

Short title:

Self-report physical activity and associated determinants in children - systematic review and meta-analyses

DE-PASS Best Evidence Statement (BEST): Determinants of self-report physical activity and sedentary behaviours in children in settings: A systematic review and meta-analyses.

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1 **Abstract**

2 Previous physical activity interventions for children (5-12yrs) have aimed to change
3 determinants associated with self-report physical activity behaviour (PAB) and/or sedentary
4 behaviour (SB), however, the associations between these determinants and PAB/SB in
5 different settings are uncertain. The present study aimed to identify modifiable determinants
6 targeted in previous PAB/SB interventions for children. Intervention effects on the
7 determinants and their associations with self-report PAB/SB were assessed across settings.
8 Search of relevant interventions from pre-defined databases was conducted up to July 2023.
9 Randomized and non-randomized controlled trials with modifiable determinants were
10 included. Data extraction and risk of bias assessments were conducted by two independent
11 researchers. Where data could be pooled, we performed Robust Bayesian meta-analyses.
12 Heterogeneity, publication bias and certainty of evidence were assessed. Fifteen studies were
13 deemed eligible to be included. Thirty-seven unique determinants within four settings were
14 identified – school, family, school with family/home, and community with(out) other
15 settings. Ninety-eight percent of determinants belonged to individual/interpersonal
16 determinant categories. Narratively, intervention effects on student perception of teachers’
17 behaviour (school), self-management, perceived barriers, external motivation, exercise
18 intention, parental modeling on SB (school with family/home) and MVPA expectations
19 (community) were weak to strong, however, corresponding PAB/SB change was not evident.
20 There were negligible effects for all other determinants and the corresponding PAB/SB.
21 Meta-analyses on self-efficacy, attitude, subjective norm and parental practice and PAB/SB
22 in two settings showed weak to strong evidence *against* intervention effect, while the effect
23 on knowledge could not be determined. Similarly, publication bias and heterogeneity for
24 most analyses could not be ascertained. We found no concrete evidence of association
25 between the modifiable determinants and self-report PAB/SB in any settings. This is

26 presumably due to intervention ineffectiveness. Design of future interventions should
27 consider to follow the systems-based approach and identify determinants unique to the
28 context of a setting, including policy and environmental determinants.

29 **Introduction**

30 Globally, about 18% (over 34 million) children and adolescents are overweight or obese – a
31 10-fold increase from 40 years ago [1]. Physical inactivity has been identified as one of the
32 main risk factors whereby two-thirds of children and adolescents are insufficiently active,
33 despite the widely recognized benefits of physical activity [2]. Evidence shows that inactive
34 children are likely to become inactive adults [3,4], and it is projected that the healthcare
35 burden of physical inactivity-related non-communicable diseases will cost INT\$520 billion
36 annually between 2020-2030 if the physical inactivity pandemic continues [5].

37

38 Over the past three decades, the number of physical activity behaviour (PAB) and sedentary
39 behaviour (SB) interventions targeting childhood inactivity has seen an upward surge [6]. PA
40 is defined as any movement produced by skeletal muscles that involve the energy expenditure
41 of >1.5 metabolic equivalents of tasks (METs) whereas ≤ 1.5 METs while awake is
42 considered as SB [7]. Conclusions about the effectiveness of interventions for school-aged
43 children from recent systematic reviews have been mixed [8-12]. Typically, these
44 interventions aim to manipulate factors associated with PAB and/or SB, hence these factors
45 are also considered as determinants as their causal associations with PAB or SB are assumed
46 [13]. Not only should determinants be evidence-based, but they should also be modifiable to
47 the extent that can enact behaviour change [14]. An array of determinants relevant to the
48 youth population within the European context has been previously identified by experts of
49 PAB and SB [14,15]. Based on the socio-ecological model [16], the majority of the identified
50 PAB/SB determinants (approximately 55%) considered to be highly modifiable and have the
51 largest effect on PAB/SB, belong to the individual and interpersonal level, such as attitude,
52 support of peers/family and TV exposure [14,15]. However, there have been mixed findings
53 on the extent to which interventions that target these determinants are associated with

