Enhance physical activity through school-based active transport interventions: A systematic review and meta-analysis

Article *in* Journal of Physical Education and Sport · November 2024

DOI: 10.7752/jpes.2024.11280

Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 11), Art 280, pp. 1542-1554, November 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Enhance physical activity through school-based active transport interventions: A systematic review and meta-analysis

THIBAUT DERIGNY[1], LÉA MEKKAOUI[2], JAVIER RODRIGO-SANJOAQUÍN[3], LOUIS MEISTERMANN[4], JOSEPH GANDRIEAU[5], CHRISTOPHE SCHNITZLER[6], FRANÇOIS POTDEVIN[7]
[1] Université de Pau et des Pays de l'Adour, MEPS, Anglet, FRANCE
[2,7] Univ. Lille, Univ. Artois, Univ. Littoral Côte d'Opale, Laboratoire URePSSS – Unité de Recherche Pluridisciplinaire Sport Santé Société – ULR 7369, F-59000 Lille, FRANCE
[3] Université de Pau et des Pays de l'Adour, MEPS, Tarbes, FRANCE
[3,4] Departamento de Didactica de la Expresion Corporal, Universidad de Zaragoza, Huesca, Aragon, SPAIN
[4,6] Faculté des Sciences du Sport, Laboratoire E3S – Éducation Sport et Sciences Sociales – ULR1342, Université de Strasbourg, FRANCE
[5] Université Côte d'Azur, Laboratoire LAMHESS – Laboratoire Motricité Humaine Expertise Sport Santé – UPR 6312, Nice, FRANCE
[6] Haute Ecole Pédagogique du canton de Vaud, Teaching and Research Unit in Physical Education and Sport, Canton de Vaud, (HEP-VD), University of Teacher Education, Lausanne, SWITZERLAND

Published online: November 30, 2024
Accepted for publication: November 15, 2024
DOI:10.7752/jpes.2024.11280

Abstract
Purpose: Cycling, as a form of active transport, had become a public health issue, relevant for maintaining a sustainable level of daily physical activity. School-based interventions promoting active transport had the potential to encourage more young people to adopt physically active lifestyles, but their impact, designs, and target populations in the literature remained limited. The concept of physical literacy held great promise for developing sustainable education interventions in physical activity, but it had not yet been adapted to the specificities of cycling. This systematic review examined how physical education teachers could design active transport interventions to promote sustained engagement in physical activity. *Method*: Using the PI(E)CO framework and PRISMA checklist, a research algorithm was applied across eleven databases. The eligibility criteria included school-aged populations, active transport interventions to and/or from school, primary studies, quantitative physical activity outcomes, and English language publications. *Results*: Six studies were found to meet the inclusion criteria. Half of these studies had implicitly designed their interventions following the four dimensions of physical literacy, while the other half focused only on the physical dimension. The meta-analysis indicated a non-significant increase in physical activity but a significant negative association between the age of participants and physical activity outcomes. The two studies with the highest impact on physical activity had undertaken a design following the four dimensions of physical literacy adapted to active transport. *Discussion/Conclusion*: To achieve the effectiveness of active transport school-based interventions, physical education teachers needed to follow the four dimensions of the physical literacy concept from early primary school age.
Keywords. **Health, children, physical literacy, ecological model, energy expenditure.**

Introduction

Encouraging Active Transport to and/or from School (ATS) represents a promising public health initiative with the potential to increase Physical Activity (PA) among children and adolescents (Faulkner et al., 2009; Wanjau et al., 2023). This is especially critical given that over 80% of youth are reported to be physically inactive (Guthold et al., 2020). Reducing physical inactivity could lower the incidence of 6–10% of major non-communicable diseases, which are currently the leading cause of death worldwide (Lee et al., 2012).

However, the prevalence of active transport declines with age, accounting for 53% of total PA in adolescents (González et al., 2020) but dropping to just 36% in adults (Strain et al., 2020). One of the main barriers to maintaining PA into adulthood is the perception of a lack of time (Duffey et al., 2021), while cycling enables individuals to optimize their time to be physically active. Despite this, no study to date has examined the relationship between age and ATS, a gap that poses a significant challenge to behavior change. This is crucial for two reasons: first, Varma et al. (2017) demonstrated that establishing PA habits early in life is essential for maintaining high activity levels over time. Second, from a developmental perspective, there may be a critical age for fostering sustainable ATS behaviors (Schoen et al., 2022; Zeuwts et al., 2020).

Schools and Physical Education (PE) lessons have the potential to adress this public health challenge by implementing ATS school-based interventions. These interventions, led by PE teachers or educators, are

Corresponding Author: THIBAUT DERIGNY, E-mail: thibaut.derigny@univ-pau.fr

designed to promote various forms of active transport, such as walking, cycling, skateboarding, or rollerblading. Van Sluijs et al. (2021) highlighted schools as one of the three key pillars for encouraging behavioral change towards more physically active, healthy and sustainable lifestyles. Building on this, Derigny, Schnitzler et al. (2022) proposed incorporating "*time education*" into PE lessons to create and seize more opportunities of active transport.

Chillón et al. (2011) reported only trivial to small effects of school-based ATS intervention on PA levels. In a meta analysis, Rodrigo-Sanjoaquín et al. (2022) attributed this limited impact on sustainable PA to the failure to anchor these interventions in the ecological model (Bauman et al., 2012). This model emphazsizes the development as a multi-level approach, where a set of interlocking systems are in constant interaction (Bronfenbrenner & Morris, 2006). The relationship between the individual and their environments can be considered as a set of Russian dolls, with each layer influencing the others. Schönbach et al. (2020) recently reinforced the importance of this multi-level approach to design ATS school-based interventions. Nevertheless, there remains no consensus on the most effective design or the target population for building succesfull ATS school-based interventions.

At the individual level, the ecological model can be closely aligned with the concept of Physical Literacy (PL). O'Sullivan et al. (2020) confirmed this connection, demonstrating that PL is rooted in ecological theories of human development to promote healthy behaviour. According to the International Physical Literacy Association (IPLA), PL is traditionnaly defined as the initial definition proposed by Margareth Whitehead (2001) as "*the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life*" (IPLA, 2017). In this context, PL represents the individual behaviours at the core of the micro-system of the ecological approach. As Carl et al. (2023) highlighted, the surrounding environment plays a key role in shaping and nurturing the development of PL.

While school-based interventions using the ecological model have yielded better long terms outcomes (Hynynen et al., 2016), PL has gained increasing attention in international literature (Young et al., 2019). PL has been both philosophically (Durden-Myers et al., 2018; Pot et al., 2018) and empirically (Gandrieau et al., 2023; Carl et al., 2023) validated as a framework for designing and delivering school-based interventions. However, ATS school-based interventions have yet to be examined through the lens of PL (Carl et al., 2022). Consistent with the Australian conception (Keegan et al., 2019), pedagogical keys could be identified in the four individual dimensions of PL: physical, cognitive, psychological and social.

Schönbach et al. (2020) showed that ATS school-based interventions have been already designed for children and were mostly implemented in primary schools. Nevertheless, most of the ATS were not framed by theoretical grounds such as ecological model and/or the PL concept. For example, Rodrigo-Sanjoaquín et al. (2023) proposed a multi-level intervention based on the ecological model and assessed psychological variables on the intention to ATS (e.g., psychological domain of PL), but no other PL dimensions were targeted. Derigny, Gandrieau et al. (2024) proposed a multilevel intervention based on PL and measure the feeling of competences in ATS, but no environmental design were proposed.

