., 2019), thus contributing valuable information to the literature. This review highlights the importance of conducting, as frequent as possible, high-quality studies in our research field. Furthermore, we recommend researchers to correctly indicate their intervention program details, to describe the assessment processes as well as to detail their data analyses in deep to favor transparency, future replicability and, thus, better contribute to our field of research. Regarding potential bias in the meta-analysis, we did not restrict our eligibility criteria to only RCTs as other studies did (Love et al., 2019; Nally et al., 2021), because a lot of school-based interventions use quasi-experimental designs, and this could limit the representation of the big picture. However, some publication biases were detected in both MVPA and ST funnel plots and Egger tests, being almost sure influenced by our strict eligibility criteria. Similar concerns about publication bias were found in a meta-analysis conducted with very restricted eligibility criteria (Love et al., 2019). Therefore, restricting inclusion criteria limits the generalizability of our findings, but this represents most of the available evidence and maximises the reliability and robustness of our conclusions.

### *Limitations*

The major strengths of this meta-analysis compared with previous are the specificity (i.e., only intervention studies delivered with children in the school time and

assessed with accelerometer devices), our studies sample size in both MVPA and ST outcomes ( $n = 24$ ), the pooling of comparable accelerometer measures of daily MVPA and ST, and the assessment of different subgroup effects. The limitations of the study that could compromise the robustness of our findings are as follows: (1) although the measurement device did not vary across studies, some other variables (e.g., epochs duration, how the accelerometer data was processed, cut points for thresholds, etc.) were not homogeneous; (2) the high level of heterogeneity detected across the included studies in terms of MVPA effects. Pooled results indicated high levels of heterogeneity and some of the analyses remained unexplained despite subgroup analyses; (3) we found significant publication bias in both MVPA and ST meta-analyses; and (4) we included quasi-experimental studies, which introduced some risk of bias, mainly in terms of participants allocation and selection of the reported results.

## **5.5. Conclusion**

This systematic review and meta-analysis demonstrate that school-based interventions have been effective at decreasing children's daily time spent in ST. Furthermore, we found that even if school-based interventions are not enough effective to improve overall daily MVPA in children, multi-component interventions (i.e., 2 components) and high-quality intervention studies, are predictive of improved daily time spent in MVPA. Given the high number of intervention studies, the homogeneity of some results, the quality of the studies and the sound methodology used, these results provide robustness regarding the existing evidence. However, findings about publication bias should also be noted. Further assessment of implementation fidelity is required before it can be concluded that school-based interventions have a contribution to reduce ST in children. Thus, we recommend that further school-based interventions with children should be conducted to determine which are the most important intervention components (e.g., active breaks, school curriculum, family involvement, etc.) to improve PA and reduce ST.

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## **Chapter 6. Promoting health in Spanish children applying CAS Framework: A system approach**

Chapter 1 and 2 provided a general overview of the research field and highlighted the gaps explored in this thesis. Then, chapters 3,4 and 5 reviewed the literature and the available evidence about school-based interventions and 24-hour movement behaviours in school-aged children. Thus, this chapter contains the intervention protocol describing the school-based intervention carried out in a Spanish school among children aged 3-9 years. The main reason to report and describe the intervention protocol was to detail the co-creation process followed to design the school-based intervention, which is not usual in our research field. Thus, this chapter contains the intervention protocol which addressed the following research question:

- How effective can a co-created school-based intervention be to promote 24-hour movement behaviours in children?

This chapter has been published as:

(It is currently being assessed on peer-review process)

### **6.1. Introduction**

Childhood is an important phase of rapid growth and development in physical, psychological, and cognitive domains (Landry et al., 2011). At the same time, it becomes very important to make early prevention efforts because health-related behaviours acquired at this age usually tend to persist into adulthood (Telama et al., 2014). However, 80% of youths worldwide do not reach the global physical activity (PA) recommendations (i.e., more than 60 min of daily MVPA; Guthold et al., 2020). Moreover, sedentary behaviour (SB), referring to sedentary time (ST) and screen-time, takes up over 50% of the waking day for 7-year-old children (Janssen et al., 2016). Also, children today sleep less and less, with only 60% of them meeting the sleep recommendations (Matricciani et al., 2012), and the consumption of fruits and vegetables in the last years is becoming lower and lower in European countries (Hebestreit et al., 2014). Therefore, the number of obese children and adolescents has increased within the last 40 years from 11 million in



1975 to 124 million in 2016 (Bentham et al., 2017). Given these figures, it is not surprising that children's health worldwide poses a serious level of concern in our society.

Concretely, the school setting is of paramount importance as most of the children spend half of their daily waking time there (Hegarty et al., 2016). The scientific literature also highlights the school as a privileged environment to implement health promotion programs (Singh et al., 2017). Thus, schools have the potential to play a decisive role in health promotion, taking advantage of their organisational and social structures to provide several opportunities to promote healthy environments (Buijs, 2009). Currently, a growing number of research studies have examined their health program effectiveness (Langford et al., 2015), but few studies described their intervention development process, such as how other stakeholders were involved (McHugh et al., 2020), or how sustainable the interventions were for the future (Herlitz et al., 2020).

Interventions addressing health promotion among children have focused on 'individual-level' approaches which often fail to demonstrate large effects. Recent attention has been on an alternative 'whole-school' approach that involves promoting physical activity and other health behaviours throughout all aspects of the school environment (i.e., individual, organisational and community level) among children and adolescents (Tibbitts et al., 2021). However, the evidence of the school-based interventions is mixed depending on what it is analysed. Although it seems that whole-school approaches are effective ways to create changes and improve health and wellbeing in school settings (Vreeman and Carroll, 2007), it remains unclear which characteristics should have effective whole-school approaches to be successfully implemented and sustainable (Sallis, 2018). This question arises as there are a limited number of children intervention programs that have addressed multiple health behaviours attending to multilevel (individual, social, and institutional level) and multicomponent (curricular and non-curricular) approaches (Sallis, 2018; Schölmerich and Kawachi, 2016). Also, there are few children intervention programs that use a holistic and innovative framework to promote health behaviours (Deschesnes et al., 2013).

In 2020 to address this gap in United Kingdom (UK) schools, an experience-driven creative consultation between UK academics and public sector stakeholders led to the creation of the Creating Active Schools (CAS) framework (Daly-Smith et al., 2020). The CAS framework reinforced the need for change at the individual, school

environment, and community level, as outlined in the Health Promoting Schools (HPS) guidelines. This whole-school approach has three main levels: (1) the grand system (i.e., national organisations and policies), it refers to national organisations and policies that drive the educational focus of schools and the training needs of the key stakeholders; (2) the local system, which is composed by the social environment (i.e., it refers the degree to which the stakeholders engage and support each other to provide health behaviours) and the physical environment (e.g., green space, playground, school hall and quality of available resources); and (3) the in-school factors, (e.g., school events, physical education [PE] classes, school curriculum, active breaks, active commuting, before/after school activities, family and community activities). Therefore, this framework allows to identify the priorities and modify the existing structures to promote behavioural change. Also, this is the first framework where all components have been collated and reinforces the need to create systems change through school leadership groups. Nevertheless, whereas little is currently known about the inter-relationship between the different school elements, the CAS tries to establish whole-school ethos and practice at the heart of health behaviours promotion. Thus, CAS allows to identify and activate levers at the different levels of the model to be more efficient (i.e., not only focusing on children, but also on teachers, parents, other stakeholders, etc.). This system approach will guide us to plan and implement the intervention program exposed in this manuscript. Consequently, this is the first Spanish intervention program which has been planned to use the CAS framework.

### *Aim*

The overall aim of this article is to describe the rationale, the methods, and the evaluation process of a multi-component school-based intervention to improve health behaviours promotion in the whole school setting (i.e., among children, teachers, and families), using the CAS framework. Then, beyond the overall aim and the scope of this paper, we detail the specific objectives and hypotheses expected for this school-based intervention program. They correspond to those that will be pursued more specifically through this system approach intervention. Also, they will be detailed, explained, and analysed more specifically in future studies.

- *Aim 1:* To examine the associations between the school-based intervention with children and family's health behaviours (e.g., PA, SB, healthy nutrition variables,

sleep outcomes, and wellbeing). *Hypothesis 1*: Compared with baseline, higher PA, healthy nutrition, sleep, wellbeing, and fewer SB (i.e., ST and screen-time) outcomes will be reported by children and their families at two and three years after the implementation of the program.

- *Aim 2*: To examine the associations between environmental and social changes on transport choices in children enrolled in the school program compared with their baseline data. *Hypothesis 2*: Children will have higher rates of active commuting to school, particularly cycling, and greater overall PA levels after two and three years than at baseline.
- *Aim 3*: To identify perceptions associated with the implementation of the health promotion program in teachers and school staff after three years compared with baseline. *Hypothesis 3*: Compared with baseline, fewer implementation and sustainability barriers for the program will be reported by teachers and school staff.

## 6.2. Method

This program involves one kindergarten and primary school in a small city of Huesca province (Spain). The school led the start of the intervention in 2019. The school staff wished to create a sort of intervention program for the whole school setting, and they solicited the university's help to create a natural intervention. Then, some researchers of the University of Zaragoza joined the project, and finally, we initiated a co-creation process through the functioning of a "Local Working Group". This group is composed of different stakeholders (teachers, family representatives, a municipal town hall worker [sport area] and health professionals), and it was established to give advice about main topics related to the intervention. The COVID-19 pandemic and the successive restrictions did not allow the research process to be extended to some other schools of the city and, in consequence, it was not possible to obtain a control school. It should be noted that the intervention school was a new school establishment recently created in the city and that is why only three kindergarten courses, and the first three primary school courses were available in the centre.

### *Study setting*

The school is in the sixth largest city of the Huesca territory by population (Binefar; 9742 inhabitants). Also, this city has a population density of 374,14 inhabitants per km<sup>2</sup>, and an annual mean temperature of 14,2° C. Regarding the educational setting, the city has 4 primary schools (3 public schools and 1 sponsored school). In 2019 this new school was located on a newly built site. The city's topography, climate and education settings offer the opportunity to examine the whole school setting (i.e., children health behaviours effects, children, teachers and families active commuting, school program implementation and stakeholders' interaction).

### *Research design*

In the context of a natural intervention, the study will be guided by the CAS framework that accounts for individual, social, environmental and policy school factors (Daly-Smith et al., 2020). This is a longitudinal and quasi-experimental study without a control group. It integrates both quantitative and qualitative methods during the first 3 years of the program implementation (2020-2023).

In the planning phase (i.e., year 2019), several meetings were held between the research group and the school staff to plan the design of the intervention program. To develop the intervention, the Local Working Group was formed. In addition, a co-design process was established at each meeting, whereby key stakeholders provided input into the design and development of the intervention. The Local Working Group leaders are the school staff (i.e., director, head of studies and secretary) and they led and coordinated the collaborative process.

### *Participants*

As a whole school setting approach, the participants are children, teachers, and families. Nevertheless, the eligible population of this study represents 127 students (~20 students per class/school year × 6 classes), a representative family's sample size (~60 parents; one father or mother per children) and 10 schoolteachers. We selected a representative family's sample size due to the difficulties to afford and coordinate a sample size of ~260 adults and their low available time. The children's sample size is

integrated by 3 school years of kindergarten children and 3 school years of primary school children (i.e., 4-6 and 6-9 years old respectively).

### *Conceptual Framework for the implementation*

Following the CAS framework (Daly-Smith et al., 2020), we are going to contextualise, describe and detail the three main levels (i.e., the grand system, the local system, and the in-school factors), and several examples of this intervention (See Table 1).

Table 1. Intervention program based on the CAS framework.

<b>System</b>	<b>Actions</b>	<b>Target population</b>	<b>Intervention components</b>	<b>Examples</b>
Grand System	Policy level	Children and school staff	National and regional education laws	LOMLOE and Aragon Government curriculum
	Organisational level	Children, teachers, school staff and families	Regional organisations related to health promotion	Aragon's Health Promoting School Network
Local system	Teachers training	Teachers and school staff	How to correctly promote health behaviours in children	Face to face meetings and yearly feedback, etc.
	Physical environment	Children	School furniture and school spaces modifications	Playground floor, grass zone, new material, etc.
	Social environment	Children, teachers, school staff and families	School and extracurricular connections	Stakeholders' engagement, connecting families with active leisure organisations, connections with the local medical centre, etc.
In-school factors	School curriculum	Children, school staff and teachers	Connection with other school subjects (apart from PE)	Connection with tutorial action plan and other subjects (e.g., maths and natural sciences).
	PE subject	Children	Increase weekly PE sessions	Variety of different physical activities
	Active commuting	Children and families	Tutoring sessions, family's information, and physical environment modifications	Safe transport sessions, informative newsletters, bike racks, etc.
	School nutritional guidelines	Children and families	Daily meal preparation and lunch recess	Free fruit offer, informational meetings, a newsletter, etc.
	Family involvement	Families	Staff meetings with families and a communication app	Children's health behaviours report, informative meetings, etc.
Community involvement	Children and families	Informative meetings about leisure activities, sports, and healthy events	Sport clubs, popular bike races for children and adults, etc.	

### The grand system

At the national level, the school policy is guided by the “Ley Orgánica de Modificación de la Ley Orgánica de Educación” (LOMLOE), and at the regional level by the Aragon Government who details the general requirements for the kindergarten and primary school curriculum as well as the students’ competencies in the Aragon’s territory (see further information at <https://educa.aragon.es/en/ordenacion-curricular1>). Specifically, this curriculum details the PE subjects’ requirements. Concerning the governmental organisation which gives support to health promotion in schools-based contexts, this policy is led by the “Aragon’s Health Promoting School Network ” linked to the School for Health in Europe (SHE) organisation (Bröder et al., 2018). This network offers some recommendations and activities to guide and support school health promotion (e.g., healthy lunch breaks for children, teacher training in health promotion, children active breaks, family awareness about healthy habits, etc.). For more information <http://redescuelasaron.blogspot.com/>.

### The local system

The local system components are composed of the school staff’ and teacher’s training, the physical environment, and the social environment.

According to these policies and to the objectives of the school program, we co-designed the school staff’ and teachers’ training. During the co-creation process, it was decided to have the advice of some researchers in the design of different strategies, especially providing scientific evidence regarding health behaviours and effective strategies. Thus, this training is being implemented by our research group. The school staff training is being delivered two times each year to improve leadership and management of the school intervention program with the rest of the stakeholders. This training involves face to face meetings with researchers, information requested by mail, problems resolution about questions or activities and yearly feedback about the whole intervention program. Related to the other teachers’ training (i.e., different to the school staff), the school staff directly provide them with different explanations and the details of the intervention goals and activities to deliver with each school stage (i.e., kindergarten or primary school), at the start of the academic year and at the beginning of each quarter. Both the school staff and the teachers’ training meetings are used to obtain feedback about

the intervention program (e.g., researchers to school staff or school staff to schoolteachers). The reason to involve school staff in the teachers' training instead of being directly implemented by the research team is to reinforce the sustainability of the intervention so that it continues to be carried out when the researchers leave the project. Related to the initial teacher training and background in health promotion, the school staff is composed of two PE teachers.

As we mentioned before, the school was built recently, and the school staff could take some decisions about the school spaces. Therefore, the physical environment was modified to promote health by the following changes and improvements of the school furniture and different school spaces. First, the playground has incorporated a grass zone and a covered stage in the kindergarten space. The primary school playground has been improved by redrawing the playground floor to diversify the PA and sports choices during recess time (i.e., removing basketball hoops and soccer goals). Second, the indoor modifications include the increase of some classroom's sizes, indoor floor heating adapted to kindergarten students (i.e., availability to wear slippers or barefoot), and indoor decoration supporting health, safety, and friendship attitudes (i.e., posters that suggest walking up the stairs, eating fruit, sharing the material, and helping peers). Third, the availability of material to promote active commuting to school (i.e., installation of bike racks within the school space) and to practise different sports and physical activities at the playground time (e.g., roller skating).

The social environment refers to the degree to which the stakeholders engage and support each other to provide health promotion improvements. Therefore, we divided the social environment by the school connections and the extracurricular connections. School connections are formed by the school staff engagement with other teachers (i.e., offering resources and feedback to implement the intervention, as well as support to solve difficulties, general meetings, etc.), teachers' engagement with students (i.e., delivering the intervention activities and supporting their health literacy about PA, SB, sleep and healthy eating), and school staff and teachers' engagement with families (i.e., connecting and explaining the school program with their homes, exchanges with a specific communication app). The extracurricular connections are conformed by connecting the school with sport clubs (i.e., establishing some links, common activities, and communication between both settings), connecting families with active leisure organisations (i.e., supporting the availability of leisure time activities beyond the school

time), other associations (e.g., cancer prevention, autism, mental health, etc.), and the local medical centre (i.e., informational meetings and health literacy).

### The in-school factors

The main in-school factors are composed by different actions such as the school curriculum, the PE subject, the active commuting to school, the school nutritional guidelines and the family and community involvement.

The school curriculum is built as the priority to follow the national and regional law as well as to achieve the essential learning objectives for each school stage and the subsequent student competences. The PE subject is directly linked to the regional law to achieve the expected motor and behavioural competencies. In this school setting, the PE curriculum is being implemented using a large variety of different physical activities, linked to the close context, and reinforced by more than one extra weekly hour of PE (i.e., a total of 4 weekly PE hours, which is in fact 1 hour more than the normal PE schedules). This modification allows this school to focus on several health promotion domains and keep on achieving better curricular PE competencies. As we previously detailed in the study setting, the proximity to the natural environment will also facilitate the implementation of several outdoor activities within the PE lessons using the local context facilities. After that, the second main goal of the general school curriculum is that children become active and healthy adults. This is planned through the interaction of other school subjects different to PE which may participate in a common health behaviour speech. The tutorial session is the most important subject in terms of weekly available time to promote health literacy (i.e., 1 hour a week during the whole school year). This session tries to be used consistently to promote healthy behaviours. The other curricular subjects are regularly involved along the academic year delivering transversal health promotion projects or healthy activities (e.g., to calculate a bike trip distance, or a caloric expenditure or food quality in terms of sugar percentage per dose, in maths and natural science respectively).

The active commuting promotion is an important part of the in-school factors that also engage with other in-school factors and local system areas (e.g., physical environment, teachers' training, school curriculum and family involvement) detailed previously. It includes some tutoring sessions about safe transport, active commuting



alternatives for children and families, informative newsletters sent to the families and the school physical environment modifications (i.e., bike racks at the main door and modification of the playground space to use bikes, skates, and scooters).

The school nutritional guidelines are integrated by the daily meal preparation at lunch recess and the lunch time. First, the lunch at recess is usually prepared by each child's family and some days there is a free fruit offer by an official regional program. Also, the school encourages families to prepare healthy snacks for their children by meetings and informative newsletters. Regarding the family's meal preparation, the school recommends avoiding sugar beverages, sugar or fat foods and give priority to water beverage, fruits, and healthy food. Second, the lunch time menu delivered in the school canteen is previously supervised by a nutrition expert. In addition, the menus are delivered respecting eating patterns (i.e., variety of food, fresh and balanced food, fruit intake and vegetables consumption) and other nutritional wellbeing strategies like eat in silence, take enough time to eat relaxed, optimal water hydration, etc.