54 changes in PAB/SB [17-19]. A lack of understanding of which determinants have
55 significantly contributed to changes in PAB/SB has hampered progress in physical activity
56 promotion across the lifespan [20]. Given this state of uncertainty, the DEterminants of
57 Physical Activity in SettingS (DE-PASS) consortium was formed with an aim to identify key
58 determinants effective in promoting PAB and reducing SB, and crucially, translatable at the
59 policy level to accelerate research-policy collaborations in addressing the physical inactivity
60 pandemic.

61

62 Several factors may have contributed to the mixed findings regarding the association between
63 the modifiable determinants and PAB/SB. First and foremost, the context within a setting in
64 which the determinants operate is seldom considered [21]. Interventions are often complex
65 for many reasons, including but not limited to the stakeholders involved and their motivation,
66 the physical and psychological capacity for (long-term) implementation and the prevailing
67 PAB/SB practice where the interventions are implemented. As such, the extent to which these
68 factors may influence the modifiable determinants may vary considerably in different settings
69 [22,23]. For example, results of realist reviews of interventions for children showed that in
70 the family setting, physical activity knowledge combined with parental reinforcement was an
71 important determinant unique to that setting, whereas parental restrictions on PAB, as a
72 determinant, hampered the effect of school-based interventions [21,22]. Another factor that
73 warrants attention is the age groups included in reviews targeting youth, where interventions
74 involving children and adolescents were examined collectively [10,12,14]. The
75 developmental journey from childhood to adolescence sees notable changes and adaptations
76 in individuals' environmental, physical and psychological conditions, all of which define the
77 individuals' context [25]. For example, while self-efficacy was found to be a common
78 modifiable PAB determinant for children and adolescents, intention appears to be unique to

79 children and perceived behaviour control and planning are unique to adolescents [26,27].
80 Given the above considerations, the current systematic review will examine PAB/SB
81 determinants in interventions from different settings, targeting children aged 5-12 years only.
82
83 To address a main objective of DE-PASS of generating a Best Evidence Statement (BEST)
84 with regards to the key modifiable determinants for youth PAB/SB from existing best
85 evidence, the current review aimed to examine interventions that target PAB and/or SB using
86 the randomized controlled trial (RCT) and controlled trial (CT) designs. While RCTs are
87 considered the gold standard in intervention design, CTs could be a viable alternative when
88 randomization is challenging due to factors such as participants' or stakeholders' preference.
89 This review also focused on self-report PAB/SB measures only, while other planned
90 systematic reviews addressing the same DE-PASS objective will focus on device-based
91 measures, as the discrepancy in measurement is evidenced [28-30]. Therefore, the aims of
92 this systematic review were three-fold – i) to identify the modifiable determinants that have
93 been targeted in PAB/SB interventions in different settings, ii) to evaluate the extent to which
94 these determinants have been modified, and iii) to investigate their association with self-
95 report PAB/SB in school-aged children.

96

97 **Methods**

98 This review is one of the five planned systematic reviews conducted under the same
99 deliverable (youth focus) within the DE-PASS consortium. Workshops for all members
100 involved in the review activities were conducted to ensure mutual understanding of the
101 eligibility criteria and the practice in study screening, data extraction, risk of bias
102 assessments, and the use of Covidence, an online systematic review platform
103 (www.covidence.org).

104

105 **Study design**

106 This systematic review was conducted following the Preferred Reporting Items for
107 Systematic Reviews and Meta-Analysis Protocols (PRISMA-P) guidelines (see S1 Checklist)
108 [31]. The study protocol was prospectively registered in PROSPERO (CRD42021282874).