Thus, it seems essential to analyze ATS school-based interventions through the combined lens of the ecological model and PL to identify the pedagogical key elements that can enhance the effectiveness of these interventions and promote sustainable PA. Whithead (2010) explained that the physical dimension relates both to motor engagement as a learning objective and as an end goal of engagement. For instance, Derigny, Gandrieau et al. (2024) suggest adaptating ATS through the development of motor skills specific to cycling (i.e., physical dimension), acquiring technical knowledge about cycling path or bycicle repairs (i.e., cognitive domain and raising awareness of a collective road environment (i.e., social domain) to foster motivation and pleasure in cycling (i.e., the psychological dimension

This systematic review, combined with a meta-analysis, aims to identify the most effective design and target age group for ATS interventions that enhance PA among children and adolescents. Grounded in both the ecological and PL models, the findings will provide a strong foundation for improving the design of ATS interventions that promote PA and overall health.

Matherial & methods

Information sources

This systematic review was conducted using the protocol developed by the Cochrane Institute (Higgins et al., 2023), following the checklist of the "*Preferred Reporting Items for Systematic Reviews and Meta-Analysis: The PRISMA Statement*" (Page et al., 2021) and have been registered in PROSPERO. The research algorithm was run throughout January 2023 on 11 databases: Web Of Science, Embase, PsycInfo, Cochrane, PubMed, Proquest, Education Resources Information Center, Opengrey, Latin American and Caribbean Health Sciences Literature, SportDiscus and Scopus. All articles included were published before December 2022.

Search strategy

Table 1 indicates the keywords used in the search strategy. The following research question was formulated, based on the PI(E)CO protocol (Population, Intervention, Exclusion, Comparison, Outcome): "*Among school-aged children and adolescents from 6-to-18 years of age (P), with no health problems (E), what* *are the characteristics of cycling interventions (I) that impact PA in a short and long term process (O), compared with children and adolescents of the same age who did not benefit from these interventions (C)?*".

Table 1. Keywords of PI(E)CO algorithms

Participants	"child* OR teen* OR student* OR pupil* OR "young adult*"
Intervention	"bicycl* intervention*" OR "bik* intervention*" OR "transport* intervention*" OR "bicycl* lesson*" OR "bik* lesson*" OR "bicycl* teach*" OR "bik* teach*" OR "bicycl* educati*" OR "bik* educati*" OR "transport* educati*" OR "bicycl* instruction*" OR "bik* instruction*" OR "bicycl* program*" OR "bik* program*" OR "transport* program*" OR "bicycl* training" OR "bik* training*" OR "transport* training*" OR "bicycl* participation*" OR "bik* participation*" OR "transport* participation*" OR "bicycl* path*" OR "bik* path*" OR "transport* path*" OR "bicycl* built environment*" OR "bik* built environment*" OR "transport* built environment*" OR "bicycl* environment*" OR "bik* environment*" OR "transport* intervention*"
Exclusion	"obesity* OR diseas* OR autism* OR disabilit* OR suicide OR ADHD OR patholog* OR asthma OR depression OR cancer OR deficienc* OR injur*"
Controle	Not applicable these keywords in search strategy.
Outcomes	"physic* activit*" OR PA OR skill* OR competenc* OR "physical literac*" OR sedentarit* OR behavi* OR inactivit* OR perce* OR feel* OR prevention* OR risk* OR secur* OR environment* OR "activ* transpor*"

Eligibility criteria. The inclusion criteria were: (1) sampling a school-aged population, (2) ATS school-based interventions, (3) a primary study, (4) quantitative outcomes on PA engagement, and (5), written in the English language. Studies on populations with special needs (e.g., disabilities) were excluded. Once all the articles were included in the full-text analysis, a snowballing process was carried out in the references. The title article matching the inclusion criteria were included in the abstract and full-text analysis.

Selection process. After running the algorithm in the databases, duplicates were removed. The title, abstract and full-text were screened in a double-blinded process (LéM and LoM). Disagreements on the inclusion of any study were solved by consensus with a third researcher (TD). If an article was not published in open-acess, a personal message was send to the corresponding author.

Data extraction. Information was extracted in a double-blinded step (LéM and LoM) with a third agreement by the same researchers as part of the selection process (TD). Data were saved on an Excel spreadsheet shared between the research team on the security application "Nuage" [Cloud of the University]. During the full-text analysis, the following information were extracted: (1) authors and date of publication, (2) study design including pre-post and follow-up measurement, (3) total number of participants (4) in both experimental and control groups included in the analysis, (5) population age, (6), interventions duration, (7) interventions description, (8) theoretical framework used, (9) measurement tools, and (10), outcomes. Then, each study design was analysed according to the four individual dimensions of PL (i.e., physical, psychological, social and cognitive) and the environmental dimension (e.g., all dimensions of the ecological model, except the individual's one).

Risk of bias assessment. For both the Quasi-Experimental Study (QES) and Randomized Controlled Trial (RCT), the risk of bias was assessed by two researchers (LoM and TD) using, respectively, the Cochrane Risk Of Bias in Non-randomised Studies of interventions (ROBINS-I) tool (Sterne et al., 2016) and the Risk of Bias for randomised trials (RoB 2) tool (Sterne et al., 2019). For QES, seven items were assessed: (1) confounding, (2) selection of the participants, (3) classification of the interventions, (4) deviations from planned confounding interventions, (5) missing data, (6) measurement of outcome(s), and (7), selection of the reported outcome(s). For RCT, five items were assessed: (1) randomisation process, (2) deviations from the planned intervention, (3) missing data on outcomes, (4) the measurement of outcomes, and (5), the selection of the reported outcome(s).

Meta-analysis

A meta-analysis was conducted to observe the effect of ATS interventions on PA outcomes. According to the literature (Higgins et al., 2023), no sub-group analyses were planned due to the reduced number of studies included (i.e., less than 10 studies). Effects were analysed using the DerSimonian-Laird random effects model because heterogeneity was expected among different types of interventions (Cooper et al., 2009). The Hedges' g parameter was used to report effect size (Higgins et al., 2023), classified as small ($0 \leq g \leq 0.5$), medium ($0.5< g \leq 0.8$) or large effect ($g > 0.8$). For expected outcomes, positive effect sizes values indicated greater levels of PA in the experimental group, compared with the control group. Pooled effect sizes were estimated using 95% confidence intervals (CIs).

Meta-regression analyses were performed to address whether the duration of the intervention, age of participants, theoretical framework, PL dimensions and type of design influenced the modification of the effect of ATS interventions on PA outcomes. Heterogeneity across studies was calculated using the Cochrane Q statistic and using the tau-squared test (τ^2), $\tau^2 > 0.1$ suggests substantial heterogeneity between studies (Higgins & Thompson, 2002). The proportion of variation across studies was estimated using the inconsistency index (I^2) interpreted as follows: 0% to 30%: not important, 30% to 60%: moderate, 60% to 75%: substantial or 75% to 100%: considerable.

Finally, small study effects and publication bias were examined using both the Egger regression asymmetry test and the Begg test (Higgins et al., 2023). A p-value < 0.05 was chosen to establish statistical significance levels. All statistical analyses were conducted with the Stata software (v16.1; StataCorp, College Station, TX, USA).