Finally, family and community involvement integrate different strategies. Family involvement is promoted by the school staff meetings about the school goals, the monthly reports by teachers about the project and activities, the annual or semi-annual reports about their children health behaviours made by researchers, and some informative meetings about health promotion and family questions directly answered by researchers and school staff through the app communication. The internal communication app allows communication between families, teachers, and the school staff. The community involvement is promoted by informative meetings about leisure activities in their free-time and the sports and healthy events promoted by some different sport clubs (e.g., judo club, climbing club, etc.) and the city council sports technicians (i.e., popular bike or running races for children and adults).

### *Evaluation process design*

The evaluation components should allow the exploration of the complexities of school-based healthy interventions. Nevertheless, a great number of studies in our research domain are exclusively focused on evaluating the effectiveness of the intervention programs in terms of outcome results (Langford et al., 2015), and there are not so many intervention studies that measure other important domains like

implementation or maintenance. Thus, a new research trend seeks to measure other categories from a more global perspective of the intervention. The Reach, Efficacy/Effectiveness, Adoption, Implementation, and Maintenance framework (RE-AIM), presents public health impact as a function of an intervention’s reach (i.e., proportion of the target population that participated in the intervention), effectiveness (i.e., success rate), adoption (i.e., proportion of eligible settings that adopt the intervention), implementation (i.e., extent to which the intervention is implemented as intended) and maintenance (i.e., extent to which the intervention is maintained over time; Glasgow et al., 1999). This framework has been demonstrated useful to evaluate internal and external validity indicators for several health behaviour interventions in a variety of settings, specially in the school-based contexts (Glasgow et al., 2019).

Consistent with the RE-AIM framework outlined, these five dimensions were selected to evaluate this intervention program and assess key factors of the whole school setting (Glasgow et al., 2019). Additional details of this framework can be found here <https://re-aim.org/>.

### *Assessment procedures*

Assessment procedures will include both quantitative and qualitative methods to evaluate the whole system approach created in the school (see Table 2). The core data will include: (1) Accelerometer-measured PA and ST for children, parents, and teachers; (2) Reported questionnaires for children (i.e., reported by their parents), self-reported questionnaires for parents and teachers; (3) Ad-hoc questionnaires about the implementation process of the intervention program to the school staff; (4) And finally, in-deep interviews and focus groups with teachers, families, and the school staff.

Table 2. Assessment procedures and agents involved according to REAIM dimensions.

	<b>Quantitative</b>	<b>Qualitative</b>	<b>Agents</b>
<b>Reach</b>	Checklist	Interviews & Focus groups	School staff
<b>Effectiveness</b>	Accelerometer & self-reported questionnaires	Interviews & Focus groups	Children, families, and teachers
<b>Adoption</b>	Checklist	Interviews & Focus groups	School staff, teachers, and families

<b>Implementation</b>	Ad-hoc questionnaire	Interviews & Focus groups	School staff
<b>Maintenance</b>	Accelerometer & self-reported questionnaires	Interviews & Focus groups	Children, families, and teachers

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### Reach

Based on the REAIM framework dimensions, we created some instruments. For the Reach dimension, we designed a checklist about the degree of the intervention reached on several stakeholders (i.e., children, families, teachers, and outside school stakeholders) with a Likert scale from 1 to 4.

### Effectiveness

The quantitative assessment of the effectiveness dimension will be integrated with accelerometer devices and self-reported questionnaires.

In a separate process, a sample size of consenting children, parents and teachers will be provided with an ActiGraph GT3X accelerometer to objectively measure daily PA and ST for one week. Researchers will show children, parents, and teachers how to correctly attach, wear and use the accelerometer. They will be instructed to wear the accelerometer above the right hip for  $\geq 12$  hours/day for 7 consecutive days. The valid wear time criteria will be set as  $\geq 3$  weekday and  $\geq 1$  weekend day, for  $\geq 10$  hours/day on weekdays and  $\geq 8$  hours/day on weekend days respectively (Rowlands, 2007). To encourage compliance, children, parents, and teachers will be given an accelerometer guideline about how to use these devices and the reasons allowed for taking them off during the day. An epoch length of 15 seconds interval counts will be set to detect short bursts of vigorous PA. Different cut-points will be used for pre-schoolers (Pate et al., 2006), children (Evenson et al., 2008), and adults (Troiano et al., 2008), to analyse data. Variables will include average time spent in ST, light, moderate and vigorous PA (daily, weekday and weekend). Also, several different school day timeframes will be calculated for children (Aibar et al., 2014). Data will be analysed using ActiLife v6.13.4 software.

Parents and teachers will be surveyed using a 35–40 min questionnaire which integrates different health behaviours questionnaires. Parents will answer these

questionnaires twice, first about their children's health behaviours (i.e., parental reported questionnaire) and second about themselves (i.e., self-reported questionnaire). Both questionnaires will be answered in different weeks to avoid misunderstanding. The questionnaires are not the same because each age range needs different questionnaires to be measured, but the general variables (i.e., demographics and health behaviours) will be the same. The questionnaires will be delivered and completed online (i.e., using a google form), and questions will include demographics (i.e., age, gender, self-reported weight and height, and home address), active commuting to school (e.g., type of transport used before and after school) and health behaviours like PA (Hagströmer et al., 2006), SB screen-time (Cabanas-Sánchez et al., 2018; Mielgo-Ayuso et al., 2017), sleep outcome (Currie et al., 2014; Moreno et al., 2014), food intake behaviour (Schröder et al., 2011; Serra-Majem et al., 2004), and wellbeing (Aymerich et al., 2005; Lucas-Carrasco, 2012).

### Adoption

As we have previously detailed for the Reach dimension, we designed an ad-hoc questionnaire about the degree of adoption on several stakeholders (i.e., children, families, teachers, and outside school stakeholders), using a Likert scale from 1 to 4.

### Implementation

For the Implementation dimension, we designed an ad-hoc questionnaire about the fidelity of the intervention (i.e., degree of the planned tasks and strategies accomplished during each school year).

### Maintenance

The Maintenance dimension, which will give us an idea about the sustainability of the intervention, will be measured with the follow-up measures taken at the end of each school year. It will allow us to measure the facts that have been maintained, improved, or worsened compared to the year or years previous in terms of reach, effectiveness, adoption, and implementation dimensions.

### Focus groups and in-deep interviews

The focus group and in-deep interviews will be guided using school-specific key areas about the RE-AIM dimensions. The researchers will prepare the questions regarding Reach, Effectiveness, Adoption, Implementation, and Maintenance of the intervention program. We employ qualitative methods to complement information derived from the quantitative procedures and to obtain a more complete picture of the system approach development. Thus, the focus groups and in-deep interviews will provide a unique opportunity to explore stakeholders' perceptions about school-specific issues, as well as intervention program barriers or improvement proposals. This will allow us to reorganise and adapt it to the ongoing process.

Interviews will be conducted with the main stakeholders in charge of implementing the intervention program (i.e., teachers and school staff). In fact, we will select at least one kindergarten teacher, one primary school teacher and one school staff member for one annual interview. Focus groups will be conducted with kindergarten and primary school children's families. The proposed size and number of focus groups will be apparently sufficient to reach data saturation (Baruth et al., 2014).

Examining both interviews and focus groups will tap into their in-depth understanding about the complex characteristics of the intervention program and will provide rich contextual information for interpretation of the quantitative data. Researchers will record interviews and focus groups digitally and take notes during the sessions. The digitally audio-recorded interviews and focus group data will be transcribed, then checked for errors by researchers. Data will be collected following the literature recommendations to retrieve qualitative information (Baruth et al., 2014). Kappa coefficient will also be calculated with an independent analysis of the transcripts by two different researchers to obtain the percentage of concordance between them. Finally, data will be read, coded, and analysed thematically by more than two investigators using NVivo Pro v.11 qualitative analysis software.

### **6.3. Ethics and Dissemination**

The Ethics Committee for Clinical Research of Aragon (CEICA) has approved all procedures, methodologies, and studies for this project (Ethic code: PI20/009). Consultation with CEICA has been ongoing since early 2020. This committee provided

guidance on data collection and dissemination findings to the city community, which have been incorporated into the study.

The outcomes of the study are relevant to regional schools and will provide relevant school-specific knowledge for health promoters and policymakers. Study findings will be shared with Aragon's Education Department, key stakeholders involved, and the wider community. It will be done through several dissemination channels, including peer-reviewed journal articles and conference abstracts (i.e., academic and community presentations, technical reports, policy briefings, etc.).

We will maximise the impact of the study locally, nationally, and internationally. The study will generate relevant information for key stakeholders to plan future school-based interventions involving family and community health behaviour changes to encourage health promotion as a means of equitably increasing PA, good sleep habits, wellbeing and decreasing SB and bad food intake habits among children. This study will also provide timely, valuable, and stakeholder-specific information at local and regional level: (1) City schools (comprehensive information about to tailor future school-based interventions in terms of health promotion); (2) Aragon's Health Promotion School Network (e.g., the effects of the physical and social environment changes on children's health behaviours). And at national and international level: (3) An example of a system approach study based on the CAS framework; (4) Adding value to our research field through scientific articles about the inception, results, and evaluation of the whole school setting.

#### **6.4. Conclusion**

Intervention planning is a crucial stage in the process of developing the evidence needed to improve children's health outcomes. However, health behaviour interventions are rarely developed systematically and, when reported, poor description of active components often become a barrier for subsequent replication and scaling-up processes. In this protocol article, and based on a recent theoretical framework, we have provided a detailed description of the development, characteristics, and evaluation of a system approach intervention to improve the school setting and, basically, children's health behaviours. Thus, this manuscript provides the innovative backdrop for highlighting a new approach based on the CAS framework in relation to the planning and evaluation of

a whole school setting. Identification of any modifications to the intervention or evaluation which are required will provide insight for a fully powered effectiveness trial with several schools in the future.

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## **Chapter 7. Effects of a multilevel and multicomponent intervention to improve movement behaviours and compliance of the 24-hour Movement Guidelines among 3- to 9-Year-old Spanish children**

Chapter 6 provided the protocol of the school-based intervention describing the school-based intervention carried out in a Spanish school among children. Then, this chapter provides the results about physical activity, sedentary behaviour, and sleep measured during two years of intervention. Thus, this chapter allows to understand what the degree of effectiveness in children 24-hour movement behaviours was after conducting the school-based intervention.

This study addressed the same research question provided previously in chapter 6:

- How effective can a co-created school-based intervention be to promote 24-hour movement behaviours in children?

This chapter has been published as:

(It has been finished and prepared for this thesis format, but it will need further preparation before to be submitted to a peer-review journal).

### **7.1. Introduction**

High levels of moderate to vigorous physical activity (MVPA), a reduction of sedentary behaviour (SB), and an appropriate sleep duration and quality are correlated with numerous health benefits in children (Saunders et al., 2016). Nevertheless, the most recent World Health Organization (WHO) study about global trends in PA among children and adolescents found that 81% of them were not enough physically active (i.e., performed less than 60 minutes of MVPA per day), with 77.6% and 84.7% for boys and girls respectively (Guthold et al., 2020). Also, excessive SB is widespread among children and adolescents around the world (Bull et al., 2020; Chaput et al., 2020), being the most common SB among children screen-time (e.g., computer use, TV viewing, etc.), and sitting time (e.g., reading or studying). Furthermore, a study focused on the “Global Prevalence of Meeting Screen Time Guidelines Among Children 5 Years and Younger” with a sample of 63 studies and 89,163 children concluded that the mean prevalence of meeting the screen time guideline for children aged 2 to 5 years (i.e., maximum of 1 hour

per day), was only 35.6% (McArthur et al., 2022). In terms of sleep behaviour, children nowadays sleep less and less, with only 60% of them meeting the sleep recommendations worldwide (Matricciani et al., 2012). According to this systematic review of 690,747 youths aged 5 to 18 years, children today sleep almost one hour less than 100 years ago, especially boys and during school days (Matricciani et al., 2012).

Regarding all these behaviours, a new paradigm was developed in 2016, called the 24-hour Movement Guidelines (Tremblay et al., 2016). This new paradigm suggested that children and pre-schoolers aged 5–12 and 3-5 years should accumulate more than 60 min of daily MVPA, spend several hours in a day doing Light Physical Activity (LPA), sleep 9-11 hours (i.e., children) and 10-13 (i.e., pre-schoolers) hours per night and dedicate less than 2 hours per day to recreational screen-time behaviours for children, and less than 1 hour for pre-schoolers (Tremblay et al., 2016, 2017). In terms of studies about the prevalence of 24-hour movement guidelines, a systematic review of 51 studies in 20 different countries that included children and adolescents (i.e., aged 5 to 17 years) found that only a small proportion of children aged 5-12 years (i.e., 4.8%-10.8%) met the overall 24-hour Movement Guidelines of all movement behaviours (Rollo et al., 2020). Furthermore, a recent meta-analysis of 63 studies and 387,437 participants aged 3 to 18 years showed that the overall adherence to 24-hour movement guidelines was 7.12% (Tapia-Serrano et al., 2022). More specifically, this study highlighted that only 11.26% of pre-schoolers, 10.31% of children and a scarce 2.68% of adolescents met the full guidelines (Tapia-Serrano et al., 2022). Moreover, the overall adherence of the sample was significantly lower in girls (3.75%) than in boys (6.89%), and this difference remained between children's girls (6.94%) and boys (11.05%), but there were not differences by sex in pre-schoolers and adolescents' samples (Tapia-Serrano et al., 2022). On the other hand, 8.81% of pre-schoolers and 15.57% of children, did not meet any of the 24-hour movement guidelines, and the overall prevalence of the sample was higher in girls (15.66%) than boys (12.95%), without specific sex differences in pre-schoolers, children, and adolescents (Tapia-Serrano et al., 2022).

In recent years, school health research has been mainly and exclusively focused on physical activity (PA) and SB (Chaput et al., 2014), with sleep being independently treated from the other two behaviours (Busch et al., 2017). After conducting a scoping review about school-based interventions targeting 24-hour movement behaviours from 2010 to 2021 (Chapter 4), we found a lack of studies addressed to improve the three

movement behaviours. Nevertheless, a school-based intervention which targeted all 24-hour movement behaviours among children aged 8-10 years has been recently published (Tapia-Serrano et al., 2022). Then, we found in our meta-analysis that school-based interventions seem to be effective for reducing ST, but they fail to improve MVPA (Chapter 5). Finally, most available evidence about 24-hour movement behaviours have been collected through cross-sectional studies (Rollo et al., 2020; Tapia-Serrano et al., 2022). To our knowledge, no previous multicomponent intervention studies have been conducted targeting 24-hour movement behaviours among both, pre-schoolers and children's samples. Therefore, there is a lack of school-based interventions about 24-hour movement behaviours conducted with children and pre-schoolers, highlighting an important gap in the literature. In this regard, we present the following aims and hypotheses for this study:

- *Aim 1:* To examine the effects of a school-based intervention on children's movement behaviours (e.g., MVPA, ST, screen-time and sleep outcomes). *Hypothesis 1:* Compared with baseline, higher MVPA, sleep, and fewer SB (i.e., ST and screen-time) minutes will be reported by pre-schoolers and children after the implementation of the program.
- *Aim 2:* To describe the proportion of 3 to 9-year-old children meeting the 24-hour movement guidelines at the end of the intervention. *Hypothesis 2:* The prevalence of meeting guidelines will be a) higher in boys than in girls and b) higher in pre-schoolers than in primary schoolers.

## 7.2. Methods

### *Intervention design.*

A quasi-experimental design without a control group was conducted. Data about 24-hour movement behaviours was collected before starting the intervention and at the end of two academic years (from September to June 2020-2021 and 2021-2022). The study included three measurement points: T0 was the pre-test in October 2020, while T1 and T2 were two different post-tests in May 2021 (belonging to 20-21 academic year) and March 2022 (belonging to 21-22) respectively. Also, a cross-sectional design was conducted to know the proportion of children meeting the 24-h movement guidelines, at the end of the second year of intervention (i.e., T2 sample).

### *Participants*

A total of 139 students ( $M=5.9$ ;  $SD=2.2$ ; 53% girls; 55% primary school) from one school of Binefar (Spain) were recruited. The children's sample size was integrated by 3 school years of kindergarten children and 4 school years of primary school children (i.e., 3-5 and 6-9 years old respectively). The school staff was contacted for permission to conduct the study. There is only a group class by each school year in this school and all children from preschool to primary school were invited to participate. Then, each child's legal representant at school (i.e., families or caregivers) signed the informed consent to participate in the study. This study was also approved by the scientific ethics committee of Aragon, Spain (CEICA PI20/009).

### *Intervention program*

This intervention program aimed to improve 24-hour movement behaviours in both pre-schoolers and primary school children. The Creative and Active Schools (CAS) framework was selected to guide and organise the intervention program (Daly-Smith et al., 2020). This framework reinforces the need for change at the individual, school environment, and community level, allowing to identify the priorities and modify the existing structures to promote behavioural change. Also, this is the first framework where all components have been collated so that a "system change" can be created in the school. This whole-school approach is structured in three main levels (i.e., the grand system, the local system, and the in-school factors), and they are subdivided in several components. Further details about the intervention program are provided in chapter 6.

### *Measures*

Self-reported questionnaires were provided online to be completed by the families about their own children's movement behaviours and demographics variables (i.e., age, gender and group class). Families were surveyed using a 10 min questionnaire which integrated different movement behaviours questionnaires (i.e., screen-time and sleep) about their children's health behaviours. Self-reported data about recreational screen time and sleep behaviour were collected using the Spanish questionnaire of the Health Behaviour in School-aged Children (HBSC) study (Moreno et al., 2014).

Recreational screen time was measured by asking (1) “On average, how many hours/day did your child spend in front of a screen (i.e., watching TV, using a computer or mobile phone and playing video games) during his/her school day free time?” (2) “On average, how many hours/day did your child spend in front of a screen (i.e., watching TV, using a computer or mobile phone and playing video games) during his/her weekend day free time?”. Therefore, it was collected total screen time for both school and weekend days separately. Then, the average daily recreational screen time was calculated using the following formula:  $(\text{recreational screen time reported on school day} \times 5 + \text{recreational screen time reported on weekend} \times 2) / 7$  (Aguilar-Farias et al., 2020). Self-reported sleeping time was collected from the time difference between the hour when the child went to sleep and the waking hour during the last week for both school and weekend days. The participants answered the following questions: (1) During the past week, what time did your child go to sleep on school days? (2) During the past week, what time did your child go to sleep on weekend days? Following the same procedure as screen-time, it was collected total sleep time for both school and weekend days separately and the average daily sleeping time was calculated using the same formula:  $(\text{sleeping time on school day} \times 5 + \text{sleeping time on weekend} \times 2) / 7$  (Aguilar-Farias et al., 2020).

Regarding PA variables (i.e., MVPA, LPA) and ST, they were measured using accelerometer devices. The research team visited the schools to place them in collaboration with school staff. All consenting children were provided with an ActiGraph GT3X accelerometer to objectively measure their daily MVPA, LPA and ST. Researchers showed children, parents, and teachers how to correctly attach, wear and use the accelerometer, as well as to remove it during water-based activities (showering or swimming) through different meetings. Also, they were instructed to wear the accelerometer above the right hip for  $\geq 12$  hours/day for 7 consecutive days. Seven days after the first school visit, the research team made a second visit to collect with the help of the school staff the accelerometers for the analysis. Variables measured included daily, school day and weekend day average time spent in ST, LPA and MVPA.