109

110 **Search strategy**

111 The current study applied the same search strategy for all the five systematic reviews under
112 the same deliverable (youth focus) within DE-PASS. A search was conducted on MEDLINE,
113 PsycINFO, Web of Science, Sport Discus and Cochrane Central Register of Controlled Trials
114 for literature from 2010 up to July, 2023. We considered publications from 2010 because this
115 was when WHO published the first global PA guidelines [32]. For the full search strategies
116 and terms, please refer to the published study protocol [http://dx.doi.org/10.1136/bmjopen-](http://dx.doi.org/10.1136/bmjopen-2021-059202)
117 [2021-059202](http://dx.doi.org/10.1136/bmjopen-2021-059202) [33].

118

119 **Eligibility criteria**

120 **Population**

121 We included children aged 5-12 years (inclusive) without known medical conditions that
122 would hinder habitual PAB, such as spina bifida and arthritis.

123

124 **Interventions**

125 Interventions targeting PAB/SB in children using self-report, and that i) had measured
126 modifiable determinants at ≥ 2 time points (pre-/post-measurements), and ii) had measured the
127 PAB/SB outcomes at ≥ 2 time points (pre-/post-measurements) were included.

128

129 **Comparator**

130 All studies included a control group receiving no intervention, or a comparator group
131 receiving an alternative intervention matched to the experimental conditions.

132

133 **Outcomes**

134 This review included two types of outcomes – modifiable determinants and self-report
135 PAB/SB, as the intervention effect on both were examined separately. We assessed whether
136 an outcome is qualified as a determinant by the theoretical underpinning or the context of the
137 interventions. For example, if an intervention explicitly aimed to reduce body weight in order
138 to promote PAB, body weight status was considered a determinant. If, however, body weight
139 was clearly considered as an outcome without specifying its mechanistic influence on PAB in
140 the context of the intervention, and given no other modifiable determinants were included,
141 the study was excluded. For studies with both self-report and device-based PAB/SB
142 measurements, only the former was analyzed in this review.

143

144 **Study design**

145 Interventions that followed RCT or CT designs of any duration and follow-up period, and
146 within any settings, were analyzed. Peer-reviewed studies in any language were considered.
147 For studies that did not provide relevant information for eligibility assessment or for data
148 extraction, authors were contacted. These studies were excluded if the requested information
149 was not obtained.

150

151 **Study selection and data extraction**

152 At the initial screening, Endnote x9 was used to remove duplicates and non-peer-reviewed
153 literature. The final identified studies were transferred to Covidence for title/abstract/full-text
154 screening and data extraction. Extracted data included sample characteristics, study
155 characteristics, settings, theoretical basis of the interventions, measurements of PAB/SB and
156 determinants as well as their measurement properties. Study screening and data extraction
157 were completed by deliverable members of DE-PASS in pairs independently. Conflicts were
158 solved by discussion or with a third member.

159

160 **Quality assessment**

161 With regards to risk of bias assessments, we used the Cochrane Risk of Bias Tool for
162 Randomized Trials version 2 (RoB2.0) [34] and Risk of Bias in Non-Randomized Studies of
163 Intervention (ROBINS-I) [35] for RCTs and CTs respectively. The ‘Bias in the measurement
164 of outcome’ domain was assessed for both outcomes of interest separately, namely
165 determinant(s) and PAB/SB. Two independent reviewers assessed the risk of bias. A third
166 reviewer was consulted if consensus could not be reached. The assessment plots were
167 generated by the robvis tool [36]. To assess the certainty of evidence, three authors (FCML,
168 AM, KN) followed the Grading of Recommendations Assessment, Development and
169 Evaluation (GRADE) approach to evaluate all studies included in the meta-analyses [37].
170 GRADE includes five criteria – risk of bias, inconsistency, indirectness, imprecision and
171 publication bias. The level of certainty ranges from high to very low, depending on the extent
172 to which the true effect is considered similar to the estimated effect.