Results

Overview

The PRISMA flowchart presents the process of selection in each step of the analysis (see Figure 1). 1,091 results were obtained after running the algorithm. 329 results were immediately removed due to duplication. Of the 762 titles analysed, 129 were retained for the abstract analysis and 62 for full-text analysis. 27 articles were added by snowballing, following title, abstract and full-text analysis. At the end, 6 articles, which met the inclusion criteria, were selected to answer the research question and were subjected to qualitative and meta-analysis.

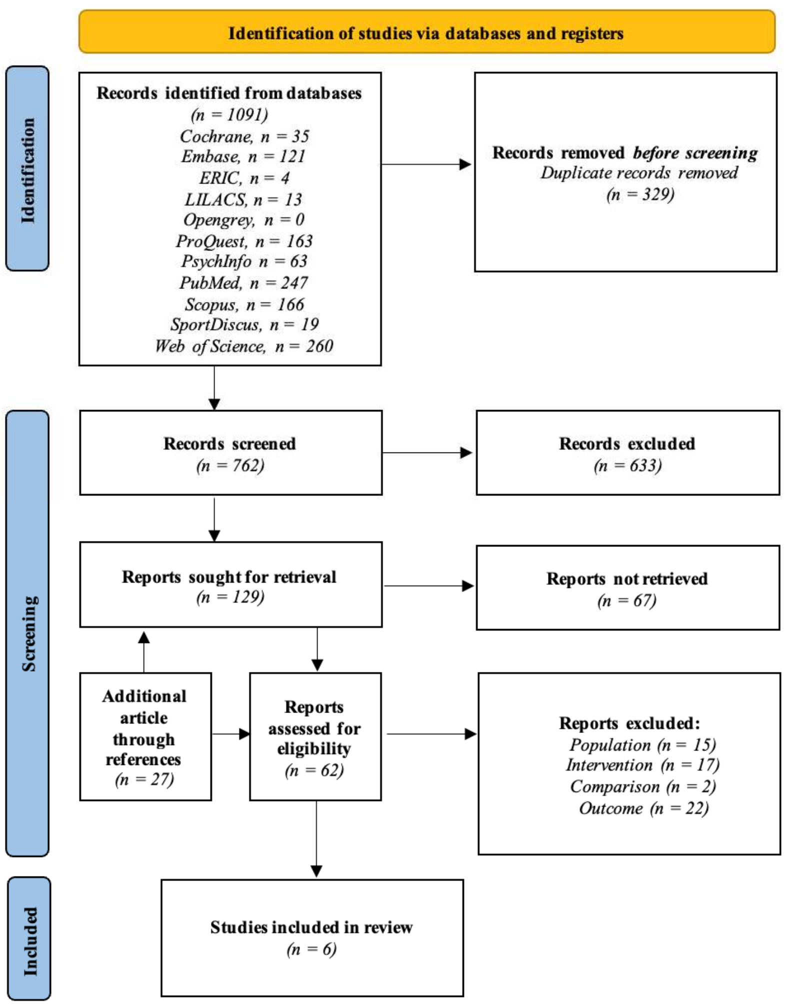


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram presenting the analysis process

Table 2. Description of the studies included.

Author(s), date	Study design	Number (% girls)	Groups (n)	Age	Duration	Intervention description	Theoritical framework	Tools	Data (unit)
Børrestad et al., 2017	RCT. Pre / post. No follow-up.	46 (47%)	*n* = 46 EG = 24 CG = 22	10.85 ± 0.7 (mean ± sd)	3 months (6 session of 30 min)	EG = Raising awareness, countering passive transport, and helping parents support, health benefits and road safety issues. CG = Not reported but delivery of four parental informational letters (study aims/implications).	Not mentioned	Ergometer	VO_2
Christiansen et al., 2014	RCT. Pre / post. No follow-up.	1,348 (48.6%)	*n* = 1,348 EG = 623 CG = 725	12.6 ± 0.63 (mean ± sd)	24 months (session not mentioned)	EG = (i) Educating students in safe cycling and (ii) establishing a school traffic patrol. CG = No intervention.	Active Living by Design: 5P model (Bors et al., 2009)	Active transport diaries	PA
Mendoza et al., 2017	RCT. Pre / post. No follow-up.	54 (64.8%)	*n* = 54 EG = 24 CG = 30	9.9 ± 0.7 (mean ± sd)	12 months (5 days per week)	EG = Promoting cycling to and from school over passive commuting. CG = No intervention.	Not mentioned	Accelerometers & GPS	MVPA
Østergaard et al., 2015	QES. Pre / post. No follow-up.	1934 (51.2%)	*n* = 968 EG = 106 CG = 862	10.9 ± 0.54 (mean ± sd)	Not mentioned	EG = Structural changes near the school and increasement of school cycling motivation as well as cycling safety. CG = No intervention.	Correlates of cycling to school (Hume et al., 2009)	Andersen test	VO_2
Villa-González et al., 2015	QES. Pre / post / follow-up.	206 (NA)	*n* = 206 EG = 117 CG = 89	8 – 11 yo (range)	6 months (60 to 120 min each month)	EG = Children and teachers participated in all scheduled activities. Parents participated to a questionnaire on mode of commuting. CG = No intervention.	Active travel in children (Panter et al., 2008)	Questionnaires mode of commuting	PA
Villa-González et al., 2017	QES. Pre / post. No follow-up.	251 (49.7%)	*n* = 251 EG = 141 CG = 110	8 – 11 yo (range)				Shuttle run test	VO_2

Note. n: number; EG: Experimental Group; CG: Control Group. RCT: Randomized Controled Trial; QES: Quasi-Experimental Study; PA: Physical Activity; MVPA: Moderate and Vigorous Physical Activirty; VO2: Oxygen Volume; yo: years old; sd: Standard Deviation

Description of articles included

Overall. As presented in Table 2, six studies, published between 2012 and 2017, were included. Three studies were RCTs (Børrestad et al., 2012; Christiansen et al., 2014; Mendoza et al., 2017) and the other three studies were QESs (Østergaard et al., 2015; Villa-González et al., 2015, 2017). Concerning the methodological reliability, only Villa-González et al. (2015) carried out a retention test six months after the post-test. The five other studies conducted a longitudinal measurement with pre- and post- tests, but without a follow-up.

A total of 3,839 children and adolescents were included in the six selected studies. The smallest sample size is in Børrestad et al.' study (2012; n = 46) and the largest in Christiansen et al.' study (2014; n = 1,348). Except for the study by Villa-González et al. (2015), where no information was provided, the numbers were balanced in terms of biological sex, ranging from 47% girls (Børrestad et al., 2012) to 64.8% (Mendoza et al., 2017). In all six studies, the number of participants in both experimental and control groups were equilibrated. Participants ranged in age from 8 (Villa-González et al., 2015, 2017) to 13 years old (Christiansen et al., 2014).

Interventions ranged from 3 (Børrestad et al., 2012) to 24 months (Christiansen et al., 2014), with daily (Mendoza et al., 2017), weekly (Børrestad et al., 2012) or monthly (Villa-González et al., 2015, 2017) interventions. For the six study included, the control group had no specific intervention. For all the experimental group, the aim was to promote ATS throughout individual and environmental actions (see Table 3). Four interventions followed the ecological framework adapted to ATS: 5P model of active living (Christiansen et al., 2014), cycling to school (Østergaard et al., 2015) and active travel in children (Villa-González et al., 2015, 2017). The two other interventions were not theoretically anchored (Børrestad et al., 2017; Mendoza et al., 2017).