### *Data Preparation*

Accelerometer data was analysed using ActiLife v6.13.4 software. First, a filter for detecting non-wear periods was applied. Second, a time filter from 23:00 to 7:00 was



used to remove sleep time. Third, the remaining data were identified as waking wear time (Tudor-Locke et al., 2015). The valid wear time criteria were set as  $\geq 3$  weekdays and  $\geq 1$  weekend day, for  $\geq 10$  hours/day on weekdays and  $\geq 8$  hours/day on weekend days respectively (Rowlands, 2007). An epoch length of 10 seconds interval counts was set to detect short bursts of MVPA. Different cut-points were used for pre-schoolers (Pate et al., 2006) and children (Evenson et al., 2008). After classifying every measured epoch, the total time spent per day in MVPA, LPA and ST were calculated.

A mixed assessment (i.e., using both self-reported and accelerometer measures) was used to describe movement behaviours data and 24-hour movement guidelines compliance (Tremblay et al., 2016, 2017). To assess the compliance MVPA guidelines, each participant was classified as meeting the recommendations if they reported  $\geq 60$  minutes of MVPA on valid mean weekly time from the accelerometer. Also, the participants were categorised as meeting screen-time guidelines if they spent on average  $\leq 1$  hour on recreational screen time per day for pre-schoolers (i.e., 3-5 years), and  $\leq 2$  hours for primary school children (i.e., 6-12 years). Regarding the sleep guidelines, pre-schoolers and primary school children were classified as meeting the sleeping recommendations if they slept, on average, 10 to 13 hours per night and 9 to 11 hours respectively (Tremblay et al., 2016, 2017). After this procedure, each participant was classified as meeting the 24-h movement guidelines if they met the 3 recommendations, as well as meeting none if they did not meet any of them. Finally, different combinations of movement behaviours compliance were also described (i.e., MVPA+Screen-time; MVPA+Sleep; Screen-time+Sleep).

### *Statistical Analysis*

To test for homogeneity of variances and normality of data distribution, Levene and Shapiro-Wilk tests were performed respectively ( $p > .050$ ). Next, descriptive statistics (i.e., M and SD) and correlation between samples (i.e.,  $r$ ) were calculated for the dependent variables of the study.

To measure the effectiveness of the intervention, both repeated measures (i.e., T0-T1-T2), and student t-test for paired samples (i.e., T0-T; T0-T2; T1-T2) were performed to see differences between all measurement points. Subsequently, a multivariate analysis of variance (MANOVA) of repeated measures (i.e., T0-T1-T2) was carried out to assess

the effects of the intervention programme on MVPA, LPA, ST, screen-time and sleep. These analyses were repeated for boys and girls as well as for pre-schoolers and primary school children to analyse the effects of the intervention regarding gender and school stage. Effect sizes ( $\eta^2$ ) greater than 0.01, 0.06 and 0.14 were considered small, moderate and large, respectively (Cohen, 1988). In all statistical calculations the confidence interval (CI) was 95%.

On the other hand, cross tables and Chi-Square tests to compare dichotomous variables were conducted to know the proportion of 3 to 9-year-old children meeting the 24-hour movement guidelines regarding weekday, gender and school stage (preschool and primary). All analyses were performed using SPSS IBM v21.0 statistical software.

### **7.3. Results**

From an initial sample size of 139 students, several children were excluded in some measurement points due to incomplete reports or invalid accelerometer data. Table 1 and 2 shows this decrease in both self-reported and accelerometer data when comparing different measurement points like T0-T1, T1-T2, and T0-T2. Then, when performing repeated measures analysis, only 68 students (56% girls; 64% primary school) completed all measurement points about self-reported data (i.e., sleep and screen-time), and 47 students (43% girls; 66% primary school) about accelerometer data (see Table 3). The sample size of the cross-sectional analysis with both accelerometer and self-reported data described in Table 4 was 81 students (55% girls; 63% primary school).

Table 1 highlights significant correlations between samples, it was achieved for all variables but screen-time in T0-T1 and T1-T2, and for all variables in T0-T2. Student t-test results described in Table 2 showed significant increase of total and weekdays screen-time between T0-T1, and its subsequent decrease for total and weekdays between T1-T2. There were not significant results for sleep behaviour. There was a significant increase for total and weekend ST between T0-T1. Then, LPA had a significant reduction for total and weekend days between T0-T1, and a significant increase on weekdays in both T1-T2 and T0-T2. Finally, MVPA levels had a significant decrease on weekend days between T0-T2.

**Table 1.** Descriptive data for 24-hour Movement behaviours and correlations between T0, T1 and T2.

	Descriptive statistics (h/day, min/day)						Correlation between samples								
	T0		T1		T2		T0-T1			T1-T2			T0-T2		
	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	r	p	N	r	p	N	r	p	N
<b>Screen-time</b>															
<i>Weekdays</i>	2.01 (1.3)	88	2.87 (3.1)	86	1.87 (1.3)	104	.210	.060	81	.003	.977	73	.255	.029	73
<i>Weekend</i>	2.64 (1.4)	88	2.94 (2.1)	86	2.57 (1.6)	104	.408	<.000	81	.302	.009	73	.315	.007	73
<i>Total</i>	2.18 (1.1)	88	2.89 (2.6)	86	2.07 (1.2)	104	.308	.005	81	.053	.658	73	.249	.033	73
<b>Sleep</b>															
<i>Weekdays</i>	10.15 (0.6)	88	10.08 (0.6)	86	10.07 (0.5)	104	.603	<.000	81	.638	<.000	73	.515	<.000	73
<i>Weekend</i>	10.21 (0.9)	88	10.03 (0.9)	86	10.17 (0.7)	104	.457	<.000	81	.573	<.000	73	.445	<.000	73
<i>Total</i>	10.17 (0.6)	88	10.07 (0.6)	86	10.10 (0.5)	104	.555	<.000	81	.639	<.000	73	.531	<.000	73
<b>ST</b>															
<i>Weekdays</i>	600.61 (106.1)	76	616.52 (105.4)	69	609.06 (91.1)	81	.893	<.000	56	.699	<.000	54	.636	<.000	57
<i>Weekend</i>	636.21 (97.7)	76	659.18 (87.9)	69	641.34 (89.7)	81	.735	<.000	56	.430	.001	54	.384	.003	57
<i>Total</i>	609.94 (100.8)	76	628.49 (96.2)	69	620.16 (84.3)	81	.906	<.000	56	.670	<.000	54	.610	<.000	57
<b>LPA</b>															
<i>Weekdays</i>	207.56 (112.8)	76	193.69 (107.3)	69	220.55 (100.1)	81	.979	<.000	56	.745	<.000	54	.709	<.000	57
<i>Weekend</i>	193.07 (106.5)	76	172.28 (90.1)	69	194.49 (87.9)	81	.921	<.000	56	.647	<.000	54	.665	<.000	57
<i>Total</i>	203.85 (110.3)	76	188.29 (102.4)	69	211.56 (93.9)	81	.977	<.000	56	.734	<.000	54	.704	<.000	57
<b>MVPA</b>															
<i>Weekdays</i>	87.9 (23.6)	76	92.82 (21.3)	69	90.56 (29.1)	81	.554	<.000	56	.616	<.000	54	.528	<.000	57
<i>Weekend</i>	78.31 (33.1)	76	77.38 (30.5)	69	75.06 (32.7)	81	.444	.001	56	.660	<.000	54	.470	<.000	57
<i>Total</i>	85.30 (23.9)	76	88.66 (21.6)	69	85.60 (27.5)	81	.593	<.000	56	.710	<.000	54	.519	<.000	57

Notes: Screen-time and sleep time are described in hours/day, while ST, LPA and MVPA in min/day. The N columns in descriptive statistics refer the total sample and N columns in correlation between samples refer to common subjects of each two measures. Abbreviations: N = sample size; SD = Standard deviation; r = Pearson correlation coefficient; p = detail the significance of the correlation.

**Table 2.** Related differences (h/day and min/day) between 24-hour Movement behaviours.

	T0-T1				T1-T2				T0-T2			
	Mean Dif. (SE)	95% CI	t	p	Mean Dif. (SE)	95% CI	t	p	Mean Dif. (SE)	95% CI	t	p
	<b>Screen-time</b>											
<i>Weekdays</i>	0.96 (0.3)	0.27; 1.65	2.78	.007*	-0.83 (0.3)	-1.56; -0.10	-2.27	.026*	-0.24 (0.1)	-0.61; 0.12	-1.31	.191
<i>Weekend</i>	0.28 (0.2)	-0.15; 0.71	1.30	.197	-0.16 (0.2)	-0.58; 0.25	-0.77	.440	-0.02 (0.2)	-0.41; 0.36	-1.40	.889
<i>Total</i>	0.77 (0.3)	0.19; 1.34	2.67	.009*	-0.64 (0.3)	-1.25; -0.03	-2.11	.038*	-0.18 (0.1)	-0.52; 0.15	-1.07	.288
<b>Sleep</b>												
<i>Weekdays</i>	-0.03 (0.6)	-0.15; 0.08	-0.51	.611	-0.01 (0.1)	-0.13; 0.10	-0.23	.813	-0.06 (0.1)	-0.19; 0.06	-0.94	.349
<i>Weekend</i>	-0.19 (0.1)	-0.40; 0.01	-1.82	.072	0.02 (0.1)	-0.14; 0.18	0.24	.808	-0.05 (0.1)	-0.24; 0.13	-0.56	.573
<i>Total</i>	-0.07 (0.1)	-0.20; 0.04	-1.22	.223	-0.01 (0.1)	-0.11; 0.10	-0.73	.942	-0.06 (0.1)	-0.18; 0.06	-0.96	.336
<b>ST</b>												
<i>Weekdays</i>	8.93 (6.6)	-4.31; 22.17	1.35	.182	-9.07 (10.4)	-30.09; 11.94	-0.86	.390	0.56 (11.2)	-21.91; 23.04	9.69	.960
<i>Weekend</i>	27.28 (9.2)	8.79; 45.77	2.95	.005*	-15.31 (12.2)	-39.90; 9.27	-1.24	.217	10.39 (13.2)	-16.17; 36.96	0.05	.437
<i>Total</i>	15.01 (5.9)	3.03; 26.98	2.51	.015*	-7.80 (9.9)	-27.76; 12.14	-0.78	.436	6.95 (10.9)	-15.04; 28.95	0.63	.529
<b>LPA</b>												
<i>Weekdays</i>	-5.56 (3.3)	-12.20; 1.08	-1.67	.099	22.64 (10.1)	2.42; 42.85	2.24	.029*	21.86 (10.9)	0.01; 43.71	2.01	.049*
<i>Weekend</i>	-13.48 (5.8)	-25.11; -1.86	-2.32	.024*	17.13 (10.1)	-3.19; 37.47	1.69	.097	-0.34 (10.8)	-22.03; 21.34	-0.03	.975
<i>Total</i>	-7.53 (3.4)	-14.45; -0.62	-2.18	.033*	18.09 (9.8)	-1.53; 37.71	1.84	.070	13.07 (10.6)	-8.27; 34.43	1.22	.225
<b>MVPA</b>												
<i>Weekdays</i>	2.87 (2.8)	-2.75; 8.50	1.02	.311	-2.11 (2.8)	-7.90; 3.67	-0.73	.466	1.82 (3.4)	-5.08; 8.73	0.56	.599
<i>Weekend</i>	-6.70 (4.5)	-15.78; 2.38	-1.48	.145	-4.80 (3.3)	-11.55; 1.94	-1.42	.159	-9.97 (4.2)	-18.46; -1.47	-2.35	.022*
<i>Total</i>	0.16 (2.7)	-5.36; 5.70	0.06	.952	-4.65 (2.3)	-9.40; 0.09	-1.96	.053	-2.90 (3.32)	-9.56; 3.76	-0.87	.387

Notes: Screen-time and sleep time are described in hours/day, while ST, LPA and MVPA in min/day. Significant results are marked with \*

Abbreviations: Mean Dif = mean differences; SE = Standard error; CI = Confidence interval; LL = Lower Limit; UL = Upper Limit.

Results from the MANOVA repeated measures analyses of self-reported measures (i.e., screen-time and sleep) indicated a significant main effect of the intervention program with a small effect size (Lambda de Wilks=.922;  $F(4,254)= 2.62$ ;  $p = .036$ ;  $\eta_p^2 = .040$ ;  $op = .730$ ). Results of accelerometer measures (i.e., ST, LPA and MVPA) also indicated a significant main effect of the intervention program with a medium effect size (Lambda de Wilks=.807;  $F(6,163)= 3.16$ ;  $p = .006$ ;  $\eta_p^2 = .101$ ;  $op = .916$ ). Then, Table 3 describes a significant interaction effect regarding gender and school stage for both total screen-time ( $F= 4.25$ ;  $p = .043$ ;  $\eta_p^2 = .062$ ;  $op=.528$ ), and sleep time ( $F= 3.87$ ;  $p = .048$ ;  $\eta_p^2 = .057$ ;  $op=.509$ ). However, further pairwise comparisons 95%CI revealed non-significant effects. Regarding within-group differences by gender, only sleep indicated a significant interaction with a moderate effect size ( $F=8.14$ ;  $p = .006$ ;  $\eta_p^2 = .113$ ;  $op=.803$ ). Also, only LPA within-group differences were found by school stage with a moderate effect size ( $F=4.62$ ;  $p = .037$ ;  $\eta_p^2 = .097$ ;  $op=.557$ ). Nevertheless, similar non-significant effects were found for both gender and school stage within-group differences when consulted 95%CI's in pairwise comparisons.

Then, results from the proportion of 3 to 9-year-old children meeting the 24-hour movement guidelines regarding weekday, gender and school stage at the end of the intervention (i.e., T2), are described in Table 4. There is a great proportion of children meeting MVPA (80.2%) and sleep (96.3%) recommendations individually and together (i.e., MVPA+Sleep: 76.5%), but only 59% children met the screen-time guidelines. Also, nearly half of the sample met all 24-hour movement guidelines (42.1%), being even more relevant that there were not any children not meeting anyone of the three recommendations.

There were significant differences between gender about meeting MVPA recommendations, with boys reporting higher percentage than girls on weekdays ( $\chi^2=4.55$ ;  $p=.033$ ), weekend days ( $\chi^2=4.76$ ;  $p=.025$ ) and in total ( $\chi^2=5.33$ ;  $p=.019$ ). Furthermore, there were significant differences regarding school stage as well. In terms of MVPA, pre-schoolers were significantly higher in percentage than primary school children on weekend days ( $\chi^2=14.14$ ;  $p<.001$ ) and in total ( $\chi^2=11.72$ ;  $p<.001$ ). Regarding total screen-time, pre-schoolers had significantly worse results than primary schoolers ( $\chi^2=3.13$ ;  $p=.046$ ). Also, primary school children registered significantly higher results than pre-schoolers when meeting sleep recommendations on weekdays ( $\chi^2=5.29$ ;  $p=.048$ ) and in total ( $\chi^2=5.22$ ;  $p=.048$ ).

**Table 3.** Descriptive statistics and analysis of within-group, school period and gender differences in Screen time, Sleep, ST, LPA and MVPA.

		<i>Descriptive statistics</i>				<i>Pairwise comparisons</i>						<i>Within-group differences</i>			
		N	T0	T1	T2	T0-T1		T0-T2		T0-T1-T2					
			Mean (SD)			M dif. (SE)	CI 95%		M dif. (SE)	CI 95%		F	p	$\eta_p^2$	op
							LL	UL		LL	UP				
<b>Screen-time</b>	<b>Total</b>	<b>68</b>	<b>2.14 (1.1)</b>	<b>2.69 (2.4)</b>	<b>1.96 (1.2)</b>	<b>0.67 (0.3)</b>	<b>-0.07</b>	<b>1.41</b>	<b>-0.21 (0.2)</b>	<b>-0.69</b>	<b>0.27</b>	<b>4.25</b>	<b>.043*</b>	<b>.062</b>	<b>.528</b>
	Boys	30	2.01 (1.2)	2.77 (2.6)	1.84 (1.1)	0.76 (0.4)	-0.26	1.79	-0.16 (.02)	-0.83	0.51	0.54	.817	.001	.056
	Girls	38	2.26 (1.1)	2.62 (2.2)	2.05 (1.3)	0.57 (0.4)	-0.50	1.65	-0.25 (0.3)	-0.96	0.45				
	Preeschool	24	1.99 (1.2)	2.25 (2.0)	1.64 (1.1)	0.39 (0.5)	-0.79	1.58	-0.35 (0.3)	-1.13	0.42	0.42	.519	.007	.098
	School	44	2.23 (1.1)	2.93 (2.6)	2.13 (1.2)	0.94 (0.3)	0.04	1.84	-0.06 (0.2)	-0.65	0.52				
<b>Sleep</b>	<b>Total</b>	<b>68</b>	<b>10.16 (0.5)</b>	<b>10.12 (0.5)</b>	<b>10.11 (0.5)</b>	<b>-0.04 (0.05)</b>	<b>-0.18</b>	<b>0.09</b>	<b>-0.05 (0.07)</b>	<b>-0.22</b>	<b>0.13</b>	<b>3.87</b>	<b>.048*</b>	<b>.057</b>	<b>.509</b>
	Boys	30	10.10 (0.5)	10.16 (0.6)	10.01 (0.5)	0.06 (0.07)	-0.13	0.24	-0.09 (0.1)	-0.33	0.15	8.14	.006*	.113	.803
	Girls	38	10.2 (0.6)	10.09 (0.5)	10.18 (0.4)	-0.15 (0.07)	-0.34	0.04	-0.05 (0.1)	-0.26	0.25				
	Preeschool	24	10.27 (0.6)	10.34 (0.5)	10.31 (0.5)	0.02 (0.09)	-0.19	0.23	0.04 (0.1)	-0.24	0.32	0.24	.621	.004	.078
	School	44	10.11 (0.5)	9.99 (0.5)	10.00 (0.5)	-0.11 (0.06)	-0.27	0.04	-0.13 (0.09)	-0.34	0.08				
<b>ST</b>	<b>Total</b>	<b>47</b>	<b>609.75 (105.9)</b>	<b>627.06 (89.1)</b>	<b>618.55 (80.6)</b>	<b>14.79 (6.9)</b>	<b>-2.57</b>	<b>32.15</b>	<b>2.78 (13.3)</b>	<b>-30.49</b>	<b>36.06</b>	<b>0.86</b>	<b>.360</b>	<b>.020</b>	<b>.148</b>
	Boys	22	640.93 (105.2)	659.62 (81.9)	636.98 (84.9)	18.68 (9.1)	-3.87	41.21	-3.94 (17.3)	-47.13	39.24	1.11	.296	.025	.178
	Girls	25	582.32 (100.8)	598.42 (86.7)	602.34 (74.7)	10.90 (10.6)	-15.52	37.32	9.52 (20.3)	-41.12	60.16				
	Preeschool	16	716.10 (36.8)	719.97 (30.4)	708.93 (59.6)	3.42 (11.4)	-25.08	31.92	-7.39 (21.92)	-62.02	47.23	0.83	.366	.019	.145
	School	31	554.86 (86.0)	579.11 (68.8)	571.91 (40.0)	26.16 (7.9)	6.32	46.01	12.96 (15.2)	-25.05	50.99				
<b>LPA</b>	<b>Total</b>	<b>47</b>	<b>206.34 (114.4)</b>	<b>197.64 (100.6)</b>	<b>217.25 (92.8)</b>	<b>-5.38 (3.8)</b>	<b>-15.05</b>	<b>4.28</b>	<b>15.92 (12.3)</b>	<b>-14.80</b>	<b>46.66</b>	<b>2.48</b>	<b>.122</b>	<b>.055</b>	<b>.338</b>
	Boys	22	166.07 (111.4)	157.28 (92.7)	182.82 (98.8)	-8.78 (5.1)	-21.33	3.76	16.75 (16.1)	-23.13	56.63	0.43	.511	.010	.099
	Girls	25	200.05 (112.6)	233.15 (95.3)	247.55 (77.1)	-1.97 (5.9)	-16.69	12.73	15.10 (18.7)	-31.66	61.87				
	Preeschool	16	81.80 (9.5)	89.24 (6.2)	94.64 (23.4)	7.89 (6.3)	-7.97	23.76	17.70 (20.2)	-32.75	68.15	4.62	.037*	.097	.557
	School	31	270.62 (86.5)	253.59 (77.5)	280.53 (28.1)	-18.65 (4.4)	-29.70	-7.61	14.15 (14.1)	-20.95	49.26				
<b>MVPA</b>	<b>Total</b>	<b>47</b>	<b>87.66 (24.2)</b>	<b>88.67 (21.7)</b>	<b>84.41 (24.8)</b>	<b>2.51 (3.4)</b>	<b>-6.08</b>	<b>11.12</b>	<b>0.35 (3.4)</b>	<b>-8.35</b>	<b>-9.05</b>	<b>0.23</b>	<b>.634</b>	<b>.005</b>	<b>.076</b>
	Boys	22	100.98 (21.1)	98.70 (17.4)	97.06 (23.6)	-2.28 (4.4)	-13.44	8.88	-3.91 (4.5)	-15.22	7.38	1.12	.295	.025	.179
	Girls	25	75.93 (20.8)	79.83 (21.6)	73.28 (20.5)	7.31 (5.2)	-5.77	20.40	4.62 (5.3)	-8.63	17.87				
	Preeschool	16	93.50 (22.6)	99.45 (14.4)	106.77 (20.2)	7.87 (5.6)	-6.24	21.99	14.22 (5.7)	-0.07	28.51	0.39	.534	.009	.094
	School	31	84.65 (24.8)	83.10 (22.9)	72.87 (18.4)	-2.84 (3.9)	-12.66	6.98	-13.51 (3.9)	-23.46	-3.57				