173

174 **Statistical analysis**

175 All determinants were categorised based on the socio-ecological model [16]. For
176 determinants with multiple indicators (e.g., different parental practices to minimize screen

177 time), either the composite score was calculated (see S1 Calculation) [38], or a total score
178 provided by the authors was used. Conceptually similar determinants were grouped for
179 analysis where possible.

180

181 For studies that reported multiple PAB/SB outcomes, the one that most reflected total daily
182 PAB/SB was used (e.g., habitual MVPA). Composite scores of SB were calculated for SB
183 outcomes that could be combined to reflect habitual SB (e.g., total daily screen time and total
184 daily computer use).

185

186 To account for the possible co-variance of individual scores within each composite score,
187 sensitivity analyses were conducted where different correlation coefficients were applied to
188 the formula by Borenstein (2011), to test if effect size might change substantially [38]. Where
189 results at multiple time points were recorded during an intervention, only results at post-
190 intervention were considered (pre-post effect). Additionally, if more than one time-point
191 follow-ups were reported, e.g., after three weeks, one month, and three months, the latest
192 time-point results were used to reflect a longer-term effect (pre-follow-up effect).

193

194 Standard mean difference and standard error for changes in determinants and PAB/SB
195 outcomes (from baseline to follow up) were calculated for each included study where
196 possible (see S1 Calculation for details). Individual studies were first inspected for
197 corresponding determinant and PAB/SB changes. For determinants and PAB/SB that could
198 be pooled for meta-analysis, Robust Bayesian meta-analysis (RoBMA) was conducted in
199 JASP 0.16.4 [39,40], which uses the RoBMA R package [41] and Markov Chain Monte Carlo
200 algorithms via JAGS [42]. We used only random-effects part of the RoBMA model ensemble
201 with the default prior distributions, resulting in 18 included models (detailed RoBMA

202 specification can be found in [43]). We used Bayes factor (BF_{01}) to measure evidence of the
203 absence of an effect over the presence of an effect. The same criteria were also applied to
204 publication bias assessment. While the Bayes factor is a continuous measure of strength of
205 evidence, we used the following rule of thumb to aid interpretation: $1 < BF_{01} < 3$ = weak
206 evidence (i.e., presence or absence of an effect cannot be ascertained), $3 < BF_{01} < 10$ =
207 moderate evidence, $BF_{01} > 10$ = strong evidence for the null [44]. When evidence for the
208 alternative was considered, the Bayes factor was simply inverted (e.g., $BF_{01} = \frac{1}{3} \rightarrow BF_{10} = 3$,
209 which implies weak evidence *for* an effect). Cohen's d with 95% credible interval (CI) was
210 also reported. Cohen's $d \geq 0.2$ (small effect), ≥ 0.5 (moderate effect), ≥ 0.8 (strong effect)
211 [45]. The degree of heterogeneity was assessed by the between-study standard deviation τ .
212 Studies that could not be included in the meta-analyses were reported narratively. For readers
213 unfamiliar with RoBMA, we supplemented the results of the corresponding indicators,
214 including effect size (95% CI), heterogeneity and publication bias, using classical frequentist
215 analysis with random effects meta-analysis and Vevea and Hedges (1995) selection model for
216 publication bias correction (see S1 Frequentist analysis) [46]. All intervention settings and
217 outcomes (PAB vs SB, and habitual vs non-habitual PAB were analysed separately. RCTs vs
218 CTs were also examined separately for the purpose of GRADE. The effect of interventions
219 on determinants was analysed regardless of their PAB or SB outcomes.

220

221 **Results**

222 **Study selection**

223 After removing duplicates, 27,581 studies were subject to title and abstract screening.

224 Screening resulted in 1,762 full texts to be assessed for eligibility. Out of the 184 eligible

225 studies, 15 were deemed relevant to the current review (self-report PAB/SB measurement
226 with children 5-12yrs) (Fig 1).