The measurement of PA showed considerable heterogeneity between studies: ergometer with VO_2 (Børrestad et al., 2012), ATS diaries with the percentage of ATS and the PA level (Christiansen et al., 2014), accelerometers and GPS with the MVPA in minute per day (Mendoza et al., 2017), the Andersen test with the VO_2 (Østergaard et al., 2015), questionnaires on commuting mode with the frequency of ATS (Villa-González et al., 2015) and a shuttle running test with VO_2 (Villa-González et al., 2017).

Design of the interventions. Table 3 describes the design of the six ATS school-based interventions included, according to the actions proposed in the four individual dimensions of PL and in the environmental dimension. All studies used both the individual and environmental dimensions of the ecological model.

All the studies suggested a design including relationships with environmental dimensions: bicycle train between homes and school (Mendoza et al., 2017), cycle path design near the school (Christiansen et al., 2014; Østergaard et al., 2015) or collaboration with parents (Børrestad et al., 2017; Villa-González et al., 2015; 2017), Three studies focused only the individual's physical dimension of PL and do not provide any evidence on the cognitive, psychological and social dimensions (Børrestad et al., 2017; Christiansen et al., 2014; Mendoza et al., 2017). The three other studies designed the interventions following the four individual dimensions of PL, without explicitely mentioned it (Østergaard et al., 2015; Villa-González et al., 2015; Villa-González et al., 2017).

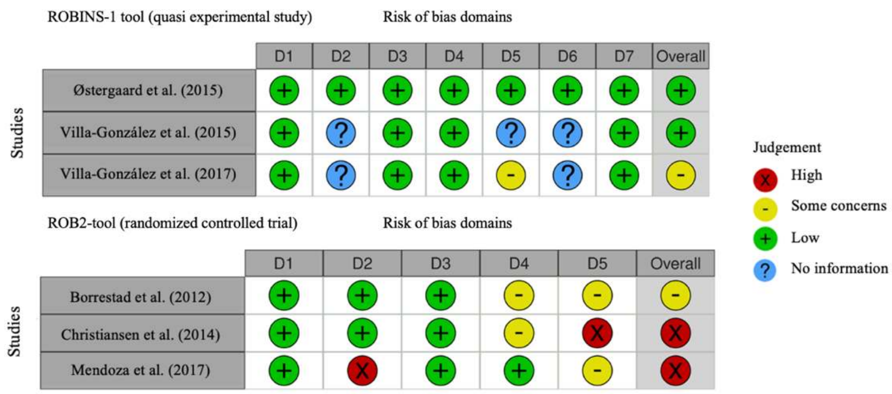
For the physical dimension, Villa-Gaonzales (2015; 2017) specified the use of activity of traditional games adapted to ATS. The other studies proposed cycling practices without specifying the motor content (Børrestad et al., 2017; Christiansen et al., 2014; Mendoza et al., 2017; Østergaard et al., 2015). For the cognitive dimension, Østergaard et al. (2015) proposed bike maintenance workshops and Villa-González et al. (2015; 2017) offered activities of knowledge about the environmental characteristics around the school. For the psychological dimension, Østergaard et al. (2015; 2017) developed the motivation to come cycling with competitive practice formats and Villa-González et al. (2015; 2017) with readings and theatre scenes related to ATS. Concerning the social dimension, all studies focused on developing safe practice, whether in the form of a school traffic policy (Østergaard et al., 2015) or activity of road safety and behaviour in the street (Villa-González et al., 2015; Villa-González et al., 2017).

Table 3. Design of each intervention according to the four individual dimension of physical literacy and the global environmental actions.

Author(s), date	**Individual dimension of physical literacy**				**Environmental dimension**
	Physical dimension	*Cognitive dimension*	*Psychological dimension*	*Social dimension*	
Børrestad et al., 2017	Bicyle learning, no information on motor skills	No information	No information	No information	Collaboration between school staff, a specialist in cycling safety and parents
Christiansen et al., 2014	Bicyle learning, no information on motor skills	No information	No information	No information	A cycle path and a new parking build near the school
Mendoza et al., 2017	Bicycle practice, no information on motor skills	No information	No information	No information	A bicycle train to be followed along the route to the school
Østergaard et al., 2015	Bicycle learning, no information on motor skills	Bicycle maintenance	Monitoring competitions to increase the school cycling motivation	School traffic policy education for safety	Structural changes near the school, no more information
Villa-González et al., 2015 Villa-González et al., 2017	Activity of traditional games adapted to a safe ATS	Knowledge activities about the characteristics around the school	Reading a story and performing scenes related to ATS	Activity of road safety and behaviour in the street	Families sensibility throughout a commuting questionnaire

Risk of bias. The risks of bias assessment are described in Figure 2. For QESs, the studies by Østergaard et al. (2015) and Villa-González et al. (2015) were rated with a low risk of bias. The study by Villa-González et al. (2017) had a moderate risk of bias due to missing data. The articles by Villa-González et al. (2015, 2017) lacked information about the selection of participants and the measurement of outcomes. In RCTs, two are rated as high risk (Christiansen et al., 2014; Mendoza et al., 2017) and one with some concerns (Børrestad et al., 2012).

Regarding the measurement of outcomes, two "some concerns" are reported (Børrestad et al., 2012; Christiansen et al., 2014). One study is reported to have a high risk of bias for deviating from the intended intervention (Mendoza et al., 2017).



Note. ROBINS-1: (D1) confounding, (D2) selection of the participants, (D3) classification of the interventions, (D4) deviations from planned confounding interventions, (D5) missing data, (D6) measurement of outcomes, and (D7), selection of the reported outcome(s). ROB2: (D1) randomisation process, (D2) deviations from the planned intervention, (D3) missing data on outcomes, (D4) the measurement of outcomes, and (D5), the selection of the reported outcome(s).

Figure 2. Risk of bias according to the both tools ROBINS-1 (top) and ROB-2 (down).

Meta- analysis

In order to assess publication bias with meta-analysis, two different tests were implemented. The Egger test (Z = 0.98, p = 0.32) and the Begg test (Z = 1.13, p = 0.26) suggest no evidence of publication bias in this meta-analysis.

Summary of results. The effect of cycling interventions on PA outcomes is displayed in Figure 3. The mean effect size for PA outcomes was g = 0.30 (95%CI, -0.08 to 0.69), indicating a statistically no-significant increase. The Cochrane Q and τ^2 showed a statistically significant level of heterogeneity (Q = 111.52, τ^2 = 0.21, p < 0.001), with a considerable inconsistency measure (I^2 = 95.52%). Sensitivity analysis removing (one at a time) each study from the total sample revealed that only one study (Villa-González et al., 2015) was a potential outlier and considered overly influential (g = -0.01, 95%CI: -0.13 to 0.12). The Cochrane Q and τ^2 showed a statistically non-significant heterogeneity level (Q = 7.87, τ^2 = 0.01, p = 0.10), with a moderate inconsistency measure (I^2 = 49.19%).