Notes: Screen-time and sleep time are described in hours/day, while ST, LPA and MVPA in min/day. Abbreviations: N = sample; SD = Standard deviation; M Dif = mean differences; SE = Standard error; op = Observed power; CI = Confidence interval; LL = Lower Limit; UL = Upper Limit.

Finally, pre-schoolers obtained significant higher results when meeting MVPA and sleep guidelines together ( $\chi^2=4.80$ ;  $p=.024$ ), while primary school children had significant better results meeting screen-time and sleep recommendations together ( $\chi^2=5.47$ ;  $p=.018$ ).

**Table 4.** Proportion of children meeting the MVPA, Screen-time, and Sleep guidelines and combinations of these recommendations by school stage and gender variables.

Individual recommendations, %	Gender differences					School stage differences				
	Total (n = 81)	Boys (n= 36)	Girls (n = 45)	$\chi^2$	$p$	Total (n = 81)	Preschoolers (n= 30)	Primary schoolers (n = 51)	$\chi^2$	$p$
<b>MVPA</b>										
<i>Weekdays</i>	88.9	97.2	82.2	4.55	.033*	88.9	96.7	84.3	2.91	.085
<i>Weekend days</i>	67.9	80.6	57.8	4.76	.025*	67.9	93.3	52.9	14.14	<.001*
<i>Total</i>	80.2	91.7	71.1	5.33	.019*	80.2	95.6	68.6	11.72	<.001*
<b>Screen-time</b>										
<i>Weekdays</i>	72.8	75.1	71.2	0.15	.446	72.8	70.1	74.4	.194	.424
<i>Weekend days</i>	50.6	55.6	46.7	0.63	.284	50.6	43.3	54.9	1.01	.219
<i>Total</i>	59.3	58.3	60.1	0.02	.530	59.3	46.7	66.7	3.13	.046*
<b>Sleep</b>										
<i>Weekdays</i>	96.3	91.7	100	3.89	.084	96.3	90.1	100	5.29	.048*
<i>Weekend days</i>	93.8	88.9	97.8	2.72	.118	93.8	90.2	96.1	1.20	.262
<i>Total</i>	96.3	91.7	99.8	3.82	.089	96.3	90.1	99.8	5.22	.048*
<b>Specific combinations, %</b>										
<i>MVPA + Screen-time</i>	44.4	52.8	37.8	1.82	.130	44.4	46.7	43.1	.095	.468
<i>MVPA + Sleep</i>	76.5	83.3	71.1	1.66	.152	76.5	89.9	68.6	4.80	.024*
<i>Screen-time + Sleep</i>	56.8	52.7	60.1	0.42	.335	56.8	40.1	66.7	5.47	.018*
<i>Met all 24-hour MG</i>	42.1	47.2	37.8	0.73	.264	42.1	39.9	43.1	0.07	.484
<i>Met none</i>	0	0	0	-	-	0	0	0	-	-

Notes: Significant results are marked with \*. Abbreviations: MG = Movement guidelines.

## 7.4. Discussion

This was the first intervention study conducted with both pre-schoolers and children targeting 24-hour movement behaviours. Also, this was the first intervention study to describe the percentage of children and pre-schoolers meeting all 24-hour movement guidelines, individually and all together respectively, after participating in a school-based intervention. Main findings in terms of effectiveness indicated significant improvements only in LPA. Then, we found that most children meet MVPA (80.2%) and sleep (96.3%) recommendations, being recreational screen-time the worst movement behaviour (59% of compliance). The following paragraphs of the discussion explore the hypotheses of these main results.

The first aim was to examine the effects of a school-based intervention on children's 24-hour movement behaviours. Then, we hypothesised to find better results in both samples (i.e., pre-schoolers and children) after conducting the school-based intervention. Results found in our study are consistent with those previously found in our systematic review and meta-analysis (Chapter 5), regarding that school-based interventions are not effective for improving MVPA. In fact, in our study MVPA did not improve after conducting two years of school-based intervention. Nevertheless, as we found in the percentage of pre-schoolers and children meeting MVPA guidelines in T2 (80.2%), this may be due to an even higher level of MVPA registered at T0, which is difficult to improve as well as a good finding for these children and this school. Furthermore, that decrease of MVPA with age is what most studies report (Guthold et al., 2020), so the intervention may have slowed down the process but not stopped it. Also, the intervention has probably helped to stop the slowdown of MVPA associated with age, as only weekend MVPA significantly decreased. On the other hand, ST did not get significantly better, but it did not get worse either. Finally, LPA was the only movement behaviour which experienced a significant improvement. However, this behaviour has not been reviewed in previous meta-analyses (Rollo et al., 2020; Tapia-Serrano et al., 2022), nor in similar intervention studies (Tapia-Serrano et al., 2022). Thus, further study and assessment of LPA is needed in 24-hour movement behaviour studies highlighting a new gap in the literature. In terms of general findings, the Tapia-Serrano et al., (2022) study also found non-significant intervention effects for recreational screen-time and sleep, while significant improvements of PA. However, this behaviour cannot be compared with our results as we differentiated LPA and MVPA and they assessed PA with self-reported questionnaires, which can introduce some bias, especially in early children. Thus, we suggest that interventions that seek to promote MVPA in school may not be successful because of the more sedentary nature of the school, coinciding with results of Chapter 5.

The second aim of our research study was to describe the proportion of 3 to 9-year-old children meeting the 24-hour movement guidelines. Based on the literature (Rollo et al., 2020; Tapia-Serrano et al., 2022), we expected at least 10% of pre-schoolers and children would all meet 24-hour movement guidelines. Also, we hypothesised that the prevalence of meeting guidelines would be higher in boys than in girls and higher in pre-schoolers than in primary schoolers. Nevertheless, results found in our study were



much better than we expected (i.e., 42.1% met all guidelines) and better than what literature recently reported (Rollo et al., 2020; Tapia-Serrano et al., 2022). Regarding specific compliance with each guideline, we also found better results in our study than reported in the literature. For example, the mean compliance rate for MVPA guidelines in this school was 80.2% whereas the literature reported near 20% (Guthold et al., 2020). Results from pre-schoolers recreational screen-time in our study were 46.7%, while the literature reported 35.6% (McArthur et al., 2022). Finally, the prevalence of meeting the sleep guidelines we found in our study was 96.3%, while the literature reported 60% (Matricciani et al., 2012). Therefore, we suggest these findings may be due to the characteristics of the intervention implemented as well as the fact of conducting an intervention which lasted two years.

In terms of gender differences, we were right about the idea that the prevalence of meeting all 24-hour movement guidelines was higher in boys (47.2%) than girls (37.8%). However, we were wrong in terms of school stage differences, being lower in pre-schoolers (39.9%) than children (43.1%). Furthermore, according to our findings, children's results for recreational screen-time (66.7%) and sleep (99.8%) guidelines were much better than for pre-schoolers (46.7% and 90.1% respectively). Nevertheless, we found the opposite for MVPA results (95.6% for pre-schoolers and 68.6% for children), which share the same MVPA guidelines for both school stages. We think these differences may be explained as the screen-time and sleep guidelines (Tremblay et al., 2017), are more restrictive for pre-schoolers than for children (Tremblay et al., 2016). Finally, it was not possible to compare our findings with a similar study (Tapia-Serrano et al., 2022), because they did not report the percentage of children meeting all 24-hour movement guidelines and they used only self-reported measures to assess all 24-hour movement behaviours.

Another important result to discuss was that 0% of children belonging to this school did not meet any of the three guidelines, while previous studies reported 8.81% for pre-schoolers and 15.57% for children (Tapia-Serrano et al., 2022). Thus, this fact seems to support the positive results of this school-based intervention explained in previous paragraphs. Then, gender effects were not found in terms of intervention effectiveness as we described in the results. Nevertheless, they were found regarding the percentage of meeting weekday, weekend and overall MVPA guidelines. Moreover, results in our study showed that boys are more active than girls on weekdays, in total and

especially on weekend days, coinciding with the information provided in the literature about PA and gender differences (Love et al., 2017; Schlund et al., 2021; Tapia-Serrano et al., 2022). Nevertheless, we cannot compare our findings with the school-based intervention of Tapia-Serrano et al., (2022), as they did not analyse gender differences. Thus, gender effects are not sufficiently reported in several behaviours like PA (Love et al., 2017; Schlund et al., 2021), as well as 24-hour movement behaviours. Furthermore, some studies highlighted that future interventions need to document gender differences and similarities to explore whether gender results are influenced by school-based interventions (Love et al., 2017; Schlund et al., 2021).

This study presents some strengths and limitations that should be highlighted. The major strength of this study is that this is the first school-based intervention to address 24-hour movement behaviours among pre-schoolers and children. Also, this is the first school-based intervention conducted exclusively following the CAS framework with both pre-schoolers and children. However, our study is not out of limitations. First, we did not include a control group and only a small convenience sample of children participated in this study, thus introducing some bias in the results of the study. Second, the intervention had several components which made it difficult to correctly interpret the causal effect of the intervention. Third, for now we did not conduct a post- follow-up after developing the intervention.

## **7.5. Conclusion**

Grounded in the CAS framework, a multi-component school-based intervention implemented through two years seems to be effective for improving LPA, but not MVPA among pre-schoolers and children. ST, recreational screen-time and sleep remained stable across the intervention. Also, we found that most children meet MVPA and sleep recommendations, being recreational screen-time the worst behaviour in terms of guidelines compliance among 24-hour movement behaviours. The overall results found in this study suggest that although a multilevel and multicomponent intervention may be an innovative way to improve 24-hour movement behaviours, it is important to test before the intervention to know which is the true starting point and correctly interpret the results at the end of the intervention. Also, it seems that school-based interventions have a limited effect on MVPA, and that issue should be further studied in future studies. Nevertheless,

we encourage researchers to keep developing long-term multicomponent interventions that involve the whole school community and different areas. Thus, as we highlighted in this study, further research and school-based interventions are needed about 24-hour movement behaviours and the CAS framework to better understand and interpret their effectiveness, especially in MVPA, as well as to improve our research field.

## 7.6. References

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## **SECTION III. DISCUSSION AND CONCLUSIONS**

## **Chapter 8. Discussion and main findings**

To avoid repetition of the discussion sections previously described in each one of the studies, this section is focused on the discussion of the general aims, research questions and gaps of this thesis. Thus, this chapter provides an overview of findings, a discussion of findings, and the implications for future research, strengths and limitations.

### 8.1. Overview of findings

The review protocol described in Chapter 3 provided transparency about the review process. Also, it described a research guide (i.e., eligibility criteria, search strategy, risk of bias and quality assessment of individual studies) that will help future researchers to conduct other valid and reliable systematic reviews related to 24-hour movement behaviours.

The scoping review described in Chapter 4 showed as a main finding that there is a lack of school-based interventions targeting the three 24-hour movement behaviours in 5-12 years old children. The second finding was that most studies addressing PA and SB did not report or indicate any follow-up measure, thus making it difficult to correctly interpret their sustainability.

The main finding of the systematic review and meta-analysis conducted and explained in Chapter 5 was that school-based interventions are effective for reducing ST among children aged 5-12 years. As a second finding about MVPA, we highlighted that school-based interventions with two intervention components and labelled as high quality seems to be effective for improving MVPA. Nevertheless, there was no evidence of effect regarding the duration, the use of a theoretical framework and the design of the school-based interventions.

The intervention protocol described in Chapter 6 provided transparency about the design, implementation and assessment process of the school-based intervention. Furthermore, this is the first school-based intervention to be described following the CAS framework and targeting the whole school setting in Spanish children.



Finally, Chapter 7 evaluates the effectiveness of the school-based intervention regarding 24-hour movement behaviours among children aged 3-9 years. As a main finding we reported effectiveness for improving LPA, but not MVPA. Also, ST, recreational screen-time and sleep remained stable across the intervention. In terms of meeting the 24-hour movement guidelines, 42% of all schoolchildren met all guidelines and 0% met none.

## 8.2. Discussion of findings

In the following paragraphs we discuss the aims and research questions outlined in chapter 1 as well as the main gaps described in chapter 2.

The overall aim of this doctoral thesis was to study the implementation and effectiveness of school-based interventions targeting 24-hour movement behaviours in children. Then, to effectively do that, we formulated two research questions: “Are school-based interventions promoting the 24-hour movement guidelines among children?”, and “Are school-based interventions effective for promoting 24-hour movement behaviours among children?”.

The first research question allowed us to identify an important gap, as we identified a lack of systematic reviews and meta-analyses about school-based interventions targeting all 24-hour movement behaviours among children (Rollo et al., 2020; Saunders et al., 2022; Tapia-Serrano et al., 2022). Then, after detecting this relevant gap in our research field, we decided to conduct the first systematic review about school-based interventions and 24-hour movement behaviours (i.e., Chapter 3 and 4). Although we expected to find several school-based interventions about the three 24-hour movement behaviours, conducting both studies allowed us to fill this gap in the literature and therefore find another gap. Thus, as we further explained in Chapter 4 and in the overview of findings, we found a lack of school-based interventions targeting the three 24-hour movement behaviours in 5-12 years old children. Basically, this fact was due to a lack of studies targeting sleep behaviour, reinforcing that school-based interventions continue nowadays to be mainly focused on PA and SB (Blunden & Rigney, 2015; Busch et al., 2017; Chaput et al., 2014).

Then, the second research question allowed us to detect two gaps in terms of

effectiveness of school-based interventions targeting PA and SB, which were partially filled with the results described in Chapter 5. We did not include sleep behaviour because of findings described in Chapter 4. The first gap was: “It is not clear if school-based interventions are effective at improving MVPA and reducing ST among children” (Dobbins et al., 2013; Jones et al., 2020; Love et al., 2019; Nally et al., 2021). And the second gap was: “There is not enough evidence about which are the most effective strategies, theoretical frameworks, or intervention components to effectively increase PA and reduce SB” (Cassar et al., 2019; Dobbins et al., 2013; van Sluijs et al., 2021). Regarding the first gap, we expected to find something new after conducting a meta-analysis in a different way as the others previously conducted in our research field (Jones et al., 2020; Love et al., 2019; Nally et al., 2021). Thus, after detecting their weaknesses, we restricted our eligibility criteria for including only children’s samples, studies conducted in the school-setting and assessed with accelerometer devices, which reduced a lot the bias about the assessment process and reported results (Ekelund et al., 2020). Consistent with our expectations, we found a significant result about ST reduction but not about MVPA improvement. Finally, regarding the second gap, we also examined these variables after performing subgroup and meta-regression analyses. Thus, we found significant effects about study quality and number of intervention components to improve MVPA, but non-significant effects for the other intervention variables analysed.

The second aim of this doctoral thesis was to describe, register and assess the co-creation process of a school-based intervention to promote 24-hour movement behaviours in children. Then, to achieve this aim we detailed the next research question: “How effective can a co-created school-based intervention be to promote 24-hour movement behaviours in children?”.

This research question allowed us to detect three gaps. The first one was: “Whereas little is known about the inter-relationship between the different school elements, the CAS framework tries to establish whole-school ethos and practise about 24-hour movement behaviours promotion” (Daly-Smith et al., 2020). Furthermore, to fill this gap and try to answer the inter-relationship between different school elements, we described the school-based intervention of this thesis based on the CAS framework in Chapter 6. However, we could not draw sound conclusions for now as only the effectiveness assessment in terms of 24-hour movement behaviours was done. Moreover,

it remains to be done in the next year the assessment of the whole school setting using the REAIM framework (Glasgow et al., 2019), detailed in Chapter 6. Thus, this gap remains open until we can update the assessment. The second gap was: “Most research about the 24-hour movement behaviours to date has been focused on cross-sectional studies, and the longitudinal effect of school-based interventions seems to be unexplored” (Rollo et al., 2020; Tapia-Serrano et al., 2022). Then, this thesis added new evidence to the literature about this topic through Chapter 7 after conducting and assessing the effectiveness of a school-based intervention for two years. Nevertheless, there might be much more school-based interventions needed in our research field to contrast our findings and fill this gap. Finally, the third gap was: “There has not yet been analysed the effect of a school-based intervention on the percentage of children meeting or not meeting the 24-hour movement guidelines” (Rollo et al., 2020; Tapia-Serrano et al., 2022). Thus, as it was previously explained in Chapter 7, this thesis added new evidence to the literature about the percentage of children meeting the 24-hour guidelines and meeting none of the guidelines after participating in a school-based intervention. However, in our opinion, more studies will be needed to complete the evidence and contribute to fill this gap in our research field.