227
228 Fig 1. PRISMA flow diagram
229

230 **Study characteristics**

231 Table 1 shows the study characteristics and participant demographics of the 15 studies
232 included in this review (10 RCTs, five CTs), totalling 13,107 participants. The settings were
233 determined based on where the interventions were delivered. Four settings were identified
234 from this pool – school only, family only, school with family/home and community
235 with/without other settings (e.g., family/home, school). Interventions that took place in the
236 home environment but without involving parents explicitly, and those that targeted parental
237 involvement, were all classified as family/home setting. Thirty-seven distinct determinants
238 were identified – 25 were individual (psychological) determinants, seven were interpersonal
239 (psychological) determinants, two were individual (behavioural) determinants, another two
240 were interpersonal (behavioural) determinants and one was institutional determinant. Further
241 study characteristics and evidence synthesis for each setting are provided in Table 1. Effect
242 size and 95% CI for each determinant and PAB/SB outcome by settings can be found in S1
243 Appendix.

Table 1. Study characteristics based on settings

Study identifier	Country	Intervention descriptions	Intervention duration	Follow-up duration	Comparison group(s)	Theoretical basis	Study design	Sample characteristics at baseline	Type of PAB/SB and measurement	Determinant (measurement)	Determinant category based on socio-ecological model [16]
Boyle-Holmes, 2010 [47]	USA	PE curriculum focusing on motor skills progression. 51 lessons per grade, 2 days/week, 30mins/day	2 years	n/a	Control – Received usual PE curriculum	Not stated	CT	n=1,464 Age: 8-12y Mean age: 9.8 Sex: not reported	Habitual PA – Self-administered Physical Activity Checklist (SAPAS, Sallis et al., 1996)	Motor skill specific self-efficacy (performance measures, van Beurden et al., 2003)	Individual – psychological
										Perception of PA competence (Perceived Physical Activity Competence Scale, Harter, 1982)	Individual – psychological
Wang, 2017 [51]	China	A video game-based intervention to promote healthy eating and PA (Diab). Diab consists of 9 episodes, played in 2x40-min sessions or 1x90min sessions.	8-10 weeks	8-10 weeks	Control – Received general diet and PA information as usual	Social Cognitive Theory, Self-Determination Theory, Elaboration-Likelihood Model	CT	n=179 Age: 8-12y Sex: 42.5% girls	Habitual PA – PAQ-C at post-intervention* and follow-up* (Wang et al., 2016)	PA self-efficacy at post-intervention* (PA Self-Efficacy scale; Jago et al., 2009)	Individual – psychological
										PA motivation – autonomous and controlled motivation (SDT-based 16-item scale, Deci & Ryan, 2017)	Individual – psychological
										PA preferences (Self-Administered Physical Activity	Individual – psychological

										Checklist (SAPAC), Sallis et al., 1996)	
Gråsten, 2019 [48]	Finland	PE teachers were educated to provide a task-involving climate to promote PA in 26x90-120-min practical sessions over 2 years. School environment was also adapted to promote PA autonomy. All participants received 90mins of PE per week.	12 months	n/a	Control – Received national PE curriculum	Achievement Goal Theory, Social Ecological Model	CT	n=661 Age: 11-13y Mean age (sd): 12.14 (.31) Sex: 51% girls	Habitual PA - Health Behavior in School-aged Children Research Protocol (HBSC), (Currie et al., 2012)	PE enjoyment (Soini et al., 2006)	Individual – psychological
Gabriel, 2011 [49]	USA	A 12-week curriculum to promote PA and positive youth development, getting participants to engage in 5k runs (Girls on the Run)	12 weeks	5 months	Control – Received no intervention	Not stated	CT	n=877 Age: ≤9 - ≥11 Sex: 100% girls	Habitual PA – PAQ-C (Crocker et al., 1995)	Physical Activity commitment at follow-up** (Neilson, 1986)	Individual – psychological
Londsdale , 2019 [50]	Australia	A teacher professional learning intervention, delivered partially via the internet, designed to maximize opportunities for students to be active during PE lessons and enhance adolescents' motivation towards PE and PA	7-8 months	14-15 months	Control – Received no intervention	Self-Determination Theory	Clustered RCT	n=1,421 Mean age (sd): 12.93 (0.54) Sex: 43% girls	Leisure time MVPA – Adolescent Physical Activity Measures (Prochaska et al., 2001)	Motivation towards Leisure time Physical Activity – Amotivation, autonomous motivation, controlled motivation (Behavioral Regulation in Exercise Questionnaire; Markland & Tobin, 2004)	Individual – psychological