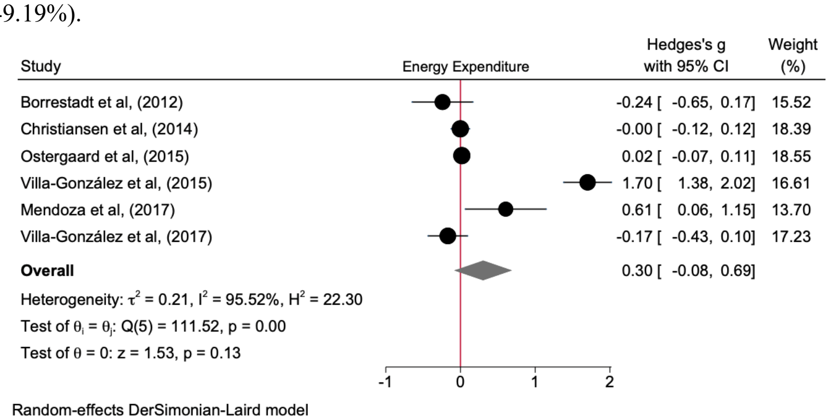


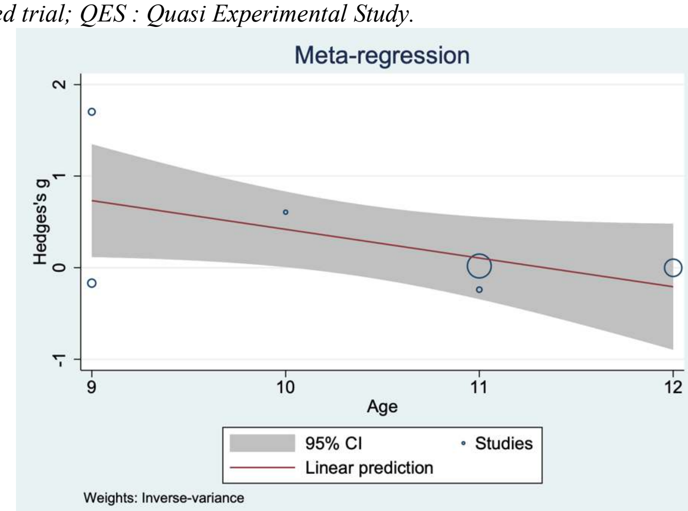
Figure 3. Forest plot showing the effects sizes (Hedges' *g*) of cycling interventions on PA outcomes for each study.

Meta-regression analysis. Results of the random-effects meta-regression analyses are presented in Table 4. Two significant association with changes in PA behaviours were found. Firstly, as can be appreciated in the bubble plot (Figure 4), there is a negative association between the age of participants and the intervention effects on PA outcomes (β = -0.311, 95%CI: -0.66 to -0.02; SE = 0.17; p = 0.047). Secondly, there is a positive association between the use of the four individual dimensions of PL for designing the intervention on PA outcomes, compared to the use of only a single dimension (β = 0.793, 95%CI: 0.06 to 1.52; SE = 0.37; p = 0.033). The duration of the intervention, theoretical framework and design were not associated with changes in PA behaviours.

Table 4. *Physical activity outcomes meta-regression analyses using random-effects models.*

Variables	Physical activity related outcomes			
	β	*95% CI*	*SE*	*p-value*
Continuous variables				
Duration (months)	–0.008	(–0.12, 0.10)	0.06	0.890
Age	-0.311	(-0.66, -0.02)	0.17	**0.047**
Dichotomous variables				
Theorical Framework				
No	Reference			
Yes	–0.383	(-1.52, 0.75)	0.58	0.510
Design				
RCT	Reference			
QES	0.396	(-0.72, 1.51)	0.57	0.488
Individual dimensions (physical literacy)				
Single dimension	Reference			
Four dimensions	0.793	(0.06, 1.52)	0.37	**0.033**

Note. *Bold: significant result; β: beta coefficient; SE: standart error ; CI: confidence interval; RCT: randomized controlled trial; QES : Quasi Experimental Study.*



Notes. The sizes of cercles correspond to the number of participants in each study (weight column in the forest plot, Figure 3). The effect sizes (y axis) are identical to those of the forest plot studies (Figure 3), making it easy to identify each study.
Figure 4. Bubble plot showing the association between the age of participants and the intervention effect sizes.

Discussion

The aim of this systematic review and meta-analysis was to highligth the key elements for designing ATS interventions, providing guidance for educators and PE teachers on implementing such programm in school settings. The analysis identified four main findings regarding the effectiveness of current ATS school-based interventions: (a) a lack of studies in the ATS field highlighting the need for high quality research methodologies to assess interventions, (b) an overall non-significant increase on PA, (c) interventions incorporated both the four indivudal dimensions of PL and an environmental dimension showed the greatest impact on PA, and (d), a significative negative association between PA-outcome and the participant age (β = -0.311, p = 0.047). This findings suggest that to maximize the effectiveness of ATS interventions, they be implemented starting in primary school age and designed with a multi-level approach that integrates PL framework.

1. An overall non-significant increase on PA

In a previous systematic review, Schnobach et al. (2020) have demonstrated the positive effects of interventions to improve ATS: bicycle train among children indicated great potential to increase cycling to school. However, our study shows that this intervention design is not sufficient to improve participants' PA. Our non-significant increase in PA among children could be explain by a high degree of methodological heterogeneity and the lack of consensus in the theoretical frameworks used. PL provide a complementary design' perspective to the study of Schnobach et al. (2020).

The main limitation of our study is that it included only six studies, compared to nine in the review by Schonbach et al. (2020). However, the research questions differ: while Schönbach et al. (2020) analysed the interventions through the lens of the ecological model, our study introduced a novel approach by incorporating the concept of PL into the design analysis. Although the limited number of studies prevented a sub-group analysis, statistical tests were applied to validate the number of participants included, ensuring reiable results (Egger test and Begg test). Despite this limitation, we present an innovative meta-analysis aimed at identifying the most effective design and age for achieving optimal outcomes.

2. Fostering the impact of ATS school-based interventions with a design anchored in the PL framework

The meta-regression analysis revealed that incorporating all four dimensions of the PL in the design of ATS interventions was a key factor in enhancing their impact on PA. Notably, two of the three interventions with the greatest benefits in PA targeted all four PL dimensions. One study (Villa-González et al., 2015) revealed significantly better results than others (g = 1.7, 95%CI: 1.38 to 2.02) by proposing a holistic development approach in children and adolescents. This approach included motor (e.g. activity of traditional games or active behaviours in the street), cognitive (e.g. activity of knowledge about the environmental characteristics around the school or road safety education), psychological (e.g. reading a story on ATS to school) and social dimensions (involvement of families). Therefore, addressing all PL dimensions, rather than focusing on just one, led to superior outcomes

The remaining five studies can be characterized as follows: (i) they did not specifically focus on developing ATS related motor skills, (ii) they focused on safety with a home to school bicycle transport service, and (iii), they involved infrastructural changes around the school often coupled with a "*awareness-raising*" campaign for children and adolescents. Although two of these studies adopted a multi-level approach, neither addressed the development of the individual across all PL dimensions.

3. Promotion of active communities as earlier as possible

The meta-regression analysis highlighted a significant negative association between participants' age and the PA outcomes. This correlation reinforces the widely accepted notion, supported by international literature, that introducing healthy habits early in life increases their likelihood of their long term adoption (Varma et al., 2017). However, there remains a lack of clarity in the literature regarding the optimal age for acquiring such healthy habits, especially in active transport.