To conclude, it was considered important to discuss the French and Spanish data. As it was highlighted in Chapter 1, this thesis has been performed during the Covid-19 pandemic and due to restrictions, it was not possible to replicate the Spanish intervention in a French school. Although efforts have been made since 2020 and 2021 to try to intervene in the French country, it was not possible until September 2021 when it was too late as only a year remained before submitting this thesis. Nevertheless, due to the relevance of conducting a cross-border thesis, even if we did not intervene in France, it was considered relevant to report Spanish and French studies about movement behaviours and school-based interventions through the theoretical framework described in Chapter 2.

### 8.3. Implications for future research

The findings of this thesis have several important implications for future research and practice.

First, this thesis identified the need for including sleep behaviour in school-based

interventions to correctly promote the 24-hour Movement Guidelines among children aged 5-12 years. In recent years, more research has emerged highlighting the impact of movement behaviours on children and adolescent's health, however this thesis found there is a lack of school-based interventions addressing them. This implies future interventions should focus on developing initiatives that benefit all three movement behaviours (i.e., reducing ST and screen-time while promoting sufficient sleep and PA), instead of just targeting PA and SB (Blunden & Rigney, 2015; Busch et al., 2017; Chaput et al., 2014).

Second, another finding of Chapter 4 was that most studies did not report or indicate any follow-up measure, so it is important to encourage researchers to include follow-up measures in their school-based interventions to be able to correctly interpret their sustainability. This suggestion coincides with the literature which also recommends follow-up measures after conducting the intervention to know about their sustainability over time (Gugglberger, 2021; Sallis, 2018). Thus, connecting with Chapters 6 and 7, a follow-up measure of the school-based intervention conducted during this thesis will be made one year after the intervention.

Third, in both scoping review and meta-analysis we have detected misleading information about the intervention details in several studies (i.e., lack of information about sample size, strategies or theoretical frameworks used, intervention components engaged, poor description of assessment and reported results etc.). Thus, researchers should try to correctly indicate their intervention details (e.g., strategies or theoretical frameworks used), assessment methods and reported outcomes in any future studies or in their protocols to favour transparency. In this regard, it is as important to know what works for designing school-based interventions as what does not work in the school setting.

Fourth, this thesis found that school-based interventions are effective for reducing ST in school-aged children. Currently this is the first study to prove it in our research field. Therefore, due to the impact and presence of ST in school-aged children's day, it seems recommendable for future studies to include ST and focus on reducing this behaviour (e.g., using active breaks) in the design of future school-based interventions.

Fifth, after conducting the meta-analysis we have highlighted the importance of designing high quality interventions (i.e., reducing assessment and researcher biases as much as possible, etc.) as well as multicomponent interventions (e.g., school curriculum and family involvement), to improve daily MVPA among school-aged children. Thus, these findings are relevant as previous studies did not reach this high level of detail regarding the analysis of several intervention variables.

Sixth, the intervention study found a great compliance of the 24-hour movement guidelines in both pre-schoolers and children after participating in the school-based intervention. This compliance was more than three times the compliance reported in the literature for both age groups worldwide (Rollo et al., 2020; Tapia-Serrano et al., 2022), suggesting an important intervention effect. Therefore, future school-based interventions should be conducted taking into account the components of our intervention study to improve the compliance of 24-hour movement guidelines among pre-schoolers and children.

To sum up, considering the influence of the school setting on children's 24-hour movement behaviours, the actual evidence to improve them through school-based interventions, and that children spend a large proportion of their time during a typical weekday at school, school appears to be an ideal setting for delivering interventions.

#### 8.4.Limitations and strengths

Despite the findings found in thesis studies described in Section II, it is important to highlight some of the overall limitations:

1. This thesis is mainly composed of only an original research article (i.e., chapter 7), while the others are two protocols (chapters 3 and 6), and a review and meta-analysis articles (chapters 4 and 5), which are secondary sources of research. However, this limitation is justified in terms of difficulties and obstacles found due to the international health context between 2020-2022 outlined in chapter 1.
2. The small sample size, the lack of a control group and the use of a convenience sampling approach may have limited the interpretability and generalisation of the results reported in Chapter 7. Furthermore, there is an inconsistency between Chapters 6 and 7 in the selection of the sample age, because while this thesis is

mainly focused on the study of movement behaviours among children aged 5-12 years, we also included pre-schoolers in the intervention sample. Nevertheless, it was due to our difficulty in collecting more primary school children's data and taking advantage of the fact that the intervention was carried out by the schoolteachers in primary and pre-school students.

3. This thesis analysed data from three surveys that were conducted at different time periods (baseline in October 2020, T1 in May 2021, and T2 in March 2022) with different lengths of follow-up (6-7 months vs. 10 months) due to the convenience collection data process. In this regard, the first period was chosen due to the start of the school year (October 2020), the data was collected in May 2021 because of the end of the school year, and finally, the last period of March 2022 was selected due to the impossibility for collecting data between April-June, as I was doing a research stay in Limerick (Ireland). These dates were established and accorded with the school staff to facilitate the completion of the entire process.
4. Finally, the last limitation is the lack of assessment of the whole school setting, by now. As we described in Chapter 6, it was planned to assess the school setting using the REAIM framework (Glasgow et al., 2019), but it was not possible to do for now due to the time limitation of the thesis. However, it will be done as soon as possible to complete the evaluation process planned in Chapter 6. Also, a follow-up of 24-hour movement behaviours assessed during the intervention will be done in the next year to interpret their sustainability.

On the other hand, the strengths of this thesis are as follows:

1. The main strength of this thesis is its contribution to the literature of 24-hour movement behaviours and subsequent school-based interventions, highlighting important gaps and interesting findings. In fact, this is the first thesis focused on school-based interventions and 24-hour movement behaviours.
2. Another strength is the description and implementation of a co-created school-based intervention among different stakeholders involved. Specially referring to the recently created CAS framework, thus being chapter 6, the first intervention study following this framework in Spain and France.
3. Furthermore, this thesis carried out the first intervention study targeting 24-hour movement behaviours among pre-schoolers. Also, this thesis includes the first

study to assess the compliance of 24-hour movement guidelines after conducting a school-based intervention.

4. Finally, it is important to highlight the sound methodology used in the body of this thesis. It means before conducting a review and an intervention study, there was a previous planning phase where two protocols were created (i.e., Chapters 3 and 6). Furthermore, before implementing an intervention study (i.e., Chapter 7), the literature was reviewed in terms of conducting a scoping review and a meta-analysis (i.e., Chapters 4 and 5). Thus, this thesis was carried out following the correct steps as well as a specific research structure.

## Chapter 9. Conclusions

In this last section, as previously done in the introduction, we present the conclusions about this doctoral thesis in French and Spanish languages according to regulations for the submission of cross-border doctoral theses.

The completion of this doctoral thesis has entailed a series of difficulties and obstacles that have been overcome throughout this process, especially in relation to the design, implementation and evaluation of the intervention program carried out. Thus, we highlight problems, solutions and orientations that can generate knowledge of great interest to the scientific community in relation to the implementation of future intervention programs aimed at promoting 24-hour movement behaviours. Some of the solutions that have been adopted are supported by the scientific literature, while other orientations are provided solely from the experience of having participated in the intervention program. These reflections are presented in the following paragraphs.

### 9.1. Main conclusions in French language.

Cette thèse a fourni de nouvelles preuves pour faire avancer la compréhension des comportements de mouvement des enfants sur 24 heures et des interventions en milieu scolaire. Comme résultat principal, il est constaté un manque d'interventions en milieu scolaire primaire qui incluent le sommeil, l'activité physique et le temps sédentaire dans leurs programmes d'intervention. Des recherches et des études supplémentaires sont donc nécessaires pour explorer cette lacune et l'efficacité des comportements de mouvement de 24 heures dans le cadre scolaire. Nous recommandons également d'intégrer des interventions en milieu scolaire qui tiennent compte du comportement en matière de sommeil, lequel est crucial pour le maintien d'un mode de vie sain non seulement pendant l'enfance, mais surtout à des stades ultérieurs comme l'adolescence et l'âge adulte.

En outre, cette thèse démontre que les interventions en milieu scolaire sont efficaces pour réduire le temps quotidien que les enfants passent à adopter un comportement sédentaire. Il s'agit d'un aspect essentiel, car l'Organisation mondiale de la santé (OMS) a souligné l'importance d'essayer de réduire le temps sédentaire quotidien chez les enfants et les adolescents dans son dernier rapport en 2020. Ce rapport détaille



les recommandations en matière d'activité physique et de temps sédentaire au niveau mondial. Bien qu'il n'existe pas de recommandation spécifique concernant le temps de sédentarité, l'importance de le réduire autant que possible a été soulignée dans ces dernières orientations. Par conséquent, la réduction du temps sédentaire total pendant l'enfance par des interventions en milieu scolaire peut encourager un mode de vie plus actif.

Une autre conclusion importante tirée de cette thèse de doctorat est que les interventions en milieu scolaire à plusieurs composantes (c'est-à-dire à deux composantes) et les interventions de haute qualité (c'est-à-dire avec un groupe de contrôle et des biais de mise en œuvre et d'évaluation réduits) sont efficaces pour augmenter le temps quotidien consacré aux APMV chez les enfants. Cela implique donc que ces aspects devraient être pris en compte lors de la conception de futures interventions en milieu scolaire visant à améliorer l'APMV chez les enfants. S'il est vrai que toutes les interventions en milieu scolaire ne peuvent être réalisées avec un groupe de contrôle ou que toutes n'ont pas les moyens de mettre en œuvre une intervention à composantes multiples, ces recommandations devraient être suivies dans la mesure du possible, surtout si les moyens nécessaires sont disponibles.

D'autre part, la conception de l'intervention est une étape cruciale dans le processus d'élaboration de données probantes pour améliorer les comportements sains des enfants. Cependant, les interventions en milieu scolaire sur les comportements sains sont rarement développées de manière systématique et, lorsqu'elles sont publiées, la description limitée de leurs composantes et d'autres variables d'intervention devient souvent un obstacle à leur reproductibilité. Néanmoins, cette thèse fournit une description détaillée du développement, des caractéristiques et de l'évaluation d'une intervention en milieu scolaire visant à améliorer les comportements de mouvement des enfants. En effet, elle apporte une contribution significative à la littérature qui non seulement soutiendra les futurs chercheurs dans la planification des interventions en milieu scolaire, mais les aidera également à concevoir et à informer des stratégies d'intervention les plus réalisables pour l'adoption et la mise en œuvre à grande échelle.

En termes d'efficacité, une autre conclusion importante tirée de cette thèse est que les interventions qui encouragent les comportements de mouvement ont un effet

important sur le degré de réalisation des schémas de mouvement sur 24 heures (c'est-à-dire l'AFMV, le temps d'écran récréatif et le sommeil) chez les élèves de la petite enfance et de l'école primaire. En ce sens, le pourcentage de conformité aux recommandations obtenu à la fin de l'intervention était plus de trois fois supérieur à celui rapporté dans la littérature pour les élèves de maternelle et de l'école primaire. Par conséquent, ces résultats nous permettent de renforcer le modèle d'intervention décrit précédemment, ainsi que de recommander à notre domaine de recherche que, pour améliorer le degré de conformité à ces recommandations, une intervention en milieu scolaire est nécessaire. En fait, il s'agit de l'une des premières interventions en milieu scolaire au monde à améliorer ces trois comportements. Nous encourageons donc les autres chercheurs à continuer à contribuer à l'augmentation des preuves sur ce sujet dans notre domaine de recherche en menant des études similaires.

Pour conclure, les résultats de cette thèse de doctorat soutiennent l'adoption de comportements de mouvement sur 24 heures en milieu scolaire. Bien qu'il y ait un manque d'études visant à améliorer ces comportements sains, la littérature scientifique détaillée dans le cadre théorique, ainsi que la faible conformité aux recommandations internationales, justifient de futures interventions en milieu scolaire visant à promouvoir des comportements de mouvement de 24 heures chez les élèves de l'école primaire. Dans une perspective globale de promotion de la santé, il est nécessaire que les écoles participent activement à la réalisation et à la promotion des comportements sains chez les enfants et les adolescents dans le but de consolider des habitudes saines avant d'atteindre l'âge adulte. Il est donc crucial d'aborder tous les comportements mentionnés dans cette thèse de manière holistique, car ils permettent d'améliorer la santé générale et de promouvoir le maintien d'un mode de vie actif.

## 9.2. Main conclusions in Spanish language.

Esta tesis aporta nuevos hallazgos en cuanto a la comprensión de los comportamientos de movimiento de 24 horas en niños, así como sobre las intervenciones escolares. Como resultado principal, se destaca una falta de intervenciones en escuela primaria que incluyan el comportamiento del sueño. Por lo tanto, son necesarias más investigaciones y estudios que exploren tanto este vacío en la literatura científica, como la eficacia de los comportamientos de movimiento de 24 horas en el entorno escolar. Asimismo, recomendamos incorporar la realización de intervenciones escolares que

tengan en cuenta el comportamiento del sueño, el cual es crucial a la hora de mantener un estilo de vida saludable no solo en la infancia sino especialmente en futuras etapas como la adolescencia y la edad adulta.

Además, esta tesis demuestra que las intervenciones escolares son eficaces para disminuir el tiempo diario que los niños pasan realizando un comportamiento sedentario. Esto es un aspecto clave ya que la Organización Mundial de la Salud (OMS) señaló la importancia de tratar de reducir el tiempo sedentario diario en niños y adolescentes en su último informe de 2020. En este informe se detallaron las recomendaciones de actividad física y tiempo sedentario a nivel mundial. Aunque no existe una recomendación específica para el tiempo sedentario, se remarcó en esta última guía la importancia de reducirlo todo lo posible. Por lo tanto, la disminución del tiempo sedentario total en la infancia a través de intervenciones escolares permitiría fomentar un estilo de vida más activo y saludable.

Otra conclusión importante que se deriva de esta tesis doctoral es que las intervenciones escolares multicomponente (es decir, de dos componentes) y las intervenciones de alta calidad (es decir, que tienen sesgos de implementación y evaluación reducidos) son eficaces para aumentar el tiempo diario de AFMV en niños. Por lo tanto, esto implica que a la hora de diseñar futuras intervenciones escolares que pretendan mejorar la AFMV en niños se deberían tener en cuenta estos aspectos. Si bien es cierto que no todas las intervenciones escolares pueden realizarse con un grupo control o que no todas tienen los medios para implementar una intervención multicomponente, se debería tratar de seguir estas recomendaciones en la medida de lo posible, especialmente si se dispone de los medios necesarios.

Por otra parte, el diseño de la intervención es una etapa crucial en el proceso de desarrollo de la evidencia para mejorar los comportamientos saludables de los niños. Sin embargo, las intervenciones escolares sobre conductas saludables rara vez se desarrollan de forma sistemática y, cuando se publican, la escasa descripción de sus componentes y de otras variables de la intervención suele convertirse en un obstáculo para que puedan ser replicadas. No obstante, en esta tesis se ofrece una descripción detallada del desarrollo, las características y la evaluación de una intervención escolar para mejorar los comportamientos de movimiento de los niños. De hecho, se aporta una contribución

significativa a la literatura que no sólo servirá de apoyo a futuros investigadores para planificar intervenciones escolares, sino que también les ayudará a diseñar e informar sobre estrategias de intervención más factibles para su adopción y su aplicación a gran escala.

En términos de efectividad, otra de las conclusiones importantes que se deriva de esta tesis doctoral es que las intervenciones que promueven los comportamientos del movimiento tienen un gran efecto en el grado de consecución de las pautas de movimiento de 24-horas (es decir, AFMV, tiempo recreativo de pantalla y sueño) en alumnado de educación infantil y de educación primaria. En este sentido, el porcentaje de cumplimiento de las recomendaciones que se obtuvo al final de la intervención fue más del triple del que reporta la literatura científica, tanto para alumnado de educación infantil como de educación primaria. Por lo tanto, la obtención de estos hallazgos nos permite reforzar el diseño de la intervención previamente descrito, así como recomendar a nuestro campo de investigación que, para mejorar el grado de cumplimiento de estas recomendaciones, es necesario realizar una intervención escolar. De hecho, esta es una de las primeras intervenciones escolares a nivel mundial que se han realizado para mejorar estos tres comportamientos. Por ello, animamos al resto de investigadores a que sigan contribuyendo a aumentar la evidencia sobre esta temática en nuestro campo de investigación realizando estudios similares.

Para concluir, los hallazgos de esta tesis doctoral apoyan la adopción de las conductas de movimiento de 24 horas en el entorno escolar. Aunque existe una falta de estudios dirigidos a la mejora de estos comportamientos saludables, la literatura científica detallada en el marco teórico, así como el bajo cumplimiento de las recomendaciones internacionales justifican la realización de futuras intervenciones escolares que promuevan las pautas de movimiento de 24 horas en alumnado de educación primaria. Desde una perspectiva global de promoción de la salud, es necesario que las escuelas participen activamente en la consecución y el fomento de los comportamientos saludables en niños y adolescentes con el objetivo de afianzar hábitos saludables antes de llegar a la edad adulta. Por ello, es determinante poder abordar todos aquellos comportamientos referenciados en esta tesis doctoral de una manera holística, ya que permiten mejorar la salud general, así como fomentar el mantenimiento de un estilo de vida activo.