		(Activity and Motivation in Physical Education; AMPED)								Motivation towards PE – Amotivation, autonomous motivation, controlled motivation (Behavioral Regulation in Exercise Questionnaire; Markland & Tobin, 2004)	Individual – psychological
										Needs Satisfaction in PE – Autonomy need, competence need, relatedness need (multiple scales, Standage et al., 2003; McAuley et al., 1989; Richer & Vallerand, 1998)	Individual – psychological
										Student Perceptions of PE Teacher Behavior - Controlling behaviour at follow-up* (Controlling Coach Behaviors Scale, CCBS; Bartholomew et al., 2010) Student Perceptions of PE Teacher	Interpersonal – psychological

										Behavior - Supportive behaviour (Belmont et al., 1988)	
Maddison, 2014 [52]	New Zealand	Parents were provided with information (in face-to-face meeting, monthly newsletters and a dedicated website) regarding SB and how to reduce SB. Children also received an activity pack with alternatives to SB activities (SWITCH; Screen-Time Weight-loss Intervention Targeting Children at Home)	24 weeks	n/a	Control – Received no intervention	Social Cognitive Theory, Behavioural Economics Theory	RCT	n=251 Age: 9-12y Sex: 43% girls	SB – Total (min/day) PAB – MET/day (Multimedia Activity Recall for Children and Adolescents; MARCA) (Ridley et al., 2006)	Perceived enjoyment of SB (Salmon et al., 2003)	Individual – psychological
										Perceived enjoyment of PA Physical Activity Enjoyment Scale (Motl et al., 2001)	Individual – psychological
										Primary caregiver total PA – IPAC LF (Booth et al., 2003)	Interpersonal – behavioural
Pearce, 2019 [53]	Australia	School -based training on PA-related knowledge (benefits of PA, goal-setting and PA at home) (10x1hr), home-based activity booklet and parent workshops on healthy eating and PA.	10 weeks	10 weeks	Control – Received no intervention	Social Cognitive Theory	CT	n=147 Age: 9-13y Sex: 59% girls	Habitual PA - PAQ-C (Crocker et al., 1997)	Self-management at follow-up* (6 items Dishman et al., 2005)	Individual – psychological
										Perceived barriers to PA at post-intervention* (9 items Dishman et al., 2005)	Individual – psychological
										Outcome expectancy value of PA (9	Individual – psychological

										items, Dishman et al., 2010)	
										Enjoyment of PA (6 items, Motl et al., 2001)	Individual – psychological
										Self-efficacy (8 items, Dishman et al., 2002)	Individual – psychological
										Social support – home (Sallis et al., 2002)	Interpersonal – psychological
										School support -school at follow-up** (Sallis et al., 2002)	Interpersonal – psychological
Quaresma, 2014 [55]	Portugal	Health and weight educational program (PESSOA) with homework completed with parents to raise awareness of child's behaviour and its assessment.	52 weeks	n/a	Control – Received no intervention	Self-Determinati on Theory	Cluste red RCT	n=617 Mean age (sd): 10.42 (1.09)	Habitual PA – PAQ (Telama et al., 1997)	Peer support (Ommundsen et al., 2008)	Interpersonal – psychological
										Teacher support (Ommundsen et al.,2008)	Interpersonal – psychological
										Parental social support* (Ommundsen et al.,2008)	Interpersonal – psychological
										Parental encouragement (Ommundsen et al.,2008)	Interpersonal – psychological