These results can be explained by the fact that children start to ride their bicycle at the young age of five (Zeuwts et al., 2016). Zeuwts et al. (2020) considered cycling as a "*joint-skill*" that requires sufficient (1) motor skills (e.g., the ability to coordinate steering, balancing, pedalling, braking, etc.), (2) perceptual-motor skills (e.g., hazard perception, time-to-contact, attention, planning, judgment, decision-making, etc.), (3) knowledge of the traffic rules and (4) attitudes (e.g., the willingness to obey the traffic rules or risky behaviour (Ducheyne et al., 2013). Given that most of thid children's holistic development continues well into adolescence, with age-related maturation of the central nervous system and practice (Casey et al., 2000), education can be used to prepare young cyclists to manage the risks they face and provide them with the necessary motor skills and strategies to cope with the dynamicity of traffic. However, although cycling education programmes improve cycling motors skills (Ducheyne et al., 2013), the relationship between the level of cycling motor skills and lifestyle habits in terms of PA (particularly cycling to and/or from school) remains to be demonstrated (Ducheyne et al., 2014).

The inclusion of parents in these programmes seems to be a promising avenue, particularly since the studies by Børrestad et al (2017) and Villa-González et al (2015; 2017) proposed a plan with parents and had positive results. In France, the mandatory national curriculum on "*knowing how to ride a bike*" encourages motor development from the age of 8. However, the design of lessons based on the PL reinforces the need for multidimensional teaching. In the context of New-Zealand, Mandic et al. (2022) have demonstrated the importance of parental support, geographical proximity and a safe environment to increase PA levels. In France, educational initiatives on cycling according to the LP are emerging through professional (Derigny, Gandrieau, et al., 2022) or scientific (Derigny, Gandrieau et al., 2024) publications, but the multidimensional aspect remains to be explored.

4. Methological recommandations: the need to measure sustainability

Although only Villa-González et al. (2015) reported encouraging results on the sustainability of ATS through a follow-up retention test, the issue of long-term persistence remains unresolved. Specifically, how do individuals who adopt active travel modes maintain this behavior throughout their lives? Educating children and adolescents to adopt persistent PA behaviours is a critical challenge in contemporary societies, where various life events and transitions often lead to a decline in active lifestyles (Gropper et al., 2020). Initial studies have highlighted ATS as a resilient form of PA, underscoring the need for more interventions that engage adolescents and emerging adults in active travel (Derigny, Gandrieau et al., 2022). However, future interventions should include three key assessments: pre-, post- and follow-up to better understand long-term impacts.

Conclusions

To the best of our knowledge, while previous systematic reviews have addressed the effectiveness of cycling school-based interventions (Schönbach et al., 2020), this study is the first one to synthesize evidence for PA outcomes. Some reviews have already explored a broader domain of results, helping to provide an overview of the effectiveness of ATS interventions: skills (Ducheyne et al., 2014), perceptions of practice (Mandic et al., 2022) or parental-control (Gutierrez et al., 2014). A scoping review of reviews indicates that current teaching approaches may overly focus on enhancing motor skills and increasing PA, while neglecting the cognitive, social, and environmental dimensions of healthy habits (Ramires et al., 2023). The concept of PL represents a promising avenue for future school-based active transport interventions.

This systematic review has provided evidence to design further ATS school-based intervention, reinforcing the four following message: (1) future RCTs on ATS promotion must start as ealier as possible (i.e., ideally in primary school), (2) must seek to develop children and adolescents in all dimensions (i.e., physical, cognitive, psychological and social), (3) must be rooted in the interaction of the evels of the ecological model to effectively and sustainably change behaviours and (4) must included a follow-up measurements to ensure sustainability.

Conflict of interest.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Theo Lenig, a Masters student from the University of Strasbourg for his participation in the data analysis process.

CRediT authorship contribution statement

Thibaut Derigny: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Supervision. **Léa Mekkaoui**: Conceptualization, Methodology, Investigation, Writing – original draft. **Louis Meistermann**: Methodology, Investigation, Writing – review & editing. **Javier Rodrigo-Sanjoaquín**: Software, Formal analysis, Writing – original draft. **Joseph Gandrieau**: Writing – review & editing **Christophe Schnitzler**: Writing – review & editing. **François Potdevin**: Supervision, Writing – review & editing.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Underlying data. Zenodo: Enhance physical activity by designing school based active transport interventions. A systematic review with meta-analysis. https://doi.org/10.5281/zenodo.13769820 (Derigny, Mekkaoui et al., 2024)/ The project contains the following underlying data:

- Data_ATS_systematic_review: xlsx files with data on articles identified for systematic review (qualitative analysis).
- Script_ATS_systematic_review: STATA files with data analysis for meta-analysis (quantitative analysis).

References

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., & Martin, B. W. (2012). Correlates of physical activity : Why are some people physically active and others not? *The Lancet*, *380*(9838), 258-271. https://doi.org/10.1016/S0140-6736(12)60735-1

Børrestad, L. A. B., Østergaard, L., Andersen, L. B., & Bere, E. (2012). Experiences from a randomised, controlled trial on cycling to school : Does cycling increase cardiorespiratory fitness? *Scandinavian Journal of Public Health*, *40*(3), 245-252. https://doi.org/10.1177/1403494812443606

Bronfenbrenner, U., & Morris, P. A. (2006). The Bioecological Model of Human Development. In *Handbook of child psychology : Theoretical models of human development, Vol. 1, 6th ed* (p. 793-828). John Wiley & Sons, Inc.

Carl, J., Barratt, J., Arbour-Nicitopoulos, K. P., Barnett, L. M., Dudley, D. A., Holler, P., Keegan, R., Kwan, M., Scurati, R., Sum, R. K.-W., Wainwright, N., & Cairney, J. (2023). Development, explanation, and presentation of the Physical Literacy Interventions Reporting Template (PLIRT). *International Journal of Behavioral Nutrition and Physical Activity*, *20*(1), 21. https://doi.org/10.1186/s12966-023-01423-3

Carl, J., Barratt, J., Wanner, P., Töpfer, C., Cairney, J., & Pfeifer, K. (2022). The Effectiveness of Physical Literacy Interventions : A Systematic Review with Meta-Analysis. *Sports Medicine*, *52*(12), 2965-2999. https://doi.org/10.1007/s40279-022-01738-4

Casey, B. J., Giedd, J. N., & Thomas, K. M. (2000). Structural and functional brain development and its relation to cognitive development. *Biological Psychology*, *54*(1), 241-257. https://doi.org/10.1016/S0301-0511(00)00058-2

Chillón, P., Evenson, K. R., Vaughn, A., & Ward, D. S. (2011). A systematic review of interventions for promoting active transportation to school. *International Journal of Behavioral Nutrition and Physical Activity*, *8*(1), 10. https://doi.org/10.1186/1479-5868-8-10

Chillón, P., Gálvez-Fernández, P., Huertas-Delgado, F. J., Herrador-Colmenero, M., Barranco-Ruiz, Y., Villa-González, E., Aranda-Balboa, M. J., Saucedo-Araujo, R. G., Campos-Garzón, P., Molina-Soberanes, D., Segura-Díaz, J. M., Rodríguez-Rodríguez, F., Lara-Sánchez, A. J., Queralt, A., Molina-García, J., Bengoechea, E. G., & Mandic, S. (2021). A School-Based Randomized Controlled Trial to Promote Cycling to School in Adolescents : The PACO Study. *International Journal of Environmental Research* *and Public Health*, *18*(4), 2066. https://doi.org/10.3390/ijerph18042066