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## **SECTION V. ANEXES**

## Annexes of Chapter 3.

### 3.1. PRISMA-P Checklist

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
<b>ADMINISTRATIVE INFORMATION</b>					
<b>Title</b>					
Identification	1a	Identify the report as a protocol of a systematic review	<input checked="" type="checkbox"/>	<input type="checkbox"/>	2-4
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	<input type="checkbox"/>	<input checked="" type="checkbox"/>	n/a
<b>Registration</b>	2	If registered, provide the name of the registry (e.g., PROSPERO) and registration number in the Abstract	<input checked="" type="checkbox"/>	<input type="checkbox"/>	50
<b>Authors</b>					
Contact	3a	Provide name, institutional affiliation, and e-mail address of all protocol authors; provide physical mailing address of corresponding author	<input checked="" type="checkbox"/>	<input type="checkbox"/>	6-17
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	<input checked="" type="checkbox"/>	<input type="checkbox"/>	227-229
<b>Amendments</b>	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	<input type="checkbox"/>	<input checked="" type="checkbox"/>	n/a
<b>Support</b>					
Sources	5a	Indicate sources of financial or other support for the review	<input checked="" type="checkbox"/>	<input type="checkbox"/>	224-226
Sponsor	5b	Provide name for the review funder and/or sponsor	<input checked="" type="checkbox"/>	<input type="checkbox"/>	224-226
Role of sponsor/funder	5c	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	<input checked="" type="checkbox"/>	<input type="checkbox"/>	224-226
<b>INTRODUCTION</b>					



Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
<b>Rationale</b>	6	Describe the rationale for the review in the context of what is already known	<input checked="" type="checkbox"/>	<input type="checkbox"/>	51-109
<b>Objectives</b>	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	111-121
<b>METHODS</b>					
<b>Eligibility criteria</b>	8	Specify the study characteristics (e.g., PICO, study design, setting, time frame) and report characteristics (e.g., years considered, language, publication status) to be used as criteria for eligibility for the review	<input checked="" type="checkbox"/>	<input type="checkbox"/>	130-145
<b>Information sources</b>	9	Describe all intended information sources (e.g., electronic databases, contact with study authors, trial registers, or other grey literature sources) with planned dates of coverage	<input checked="" type="checkbox"/>	<input type="checkbox"/>	147-158
<b>Search strategy</b>	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	<input checked="" type="checkbox"/>	<input type="checkbox"/>	147-158, Additional file 2
<b>STUDY RECORDS</b>					
Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	<input checked="" type="checkbox"/>	<input type="checkbox"/>	160-175
Selection process	11b	State the process that will be used for selecting studies (e.g., two independent reviewers) through each phase of the review (i.e., screening, eligibility, and inclusion in meta-analysis)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	160-175
Data collection process	11c	Describe planned method of extracting data from reports (e.g., piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	<input checked="" type="checkbox"/>	<input type="checkbox"/>	160-175
<b>Data items</b>	12	List and define all variables for which data will be sought (e.g., PICO items, funding sources), any pre-planned data assumptions and simplifications	<input checked="" type="checkbox"/>	<input type="checkbox"/>	177-188

Section/topic	#	Checklist item	Information reported		Line number(s)
			Yes	No	
<b>Outcomes and prioritization</b>	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	<input checked="" type="checkbox"/>	<input type="checkbox"/>	177-188
<b>Risk of bias in individual studies</b>	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	<input checked="" type="checkbox"/>	<input type="checkbox"/>	190-198
<b>DATA</b>					
<b>Synthesis</b>	15a	Describe criteria under which study data will be quantitatively synthesized	<input checked="" type="checkbox"/>	<input type="checkbox"/>	200-207
	15b	If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data, and methods of combining data from studies, including any planned exploration of consistency (e.g., $I^2$ , Kendall's tau)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	200-207
	15c	Describe any proposed additional analyses (e.g., sensitivity or subgroup analyses, meta-regression)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	n/a
	15d	If quantitative synthesis is not appropriate, describe the type of summary planned	<input checked="" type="checkbox"/>	<input type="checkbox"/>	200-207
<b>Meta-bias(es)</b>	16	Specify any planned assessment of meta-bias(es) (e.g., publication bias across studies, selective reporting within studies)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	n/a
<b>Confidence in cumulative evidence</b>	17	Describe how the strength of the body of evidence will be assessed (e.g., GRADE)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	206-207

### 3.2. Databases and terms included

#### Web of science (WOS):

TS=(child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR school children OR schoolage\* OR school-age\* OR school age\* NOT adolescent\*) AND TS=(strateg\* OR technique\* OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health promotion intervention OR health education OR health intervention OR school setting OR school based intervention OR school-based intervention OR school based program\* OR school-based program\* OR school program\* OR school intervention OR school health intervention) AND TS=(PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement) AND TS=(sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities OR computer use OR computer time OR media use OR video games OR tablet use OR smartphone use OR mobile phone use OR computer time OR television time OR TV time OR gaming OR screen time OR screen-time OR reading OR TV viewing OR TV child room OR television viewing OR video viewing) AND TS=(sleep\* OR sleep behavio\* OR sleep duration OR sleep quality OR sleep pattern\* OR bedtime OR sleep disturbance OR insomnia).

Additional filters: Main collection of Web of Science, only articles, English language, search interval (2010- 2020), builder terms: TS [Topic].

#### Scopus:

TITLE-ABS-KEY(child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR "school age\*" AND NOT adolescent\*) AND TITLE-ABS-KEY(strateg\* OR technique\* OR intervention\* OR program\* OR "health prevention" OR "health prevention program\*" OR "health program\*" OR "health promotion program\*" OR "health education" OR "health intervention" OR "school setting" OR "school program\*" OR "school intervention") AND TITLE-ABS-KEY(PA

OR "Total PA" OR MVPA OR VPA OR LPA OR "total physical activity" OR "moderate to vigorous physical activity" OR "vigorous physical activity" OR "light physical activity" OR "physical activity" OR "physical inactivity" OR active OR activit\* OR sport\* OR "sports participation" OR "active transport" OR "active commuting" OR "leisure activity" OR walking OR "aerobic exercise" OR "outdoor play" OR exercise OR "motor behavio\*" OR movement) AND TITLE-ABS- KEY(sedentar\* OR "sedentary behavio\*" OR "sedentary time" OR "sedentary lifestyle" OR "total sedentary time" OR "sitting behavio\*" OR "sitting time" OR "prolonged sitting" OR "domestic activities" OR "computer use" OR "computer time" OR "media use" OR "video games" OR "tablet use" OR "smartphone use" OR "mobile phone use" OR "computer time" OR "television time" OR TV time OR gaming OR "screen time" OR reading OR "TV viewing" OR "television viewing" OR "video viewing" OR sleep\* OR "sleep behavio\*" OR "sleep duration" OR "sleep quality" OR "sleep pattern\*" OR bedtime OR "sleep disturbance" OR insomnia).

Additional filters: Scopus database, only articles, English language, search interval (2010-2020), builder terms: TITLE-ABS-KEY [Title, Abstract, Keywords].

**Pubmed:**

((child\*[Title/Abstract] OR student[Title/Abstract] OR pupil[Title/Abstract] OR infant[Title/Abstract] OR childhood[Title/Abstract] OR school\*[Title/Abstract] OR schoolchildren[Title/Abstract] OR schoolaged[Title/Abstract] OR school age\*[Title/Abstract] NOT adolescent\*[Title/Abstract]) AND (strateg\*[Title/Abstract] OR technique\*[Title/Abstract] OR intervention\*[Title/Abstract] OR program\*[Title/Abstract] OR "health prevention"[Title/Abstract] OR health prevention program\*[Title/Abstract] OR health program\*[Title/Abstract] OR health promotion program\*[Title/Abstract] OR health education[Title/Abstract] OR health intervention[Title/Abstract] OR school setting[Title/Abstract] OR school program\*[Title/Abstract] OR school intervention[Title/Abstract]) AND (PA[Title/Abstract] OR Total PA[Title/Abstract] OR MVPA[Title/Abstract] OR VPA[Title/Abstract] OR LPA[Title/Abstract] OR total physical activity[Title/Abstract] OR moderate to vigorous physical activity[Title/Abstract] OR vigorous physical activity[Title/Abstract] OR light physical activity[Title/Abstract] OR physical activity[Title/Abstract] OR physical inactivity[Title/Abstract] OR active[Title/Abstract] OR activit\*[Title/Abstract] OR sport\*[Title/Abstract] OR sports

participation[Title/Abstract] OR active transport[Title/Abstract] OR active commuting[Title/Abstract] OR leisure activity[Title/Abstract] OR walking[Title/Abstract] OR aerobic exercise[Title/Abstract] OR outdoor play[Title/Abstract] OR exercise[Title/Abstract] OR motor behavio\*[Title/Abstract] OR movement[Title/Abstract]) AND (sedentar\*[Title/Abstract] OR sedentary behavio\*[Title/Abstract] OR sedentary time[Title/Abstract] OR sedentary lifestyle[Title/Abstract] OR total sedentary time[Title/Abstract] OR sitting behavio\*[Title/Abstract] OR sitting time[Title/Abstract] OR prolonged sitting[Title/Abstract] OR domestic activities[Title/Abstract] OR computer use[Title/Abstract] OR computer time[Title/Abstract] OR media use[Title/Abstract] OR video games[Title/Abstract] OR tablet use[Title/Abstract] OR smartphone use[Title/Abstract] OR mobile phone use[Title/Abstract] OR computer time[Title/Abstract] OR television time[Title/Abstract] OR TV time[Title/Abstract] OR gaming[Title/Abstract] OR screen time[Title/Abstract] OR reading[Title/Abstract] OR TV viewing[Title/Abstract] OR television viewing[Title/Abstract] OR video viewing[Title/Abstract] OR sleep\*[Title/Abstract] OR sleep behavio\*[Title/Abstract] OR sleep duration[Title/Abstract] OR sleep quality[Title/Abstract] OR sleep pattern\*[Title/Abstract] OR bedtime[Title/Abstract] OR sleep disturbance[Title/Abstract] OR insomnia[Title/Abstract])).

Additional filters: MEDLINE collection, only clinical trial and randomized controlled trial, English language, search interval (2010-2020), builder terms: Title/Abstract.

### **SportDiscus:**

AB (child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR school age\* NOT adolescent\*) AND AB (strateg\* OR technique\* OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health education OR health intervention OR school setting OR school program\* OR school intervention) AND AB (PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement)

AND AB (sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities OR computer use OR computer time OR media use OR video games OR tablet use OR smartphone use OR mobile phone use OR computer time OR television time OR TV time OR gaming OR screen time OR reading OR TV viewing OR television viewing OR video viewing OR sleep\* OR sleep behavio\* OR sleep duration OR sleep quality OR sleep pattern\* OR bedtime OR sleep disturbance OR insomnia).

Additional filters: EBSCO source, only articles, English language, search interval (2010-2020), builder terms: AB [Abstract].

### **The Cochrane Library:**

Title Abstract Keyword (child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR school age\* NOT adolescent\*) AND Title Abstract Keyword (strateg\* OR technique\* OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health education OR health intervention OR school setting OR school program\* OR school intervention) AND Title Abstract Keyword (PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement) AND Title Abstract Keyword (sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities OR computer use OR computer time OR media use OR video games OR tablet use OR smartphone use OR mobile phone use OR computer time OR television time OR TV time OR gaming OR screen time OR reading OR TV viewing OR television viewing OR video viewing) AND Title Abstract Keyword (sleep\* OR sleep behavio\* OR sleep duration OR sleep quality OR sleep pattern\* OR bedtime OR sleep disturbance OR insomnia).

Additional filters: EMBASE and CINAHL source, only trials, English language, search interval (2010-2020), builder terms: Title Abstract Keyword.

## Annexes of Chapter 4.

### 4.1. PRISMA guidelines for scoping reviews

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
<b>TITLE</b>			
Title	1	Identify the report as a scoping review.	1
<b>ABSTRACT</b>			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	2-3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	3
<b>METHODS</b>			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	3
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	3-4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	4-5
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	4
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	5-6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	6

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	5
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	6
<b>RESULTS</b>			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	6
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	6-7
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	7-15
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	7-15
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	9-11; 14-15
<b>DISCUSSION</b>			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	16-18
Limitations	20	Discuss the limitations of the scoping review process.	18
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	19
<b>FUNDING</b>			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	There was not any funding for the review



## 4.2. Database search.

Same as reported in Annexes of Chapter 3.

## 4.3. Measurement tools and outcome results.

STUDY	OUTCOMES			MEASUREMENT TOOLS		RESULTS			FOLLOW-UP	
	PA	SLP	SB	Self-reported (Parents and/or children)	Device-based (Children)	PA (Increase)	SLP (improve)	SB (Reduction)	PA (Increase)	SB (Reduction)
Colín-Ramírez et al., 2010	✓		✓	✓		✓				✓
Hands et al., 2011	✓		✓	✓	✓	✓			NR	NR
Salmon et al., 2011	✓		✓	✓				✓	NR	NR
Bacardí-Gascón et al., 2012	✓		✓	✓		✓		✓	NR	NR
Brandstetter et al., 2012	✓		✓	✓					NR	NR
Breslin et al., 2012	✓		✓	✓	✓	✓		✓	NR	NR
Lloyd et al., 2012	✓		✓	✓	✓			✓	NR	NR
van Stralen et al., 2012	✓		✓	✓		✓			NR	NR
Verloigne et al., 2012	✓		✓		✓	✓		✓	NR	NR
Carson et al., 2013	✓		✓		✓			✓	NR	NR
Fairclough et al., 2013	✓		✓		✓				✓	
Habib-Mourad et al., 2014	✓		✓	✓					NR	NR
Huberty et al., 2014	✓		✓		✓				NR	NR
Kipping et al., 2014	✓		✓	✓	✓			✓	NR	NR
Kobel et al., 2014	✓		✓	✓				✓	NR	NR
Bhave et al., 2015	✓		✓	✓		✓		✓	NR	NR

Madsen et al., 2015	✓	✓		✓					
Xu et al., 2015	✓	✓	✓		✓		✓	NR	NR
Amini et al., 2016	✓	✓	✓		✓			NR	NR
Anderson et al., 2016	✓	✓	✓	✓				NR	NR
Efstathiou et al., 2016	✓	✓	✓					NR	NR
Gallotta et al., 2016	✓	✓	✓		✓		✓	NR	NR
Kobel et al., 2016	✓	✓	✓					NR	NR
Lynch et al., 2016	✓	✓	✓	✓		NR		NR	NR
Nyberg et al., 2016	✓	✓	✓	✓					✓
van Kann et al., 2016	✓	✓		✓	✓			NR	NR
Brittin et al., 2017	✓	✓		✓	✓		✓	NR	NR
Hamer et al., 2017	✓	✓		✓				NR	NR
Lloyd et al., 2017	✓	✓		✓				NR	NR
Chesham et al., 2018	✓	✓		✓	✓		✓	NR	NR
Morris et al., 2018	✓	✓		✓	✓			NR	NR
Taylor et al., 2018	✓	✓		✓			✓	NR	NR
Bartelink et al., 2019	✓	✓	✓	✓				✓	✓
Duncan et al., 2019	✓	✓	✓	✓	✓			✓	
Li et al., 2019	✓	✓	✓	✓	✓		✓	NR	NR
Norman et al., 2019	✓	✓	✓			NR	NR		
Verjans-Janssen et al., 2020	✓	✓	✓	✓	✓			✓	✓

Notes: ✓ indicates the outcome targeted and the measurement tools used. Also, in the results and follow-up columns, it highlights significant positive results in the intervention group (i.e., between baseline to post-test and/or post-test to follow-up measures). Abbreviations: PA = Physical activity; SB = Sedentary behaviour; SLP = Sleep; NR= Not reported.

## Annexes of Chapter 5.

### 5.1. PRISMA Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
<b>TITLE</b>			
Title	1	Identify the report as a systematic review.	2
<b>ABSTRACT</b>			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	72-81
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	83-95
<b>METHODS</b>			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	116-130
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	103-109
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	109-114
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	132-140
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	122-130
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	132-140
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	139-140
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	141-152

Section and Topic	Item #	Checklist item	Location where item is reported
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	154-174
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	132-140
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	154-187
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	132-140
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	154-174
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	175-187
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	175-177
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	141-152
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not Applicable
<b>RESULTS</b>			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	191-195
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	195-196
Study characteristics	17	Cite each included study and present its characteristics.	198-223
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	250-266
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	265-275
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	225-249
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	265-294

Section and Topic	Item #	Checklist item	Location where item is reported
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	267-269
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	269-271
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	250-266
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not Applicable
<b>DISCUSSION</b>			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	298-304
	23b	Discuss any limitations of the evidence included in the review.	375-386
	23c	Discuss any limitations of the review processes used.	375-386
	23d	Discuss implications of the results for practice, policy, and future research.	389-401
<b>OTHER INFORMATION</b>			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	98-101
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	98-101
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not Applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Not Applicable
Competing interests	26	Declare any competing interests of review authors.	There are no competing of interests
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Supplementary materials

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *MetaArXiv*. 2020, September 14. DOI: 10.31222/osf.io/v7gm2.

For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).

## 5.2. Databases and terms included

### Web of science (WOS):

TS=(child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR school children OR schoolage\* OR school-age\* OR school age\* NOT adolescent\*) AND TS=(strateg\* OR technique\* OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health promotion intervention OR health education OR health intervention OR school setting OR school based intervention OR school-based intervention OR school based program\* OR school-based program\* OR school program\* OR school intervention OR school health intervention) AND TS=(PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement) AND TS=(sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities)

*Builder terms: TS [Topic].*

### Scopus:

TITLE-ABS-KEY(child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR "school age\*" AND NOT adolescent\*) AND TITLE-ABS-KEY(strateg\* OR technique\* OR intervention\* OR program\* OR "health prevention" OR "health prevention program\*" OR "health program\*" OR "health promotion program\*" OR "health education" OR "health intervention" OR "school setting" OR "school program\*" OR "school intervention") AND TITLE-ABS-KEY(PA OR "Total PA" OR MVPA OR VPA OR LPA OR "total physical activity" OR "moderate to vigorous physical activity" OR "vigorous physical activity" OR "light physical activity" OR "physical activity" OR "physical inactivity" OR active OR activit\* OR sport\* OR "sports participation" OR "active transport" OR "active commuting" OR "leisure activity" OR walking OR "aerobic exercise" OR "outdoor play" OR exercise OR "motor behavio\*" OR movement) AND TITLE-ABS-KEY(sedentar\* OR "sedentary behavio\*" OR "sedentary time" OR "sedentary lifestyle" OR "total sedentary time" OR

"sitting behavio\*" OR "sitting time" OR "prolonged sitting" OR "domestic activities")

*Builder terms: TITLE-ABS-KEY [Title, Abstract, Keywords].*

**Pubmed:**

((child\*[Title/Abstract] OR student[Title/Abstract] OR pupil[Title/Abstract] OR infant[Title/Abstract] OR childhood[Title/Abstract] OR school\*[Title/Abstract] OR schoolchildren[Title/Abstract] OR schoolaged[Title/Abstract] OR school age\*[Title/Abstract] NOT adolescent\*[Title/Abstract]) AND (strateg\*[Title/Abstract] OR technique\*[Title/Abstract] OR intervention\*[Title/Abstract] OR program\*[Title/Abstract] OR "health prevention"[Title/Abstract] OR health prevention program\*[Title/Abstract] OR health program\*[Title/Abstract] OR health promotion program\*[Title/Abstract] OR health education[Title/Abstract] OR health intervention[Title/Abstract] OR school setting[Title/Abstract] OR school program\*[Title/Abstract] OR school intervention[Title/Abstract]) AND (PA[Title/Abstract] OR Total PA[Title/Abstract] OR MVPA[Title/Abstract] OR VPA[Title/Abstract] OR LPA[Title/Abstract] OR total physical activity[Title/Abstract] OR moderate to vigorous physical activity[Title/Abstract] OR vigorous physical activity[Title/Abstract] OR light physical activity[Title/Abstract] OR physical activity[Title/Abstract] OR physical inactivity[Title/Abstract] OR active[Title/Abstract] OR activit\*[Title/Abstract] OR sport\*[Title/Abstract] OR sports participation[Title/Abstract] OR active transport[Title/Abstract] OR active commuting[Title/Abstract] OR leisure activity[Title/Abstract] OR walking[Title/Abstract] OR aerobic exercise[Title/Abstract] OR outdoor play[Title/Abstract] OR exercise[Title/Abstract] OR motor behavio\*[Title/Abstract] OR movement[Title/Abstract]) AND (sedentar\*[Title/Abstract] OR sedentary behavio\*[Title/Abstract] OR sedentary time[Title/Abstract] OR sedentary lifestyle[Title/Abstract] OR total sedentary time[Title/Abstract] OR sitting behavio\*[Title/Abstract] OR sitting time[Title/Abstract] OR prolonged sitting[Title/Abstract] OR domestic activities[Title/Abstract]))

*Builder terms: Title/Abstract.*

**SPORTDiscus:**

AB (child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR school age\* NOT adolescent\*) AND AB (strateg\* OR technique\*

OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health education OR health intervention OR school setting OR school program\* OR school intervention) AND AB (PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement) AND AB (sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities)