										Amotivation (BREQ-2 Palmeira et al., 2007) External motivation* (BREQ-2 Palmeira et al., 2007) Introjected motivation (BREQ-2 Palmeira et al., 2007) Identified motivation (BREQ-2 Palmeira et al., 2007) Intrinsic motivation (BREQ-2 Palmeira et al., 2007)	Individual - psychological
Zhang, 2020 [56]	China	The intervention encompassed 5 theoretical courses on benefits of PA, disadvantages of SB and sport skills, plus 3 outdoor basketball matches (45mins/session, 1 session/week). Also involved parents to make exercise plans and log exercise every week.	8 weeks	n/a	Control – Received no intervention	Theory of Planned Behaviour, Social Cognitive Theory	RCT	n=51 Mean age (sd): 12 (0.3) Sex: 47.1% girls	Habitual PA - International Physical Activity Rating Scale (Craig et al., 2003)	Self-efficacy*** (no reference to theoretical constructs, not the validity of questionnaires, but offer alpha from current study)	Individual - psychological
										Outcome expectancy (no reference to theoretical constructs, not the validity of questionnaires, but offer alpha	Individual - psychological

										from current study)	
										Exercise Attitude (Francis et al., 2004)	Individual - psychological
										Subjective norm (Francis et al., 2004)	Interpersonal - psychological
										Perceived behavioural control (Francis et al., 2004)	Individual - psychological
										Exercise Intention*** (Francis et al., 2004)	Individual - psychological
Bergh, 2014 [54]	Norway	Intervention consisted of lessons on PA, screen and dietary behaviour at school. Tailored feedback was provided on how to change screen behaviour. Parents received fact sheet on parental regulation of screen behaviour.	20 months	n/a	Control – Received no intervention	Social Ecological Model, Social Cognitive Theory	Cluster RCT	n= 1,418 Mean age (sd): 11.2 (0.26) Sex: 40.4% girls	SB - Screen behaviour (TV and computer/electronic games use; hr/day) (no reference provided)	Perceived parental regulation TV-viewing (Hardy et al., 2006)	Interpersonal - psychological
										Perceived parental regulation computer/electronic games use (Hardy et al., 2006)	Interpersonal - psychological
Vik, 2016 [57]	Belgium, Germany, Greece, Hungary, Norway	Lessons at school on SB, goal setting to reduce SB and how to do it at home (45mins/week). Assignments to be completed at home or at school. Six newsletters to parents on personalized	6 weeks	n/a	Control – Received no intervention	Model of Planned Promotion for Population Health, Socio-Ecological Model	Cluster RCT	n=3,147 Age: 10-12y Mean age: 11.2y Sex: 51.2% girls	SB – Sedentary time (TV/DVD viewing, PC/Games console use; hr/day) (van Stralen et al., 2011, Singh et al., 2011)	Self-efficacy (van Stralen et al., 2011)	Individual - psychological
										Attitude (van Stralen et al., 2011)	Individual - psychological
										Preferences/liking (van Stralen et al., 2011)	Individual - psychological
										Automaticity (van Stralen et al., 2011)	Individual - psychological