Christiansen, L. B., Toftager, M., Ersbøll, A. K., & Troelsen, J. (2014). Effects of a Danish multicomponent physical activity intervention on active school transport. *Journal of Transport & Health*, *1*(3), 174-181. https://doi.org/10.1016/j.jth.2014.05.002

Cooper, H., Hedges, L. V., & Valentine, J. C. (2009). *The Handbook of Research Synthesis and Meta-Analysis* (Second Edition | RSF). https://www.russellsage.org/publications/handbook-research-synthesis-and-meta-analysis-second-edition

Derigny, T., Gandrieau, J., Schnitzler, C., & Potdevin, F. (2022). Enseigner le vélo pour éduquer à un mode de vie physiquement actif. *Enseigner l'EPS*, *288*, 30-34.

Derigny, T., Schnitzler, C., Gandrieau, J., & Potdevin, F. (2022). Resilience of adolescents in physical activity during the covid-19 pandemic : A preliminary case study in France. *Physical Activity Review*, *10*(1), 86-97. https://doi.org/10.16926/rp.2020.12.10

Derigny, T., Schnitzler, C., Remmers, T., Van Kann, D., Gandrieau, J., Seye, N., Baquet, G., & Potdevin, F. (2022). Catch me if you can ! How French adolescents seize social occasions and opportunities to be active. *BMC Public Health*, *22*(1), 1332. https://doi.org/10.1186/s12889-022-13746-0

Derigny, T., Gandrieau, J., Mekkaoui, L., Llena C., Schnitzler, C., Potdevin, F., 2024. "Take a Ride on a Lifelong Journey!" A Physical Literacy School-Based Intervention to Safely Engage Adolescents in Active Transport. *Journal of Teaching in Physical Education*, 1-10. https://doi.org/10.1123/jtpe.2023-0356

Derigny, T., Mekkaoui, L., Meistermann, L., Rodrigo-Sanjoaquín, J., Joseph, G., Schnitzler, C., Potdevin, F., 2024. Enhance physical activity by designing school based active transport interventions. A systematic review with meta-analysis. [Data set]. *Zenodo*. https://doi.org/10.5281/zenodo.13769820

Ducheyne, F., De Bourdeaudhuij, I., Lenoir, M., & Cardon, G. (2013). Does a cycle training course improve cycling skills in children? *Accident Analysis & Prevention*, *59*, 38-45. https://doi.org/10.1016/j.aap.2013.05.018

Ducheyne, F., De Bourdeaudhuij, I., Lenoir, M., & Cardon, G. (2014). Effects of a cycle training course on children's cycling skills and levels of cycling to school. *Accident Analysis & Prevention*, *67*, 49-60. https://doi.org/10.1016/j.aap.2014.01.023

Duffey, K., Barbosa, A., Whiting, S., Mendes, R., Yordi Aguirre, I., Tcymbal, A., Abu-Omar, K., Gelius, P., & Breda, J. (2021). Barriers and Facilitators of Physical Activity Participation in Adolescent Girls : A Systematic Review of Systematic Reviews. *Frontiers in Public Health*, *9*, 743935. https://doi.org/10.3389/fpubh.2021.743935

Durden-Myers, E. J., Green, N. R., & Whitehead, M. E. (2018). Implications for Promoting Physical Literacy. *Journal of Teaching in Physical Education*, *37*(3), 262-271. https://doi.org/10.1123/jtpe.2018-0131

Faulkner, G. E. J., Buliung, R. N., Flora, P. K., & Fusco, C. (2009). Active school transport, physical activity levels and body weight of children and youth : A systematic review. *Preventive Medicine*, *48*(1), 3-8. https://doi.org/10.1016/j.ypmed.2008.10.017

Gandrieau, J., Schnitzler, C., Cairney, J., Keegan, R., Roberts, W. M., Barnett, L. M., Bentsen, P., Dudley, D. A., Raymond Sum, K. W., Venetsanou, F., Button, C., Turcotte, S., Berrigan, F., Cloes, M., Rudd, J. R., Riga, V., Mouton, A., Vašíčková, J., Blanchard, J., … Potdevin, F. (2023). Development of ELIP to Assess Physical Literacy for Emerging Adults : A Methodological and Epistemological Challenge. *Research Quarterly for Exercise and Sport*, *94*(4), 1169-1182. https://doi.org/10.1080/02701367.2022.2125927

González, S. A., Aubert, S., Barnes, J. D., Larouche, R., & Tremblay, M. S. (2020). Profiles of Active Transportation among Children and Adolescents in the Global Matrix 3.0 Initiative : A 49-Country Comparison. *International Journal of Environmental Research and Public Health*, *17*(16), 5997. https://doi.org/10.3390/ijerph17165997

Gropper, H., John, J. M., Sudeck, G., & Thiel, A. (2020). The impact of life events and transitions on physical activity : A scoping review. *PLOS ONE*, *15*(6), e0234794. https://doi.org/10.1371/journal.pone.0234794

Gutierrez, C. M., Slagle, D., Figueras, K., Anon, A., Huggins, A. C., & Hotz, G. (2014). Crossing guard presence : Impact on active transportation and injury prevention. *Journal of Transport & Health*, *1*(2), 116-123. https://doi.org/10.1016/j.jth.2014.01.005

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents : A pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health*, *4*(1), 23-35. https://doi.org/10.1016/S2352-4642(19)30323-2

Higgins, J. P. T., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine*, *21*(11), 1539-1558. https://doi.org/10.1002/sim.1186

Higgins, J., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M., & Welch, V. (2023). *Cochrane Handbook for Systematic Reviews of Interventions* (6.4). https://training.cochrane.org/handbook/current

Hynynen, S.-T., Van Stralen, M. M., Sniehotta, F. F., Araújo-Soares, V., Hardeman, W., Chinapaw, M. J. M., Vasankari, T., & Hankonen, N. (2016). A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. *International Review of Sport and Exercise Psychology*, *9*(1), 22-44. https://doi.org/10.1080/1750984X.2015.1081706

Keegan, R. J., Barnett, L. M., Dudley, D. A., Telford, R. D., Lubans, D. R., Bryant, A. S., Roberts, W. M., Morgan, P. J., Schranz, N. K., Weissensteiner, J. R., Vella, S. A., Salmon, J., Ziviani, J., Okely, A. D., Wainwright, N., & Evans, J. R. (2019). Defining Physical Literacy for Application in Australia : A Modified Delphi Method. *Journal of Teaching in Physical Education*, *38*(2), 105-118. https://doi.org/10.1123/jtpe.2018-0264

Lee, I.-M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide : An analysis of burden of disease and life expectancy. *The Lancet*, *380*(9838), 219-229. https://doi.org/10.1016/S0140-6736(12)61031-9

Mandic, S., García Bengoechea, E., Hopkins, D., Coppell, K., & Spence, J. C. (2022). Adolescents' perceptions of walking and cycling to school differ based on how far they live from school. *Journal of Transport & Health*, *24*, 101316. https://doi.org/10.1016/j.jth.2021.101316