*Builder terms: AB [Abstract].*

### **The Cochrane Library:**

Title Abstract Keyword (child\* OR student OR pupil OR infant OR childhood OR school\* OR schoolchildren OR schoolaged OR school age\* NOT adolescent\*) AND Title Abstract Keyword (strateg\* OR technique\* OR intervention\* OR program\* OR health prevention OR health prevention program\* OR health program\* OR health promotion program\* OR health education OR health intervention OR school setting OR school program\* OR school intervention) AND Title Abstract Keyword (PA OR Total PA OR MVPA OR VPA OR LPA OR total physical activity OR moderate to vigorous physical activity OR vigorous physical activity OR light physical activity OR physical activity OR physical inactivity OR active OR activit\* OR sport\* OR sports participation OR active transport OR active commuting OR leisure activity OR walking OR aerobic exercise OR outdoor play OR exercise OR motor behavio\* OR movement) AND Title Abstract Keyword (sedentar\* OR sedentary behavio\* OR sedentary time OR sedentary lifestyle OR total sedentary time OR sitting behavio\* OR sitting time OR prolonged sitting OR domestic activities)

*Builder terms: Title Abstract Keyword.*



### 5.3. Risk of bias assessment.

#### Risk of Bias for randomized studies (ROB-2)

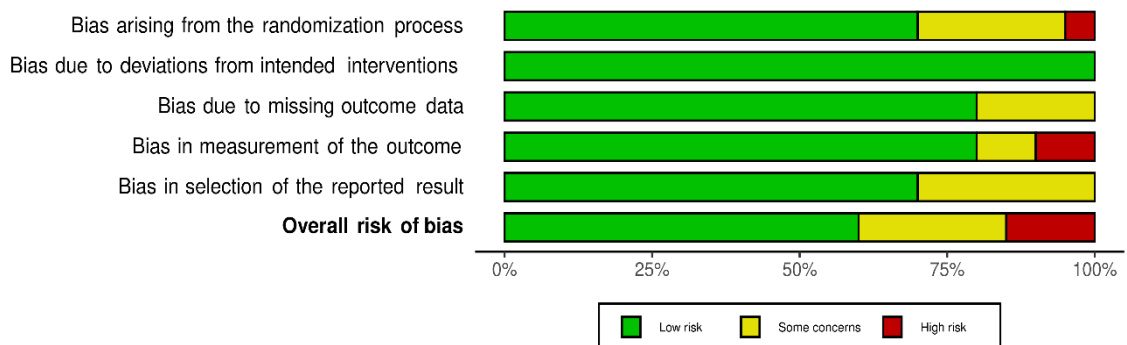
##### 1. Risk of bias of individual studies

Study	Risk of bias domains					Overall
	D1	D2	D3	D4	D5	
Lloyd et al., 2012	+	+	+	+	-	-
Verloigne et al., 2012	-	+	+	⊗	+	⊗
Fairclough et al., 2013	+	+	+	+	+	+
Engelen et al., 2013	+	+	+	+	-	+
Kipping et al., 2014	+	+	+	+	+	+
Wells et al., 2014	+	+	+	+	-	+
Madsen et al., 2015	-	+	+	⊗	+	⊗
Anderson et al., 2016	+	+	+	+	+	+
Kocken et al., 2016	+	+	-	+	-	-
Resaland et al., 2016	+	+	+	+	+	+
Telford et al., 2016	+	+	+	+	-	+
Kobel et al., 2017	-	+	-	+	+	-
Lloyd et al., 2017	+	+	+	+	+	+
Adab et al., 2018	+	+	+	+	+	+
Morris et al., 2018	-	+	+	-	+	-
Li et al., 2019	+	+	+	+	+	+
Seljebotn et al., 2019	+	+	+	+	-	+
Kobel et al., 2020	-	+	-	+	+	-
Nathan et al., 2020	+	+	+	+	+	+
Bernal et al., 2021	⊗	+	-	-	+	⊗

Domains:  
D1: Bias arising from the randomization process.  
D2: Bias due to deviations from intended intervention.  
D3: Bias due to missing outcome data.  
D4: Bias in measurement of the outcome.  
D5: Bias in selection of the reported result.

Judgement  
⊗ High  
- Some concerns  
+ Low

##### 2. Risk of bias summary



## Risk of Bias for non-randomized studies (ROBINS-I)

### 1. Risk of bias of individual studies

Study	Risk of bias domains							Overall
	D1	D2	D3	D4	D5	D6	D7	
Breslin et al., 2015	+	+	+	-	-	-	-	-
Brittin et al., 2017	-	X	-	-	X	-	X	X
Bartelink et al., 2019	-	+	+	-	-	+	+	-
Verjans-Janssen et al., 2020	+	+	+	+	-	+	+	+

Domains:

D1: Bias due to confounding.

D2: Bias due to selection of participants.

D3: Bias in classification of interventions.

D4: Bias due to deviations from intended interventions.

D5: Bias due to missing data.

D6: Bias in measurement of outcomes.

D7: Bias in selection of the reported result.

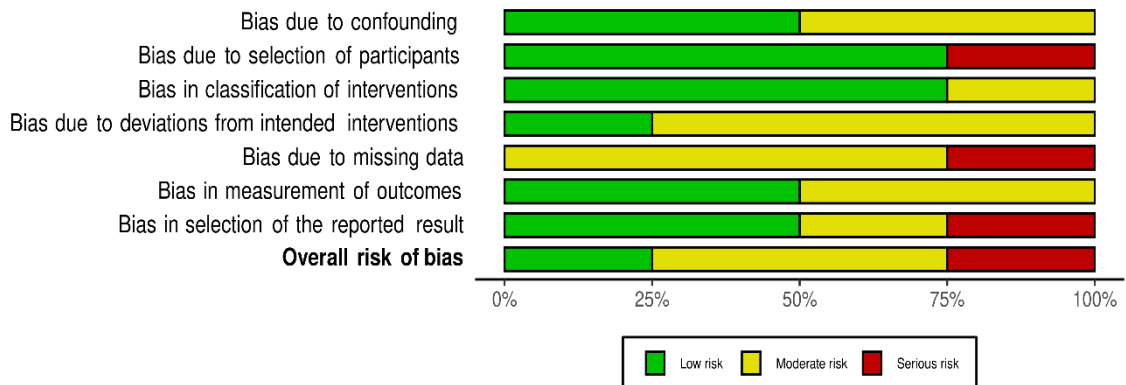
Judgement

X Serious

- Moderate

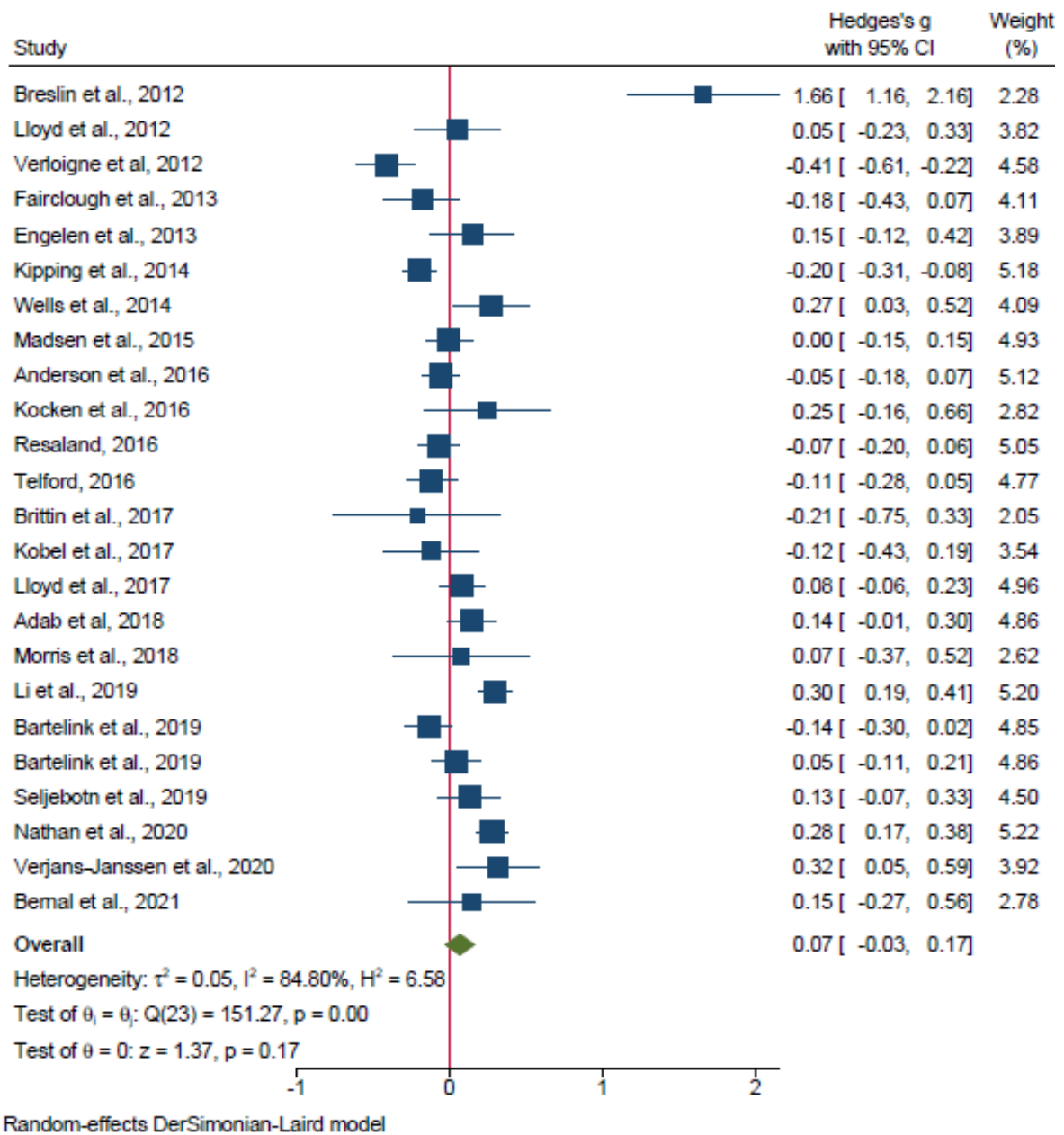
+ Low

### 2. Risk of bias summary

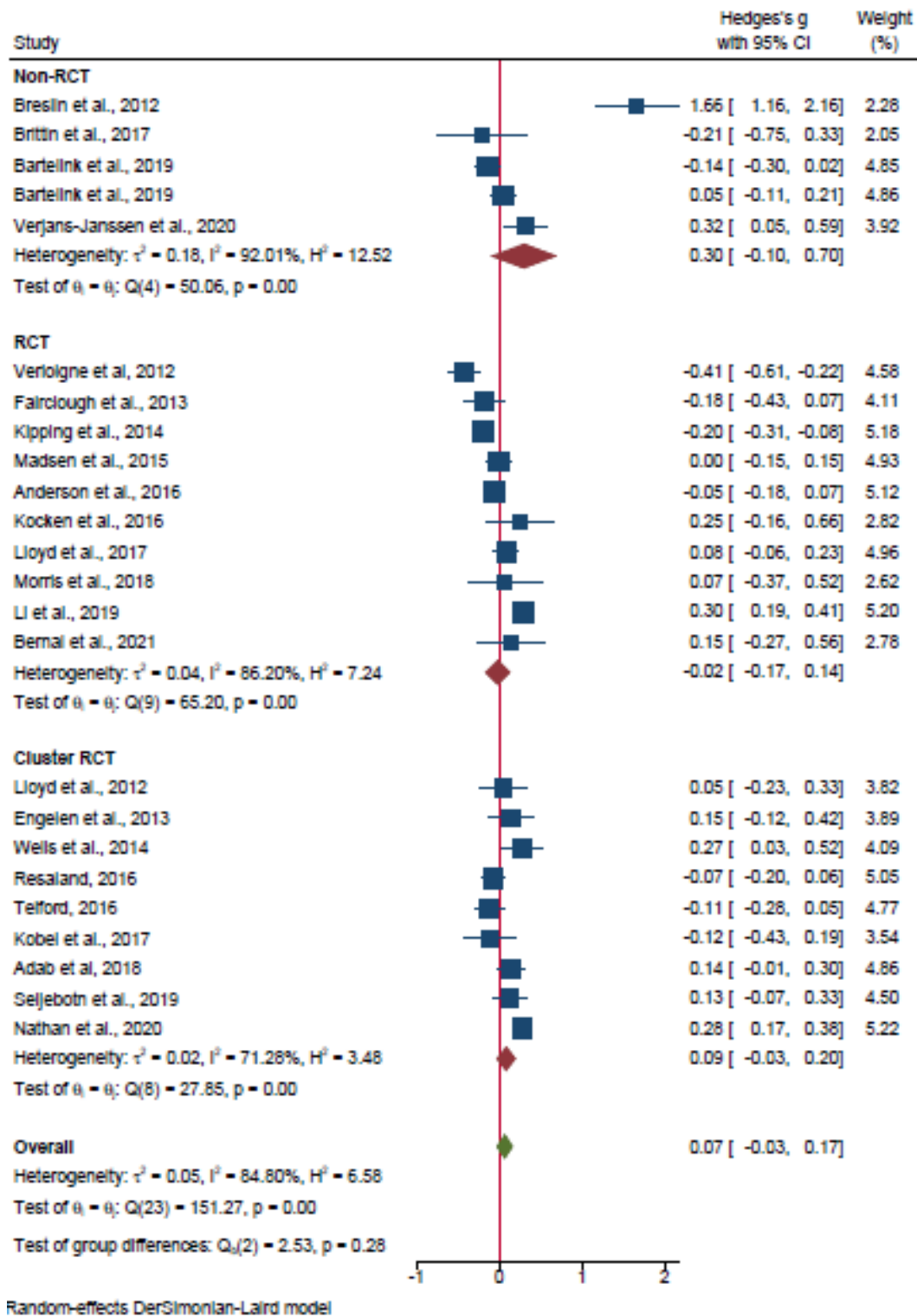


### 5.3. Meta-analysis forest plots.

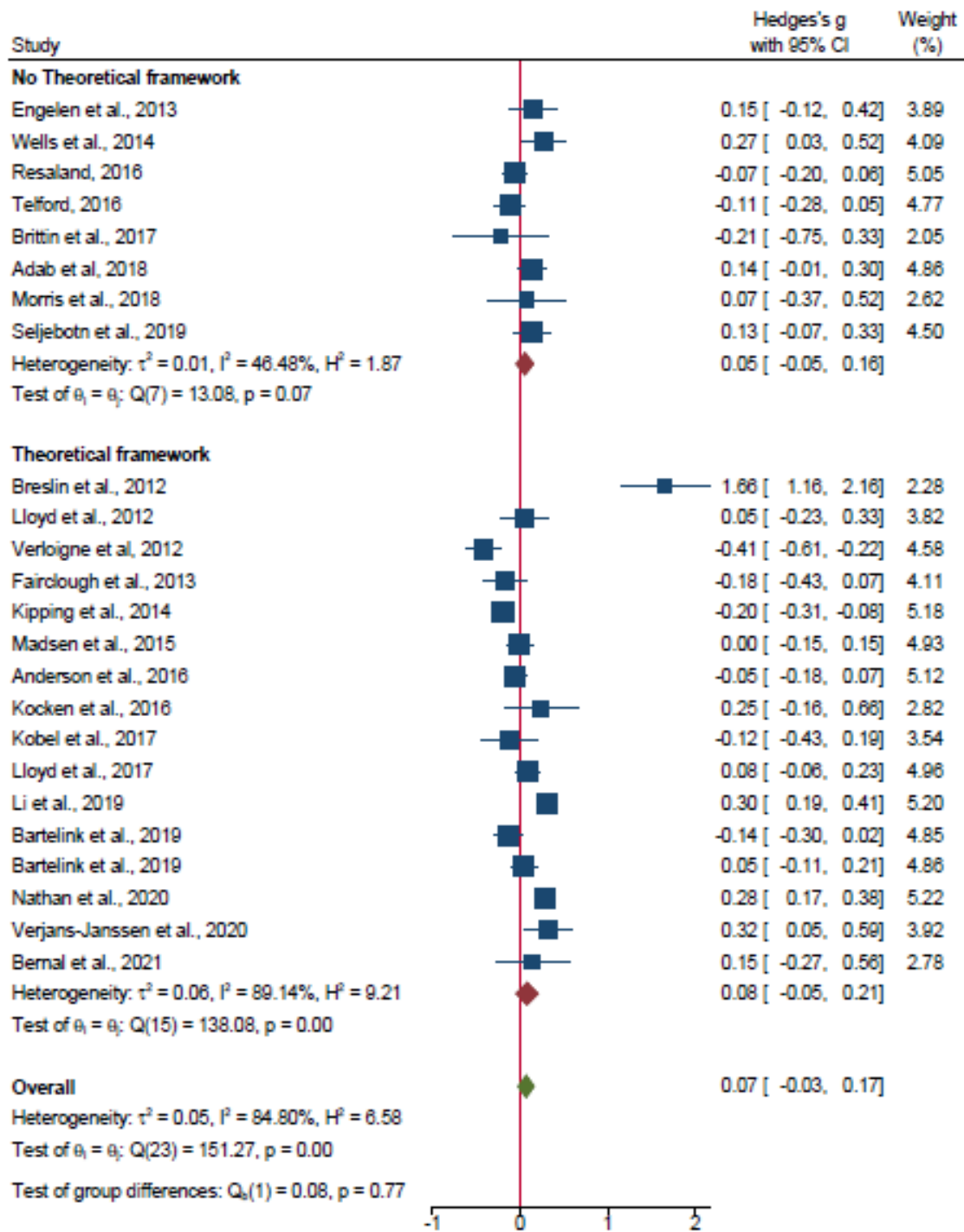
- Overall MVPA



- Subgroup analysis MVPA (Design)