Mendoza, J. A., Haaland, W., Jacobs, M., Abbey-Lambertz, M., Miller, J., Salls, D., Todd, W., Madding, R., Ellis, K., & Kerr, J. (2017). Bicycle Trains, Cycling, and Physical Activity : A Pilot Cluster RCT. *American Journal of Preventive Medicine*, *53*(4), 481-489. https://doi.org/10.1016/j.amepre.2017.05.001

Mendoza, J. A., Watson, K., Nguyen, N., Cerin, E., Baranowski, T., & Nicklas, T. A. (2011). Active commuting to school and association with physical activity and adiposity among US youth. *Journal of Physical Activity & Health*, *8*(4), 488-495. https://doi.org/10.1123/jpah.8.4.488

Østergaard, L., Støckel, J. T., & Andersen, L. B. (2015). Effectiveness and implementation of interventions to increase commuter cycling to school : A quasi-experimental study. *BMC Public Health*, *15*(1), 1199. https://doi.org/10.1186/s12889-015-2536-1

O'Sullivan, M., Davids, K., Woods, C. T., Rothwell, M., & Rudd, J. (2020). Conceptualizing Physical Literacy within an Ecological Dynamics Framework. *Quest*, *72*(4), 448-462. https://doi.org/10.1080/00336297.2020.1799828

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement : An updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed.)*, *372*, n71. https://doi.org/10.1136/bmj.n71

Pot, N., Whitehead, M. E., & Durden-Myers, E. J. (2018). Physical Literacy From Philosophy to Practice. *Journal of Teaching in Physical Education*, *37*(3), 246-251. https://doi.org/10.1123/jtpe.2018-0133

Ramires, V. V., Dos Santos, P. C., Barbosa Filho, V. C., Bandeira, A. D. S., Marinho Tenório, M. C., De Camargo, E. M., Ravagnani, F. C. D. P., Sandreschi, P., De Oliveira, V. J. M., Hallal, P. C., & Silva, K. S. (2023). Physical Education for Health Among School-Aged Children and Adolescents : A Scoping Review of Reviews. *Journal of Physical Activity and Health*, *20*(7), 586-599. https://doi.org/10.1123/jpah.2022-0395

Rodrigo-Sanjoaquín, J., Abós, Á., García-González, L., & Sevil-Serrano, J. (2023). Efectos de un programa de intervención escolar para promover el desplazamiento activo en bicicleta de los adolescentes. *MHSalud: Revista en Ciencias del Movimiento Humano y Salud*, *20*(2), Article 2. https://doi.org/10.15359/mhs.20-2.7

Rodrigo-Sanjoaquín, J., Corral-Abós, A., Aibar Solana, A., Zaragoza Casterad, J., Lhuisset, L., & Bois, J. E. (2022). Effectiveness of school-based interventions targeting physical activity and sedentary time among children : A systematic review and meta-analysis of accelerometer-assessed controlled trials. *Public Health*, *213*, 147-156. https://doi.org/10.1016/j.puhe.2022.10.004

Schoen, S. A., Ferrari, V., & Valdez, A. (2022). It's Not Just about Bicycle Riding : Sensory-Motor, Social and Emotional Benefits for Children with and without Developmental Disabilities. *Children*, *9*(8), 1224. https://doi.org/10.3390/children9081224

Schönbach, D. M. I., Altenburg, T. M., Marques, A., Chinapaw, M. J. M., & Demetriou, Y. (2020). Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents : A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 138. https://doi.org/10.1186/s12966-020-01035-1

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). RoB 2 : A revised tool for assessing risk of bias in randomised trials. *BMJ (Clinical Research Ed.)*, *366*, l4898. https://doi.org/10.1136/bmj.l4898

Sterne, J. A., Hernán, M. A., Reeves, B. C., Savović, J., Berkman, N. D., Viswanathan, M., Henry, D., Altman, D. G., Ansari, M. T., Boutron, I., Carpenter, J. R., Chan, A.-W., Churchill, R., Deeks, J. J., Hróbjartsson, A., Kirkham, J., Jüni, P., Loke, Y. K., Pigott, T. D., … Higgins, J. P. (2016). ROBINS-I :

A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ (Clinical Research Ed.)*, *355*, i4919. https://doi.org/10.1136/bmj.i4919

Strain, T., Wijndaele, K., Garcia, L., Cowan, M., Guthold, R., Brage, S., & Bull, F. C. (2020). Levels of domain-specific physical activity at work, in the household, for travel and for leisure among 327 789 adults from 104 countries. *British Journal of Sports Medicine*, *54*(24), 1488-1497. https://doi.org/10.1136/bjsports-2020-102601

van Sluijs, E. M. F., Ekelund, U., Crochemore-Silva, I., Guthold, R., Ha, A., Lubans, D., Oyeyemi, A. L., Ding, D., & Katzmarzyk, P. T. (2021). Physical activity behaviours in adolescence : Current evidence and opportunities for intervention. *Lancet (London, England)*, *398*(10298), 429-442. https://doi.org/10.1016/S0140-6736(21)01259-9

Varma, V. R., Dey, D., Leroux, A., Di, J., Urbanek, J., Xiao, L., & Zipunnikov, V. (2017). Re-evaluating the effect of age on physical activity over the lifespan. *Preventive Medicine*, *101*, 102-108. https://doi.org/10.1016/j.ypmed.2017.05.030

Villa-González, E., Ruiz, J. R., Mendoza, J. A., & Chillón, P. (2017). Effects of a school-based intervention on active commuting to school and health-related fitness. *BMC Public Health*, *17*(1), 20. https://doi.org/10.1186/s12889-016-3934-8

Villa-González, E., Ruiz, J. R., Ward, D. S., & Chillón, P. (2015). Effectiveness of an active commuting school-based intervention at 6-month follow-up. *The European Journal of Public Health*, *26*(2), 272-276. https://doi.org/10.1093/eurpub/ckv208

Wanjau, M. N., Möller, H., Haigh, F., Milat, A., Hayek, R., Lucas, P., & Veerman, J. L. (2023). Physical Activity and Depression and Anxiety Disorders : A Systematic Review of Reviews and Assessment of Causality. *AJPM Focus*, *2*(2), 100074. https://doi.org/10.1016/j.focus.2023.100074

Whitehead, M. (2001). The Concept of Physical Literacy. *European Journal of Physical Education*, *6*(2), 127-138. https://doi.org/10.1080/1740898010060205

Whitehead, M. (2010). *Physical Literacy: Throughout the Lifecourse*. Routledge.

Young, L., O'Connor, J., & Alfrey, L. (2020). Physical literacy : A concept analysis. *Sport, Education and Society*, *25*(8), 946-959. https://doi.org/10.1080/13573322.2019.1677586

Zeuwts, L. H. R. H., Deconinck, F. J. A., Vansteenkiste, P., Cardon, G., & Lenoir, M. (2020). Understanding the development of bicycling skills in children : A systematic review. *Safety Science*, *123*, 104562. https://doi.org/10.1016/j.ssci.2019.104562

Zeuwts, L., Vansteenkiste, P., Cardon, G., & Lenoir, M. (2016). Development of cycling skills in 7- to 12-year-old children. *Traffic Injury Prevention*, *17*(7), 736-742. https://doi.org/10.1080/15389588.2016.1143553