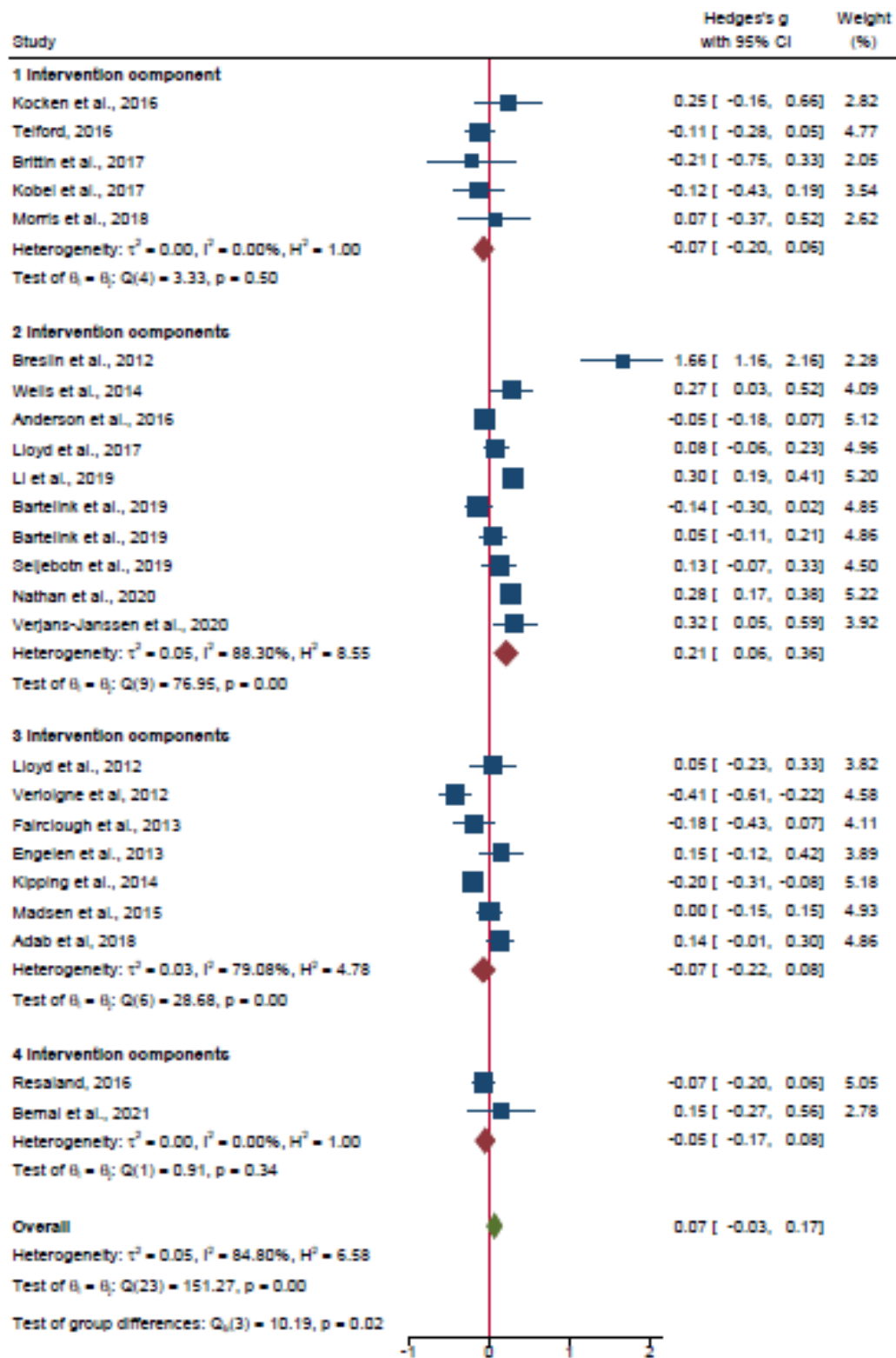


- Subgroup analysis MVPA (Framework)



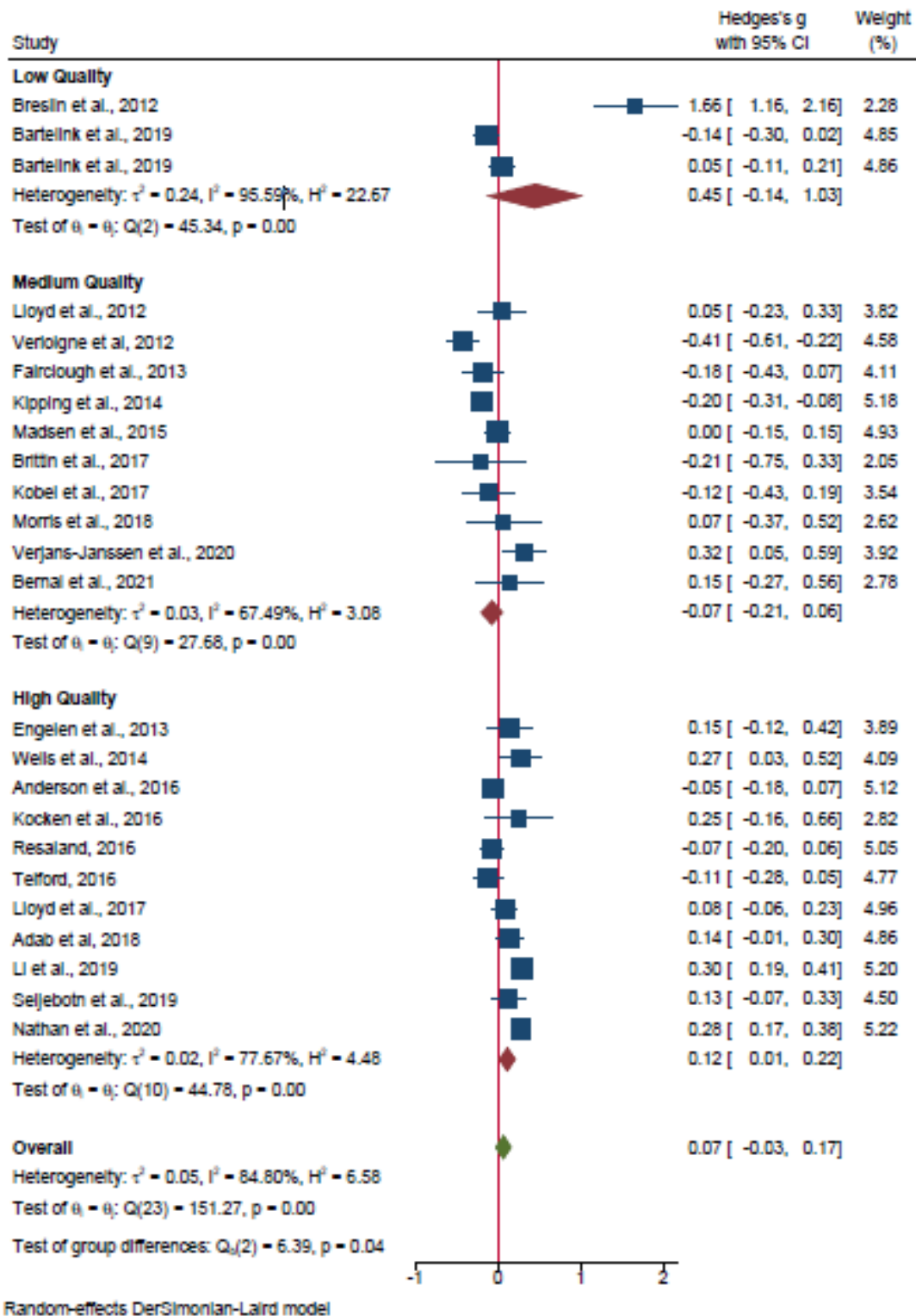
Random-effects DerSimonian-Laird model

- Subgroup analysis MVPA (Intervention components)

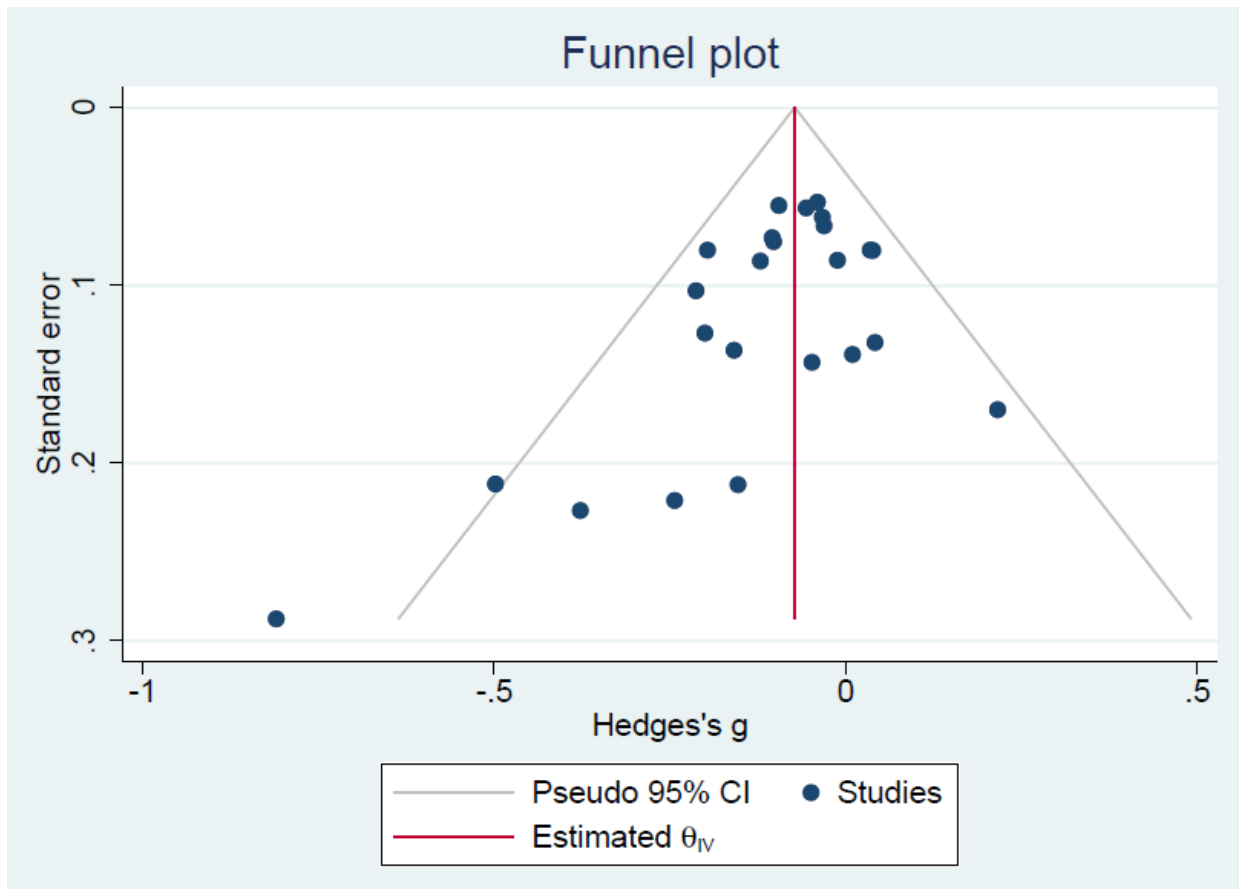


Random-effects DerSimonian-Laird model

- Subgroup analysis MVPA (Quality assessment)

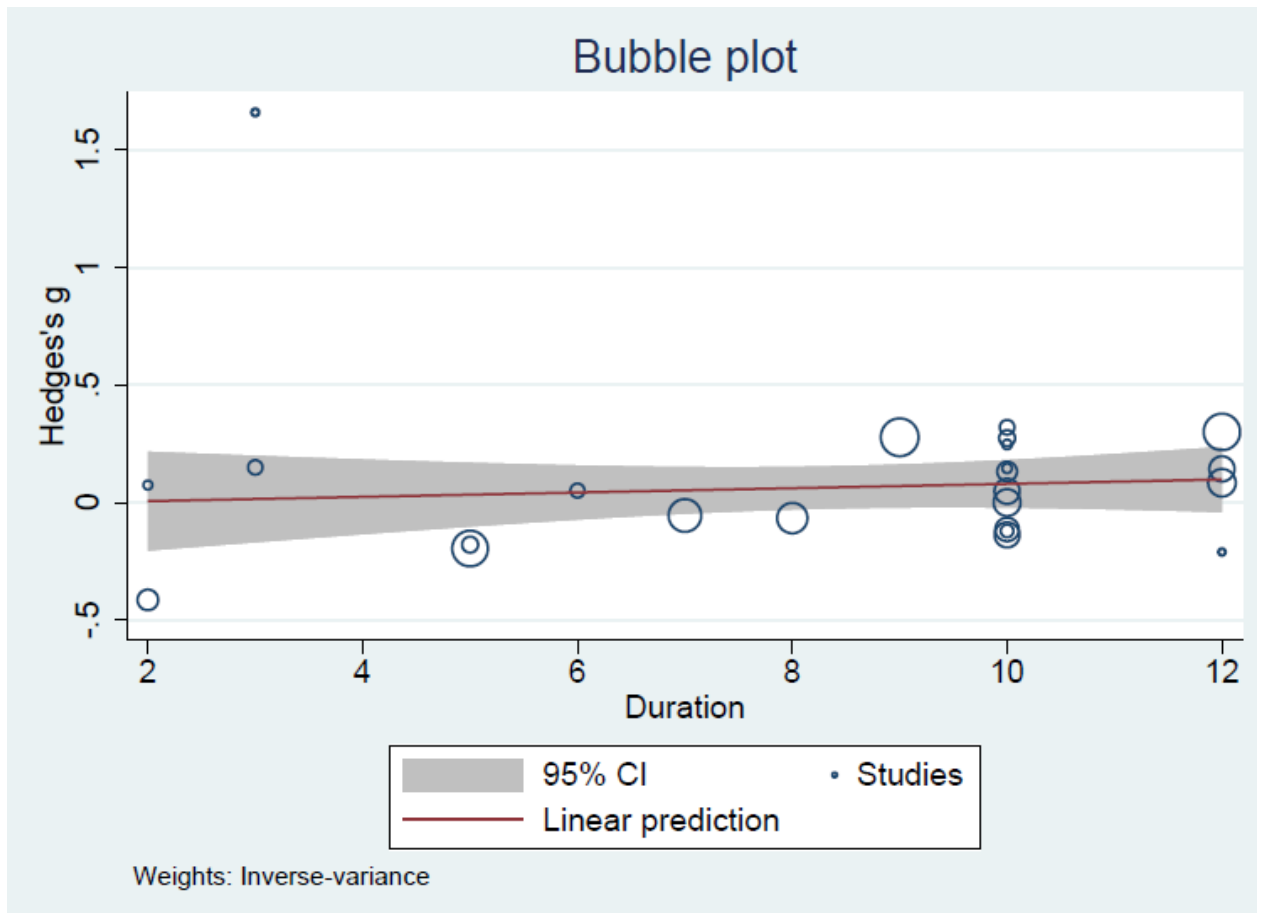


- Funnel plot ST

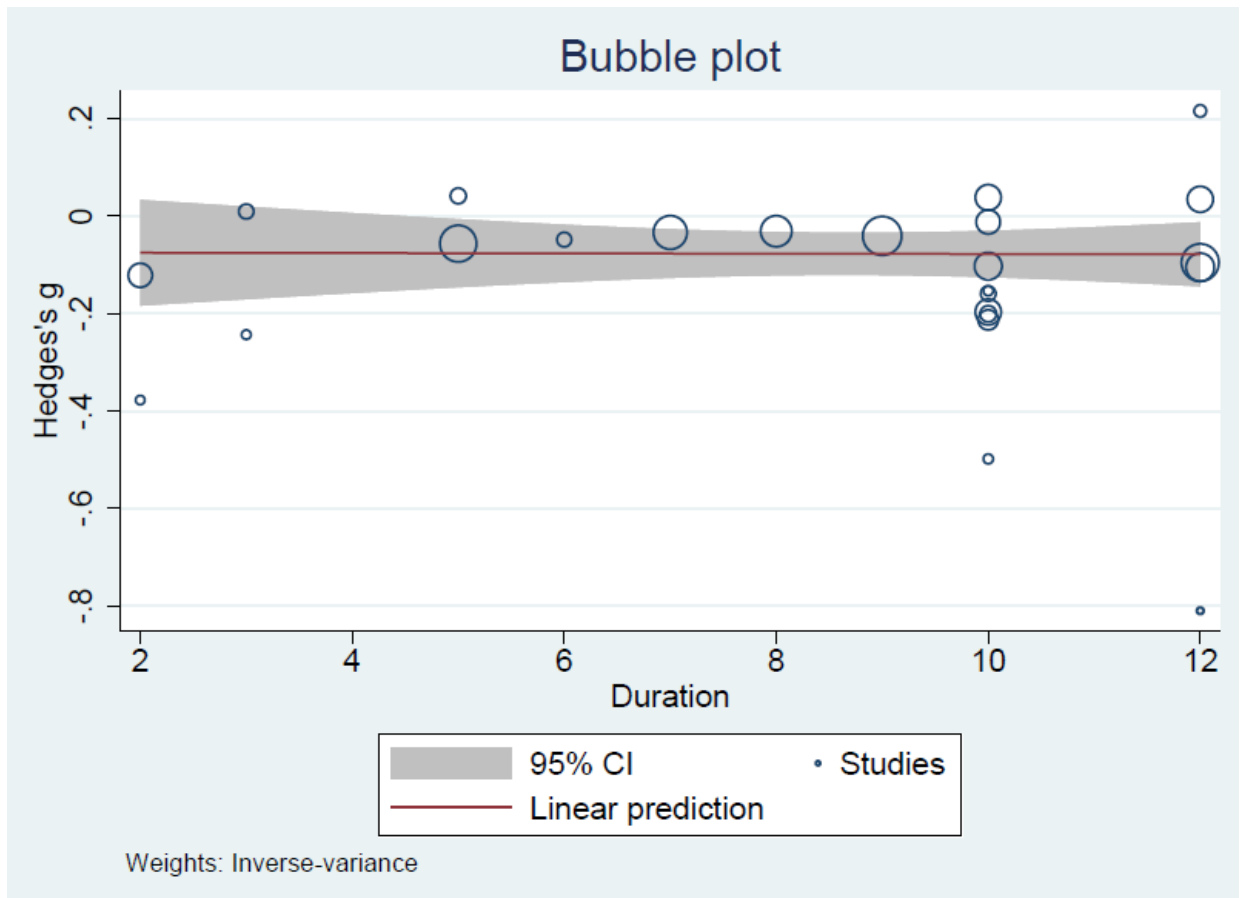




- Meta-regression MVPA



- Meta-regression ST



## Annexes Ethical regulations of the school-based intervention.



Informe Dictamen Favorable

C.P. - C.I. PI20/009  
19 de febrero de 2020

Dña. María González Hinjos, Secretaria del CEIC Aragón (CEICA)

### CERTIFICA

1º. Que el CEIC Aragón (CEICA) en su reunión del día 19/02/2020, Acta Nº 04/2020 ha evaluado la propuesta del investigador referida al estudio:

**Título: Promoción de la salud en niños: evaluación diagnóstica transfronteriza de la provincia de Huesca (España) y Aquitania (Francia); Evaluación del diseño, implementación y efectos de un programa multinivel sobre hábitos saludables en escolares de Educación Primaria.**

**Investigador Principal: Javier Rodrigo Sanjoaquin, Universidad de Zaragoza**

**Versión protocolo: v3, 11/02/2020**

**Versión documento de información: v2, 11/02/2020 (docentes, alumnos, familias)**

2º. Considera que

- El proyecto se plantea siguiendo los requisitos de la Ley 14/2007, de 3 de julio, de Investigación Biomédica y su realización es pertinente.
- Se cumplen los requisitos necesarios de idoneidad del protocolo en relación con los objetivos del estudio y están justificados los riesgos y molestias previsibles para el sujeto.
- Es adecuada la utilización de los datos y son correctos los documentos elaborados para informar a los participantes.
- El alcance de las compensaciones económicas previstas no interfiere con el respeto a los postulados éticos.
- La capacidad de los Investigadores y los medios disponibles son apropiados para llevar a cabo el estudio.

3º. Por lo que este CEIC emite **DICTAMEN FAVORABLE a la realización del estudio.**

Lo que firmo en Zaragoza

GONZALEZ HINJOS  
MARIA - DNI 03857456B

Firmado digitalmente  
por GONZALEZ HINJOS  
MARIA - DNI 03857456B  
Fecha: 2020.02.24  
13:14:06 +01'00'

María González Hinjos  
Secretaria del CEIC Aragón (CEICA)