		messages from children and homework tasks to be completed by the children, and sometimes with parents (UP4FUN, part of ENERGY).								Awareness (van Stralen et al.,2011)	Individual - psychological
										Knowledge (van Stralen et al.,2011)	Individual - psychological
										Parental practices (van Stralen et al.,2011)	Interpersonal - behavioural
										Parental modeling* (van Stralen et al.,2011)	Interpersonal - psychological
										Parental subjective norm (van Stralen et al.,2011)	Interpersonal - psychological
										Availability of TV/DVD/PC consoles (van Stralen et al., 2011)	Institutional
Salmon, 2010 [59]	Australia	The intervention consisted of 6 lessons (1 lesson/week) on PA and health, identifying TV viewing practice and alternative activities (Switch-2-Activity).	7 weeks	n/a	Control – Wait-list	Social Cognitive Theory, Behavioural Choice Theory	Clustered RCT	n= 957 Age: 9-12y Mean age (sd): 10.3 (0.62) Sex: 58% girls	SB – Screen-based entertainment (min/day) (Salmon et al., 2005) Habitual MVPA (min/dady) (Telford et al., 2004)	Self-efficacy in reducing SB and PA (Saunders et al., 1997) PA self-efficacy (Saunders et al., 1997)	Individual - psychological
										TV viewing style (Salmon et al., 2006)	Individual - behavioural
Moitra, 2021 [58]	India	The intervention comprised of weekly lessons on healthy eating and PA (50-60mins/week). To encourage engagement, a workbook and	12 weeks	n/a	Control – Received no intervention	Health Belief Model	Clustered RCT	n=498 Age: 10-12y Sex: 48.1% girls	Habitual MVPA* , habitual SB – Questionnaire psychometrics tested within the study, partially presented	PAB/SB-related knowledge **- Questionnaire psychometrics tested within the study, but not presented	Individual - psychological

		interactive educational materials were provided. Parents also attended 3 monthly sessions on healthy eating and PA, and how to incorporate small changes in their children's lifestyle (Health Eating and Activity Program for Schoolchildren, HEAPS).									
Setting – Community with or without other settings											
Branscum, 2013 [60]	USA	Using comic books to educate about PAB/SB in an after-school program. One lesson/week, 30mins/session (knowledge-based; Comics for Health)	4 weeks	3 months	Active control –theory-based covering SCT concepts	Social Cognitive Theory	RCT	n=71 Age: 8-11y Sex: 46.5% girls	Habitual PA (mins) Sedentary time (mins) at post-intervention* * (School PA and nutrition questionnaire) (Thiagarajah et al., 2008)	MVPA/SB self-efficacy - Promoting healthy lifestyles survey (Sharma et al., 2005)	Individual - psychological
										MVPA/SB expectations at follow-up* - Promoting healthy lifestyles survey (Sharma et al., 2005) (reliability questionable)	Individual - psychological
										MVPA/SB self-control - Promoting healthy lifestyles survey (Sharma et al., 2005) (reliability questionable)	Individual - psychological

Christiansen, 2014 [61]	Denmark	Active travel to school policies implemented, including encouraging parents to take active transport to schools, traffic education at school and advocating improvement of safety in the environment for active school transport (SPACE - for physical activity).	2 years	n/a	Control – Received no intervention	Not stated	Cluster RCT	n=1,348 Mean age (sd): 12.6 (0.63) Sex: 49% girls	Transportation PA - % Active trips to school (Toftager et al., 2011) (unspecific about psychometric properties)	Parents encourage cycling to school (Toftager et al., 2011) (unspecific about psychometric properties)	Interpersonal - psychological
										Perceived safe route to school (Toftager et al., 2011) (unspecific about psychometric properties)	Individual - psychological
										Positive attitude towards bicycling (no reference on instrument used; psychometrics unknown)	Individual - psychological

Note: Under ‘type of PAB/SB and measurement’ and ‘determinant’ columns – text in **bold** denotes an intervention effect: small intervention effect ($d \geq 0.2 < 0.5$)*, moderate effect ($d \geq 0.5 < 0.8$)** and strong effect ($d \geq 0.8$)*** based on Cohen’s *d*.

247 **(I) School setting**

248 Five studies – one RCT and four CTs – with sample sizes ranging from 179 to 1,464 were
249 identified. Intervention duration ranged from eight weeks to two years, and follow-up periods
250 from the end of the interventions ranged from eight weeks to 15 months. Four interventions
251 targeted changes in PE curricula and/or PE teacher training [47-50], and one intervention
252 implemented a video game-based program at schools [48]. Three interventions were theory
253 informed [48,50,51]. Four studies measured habitual PA [47-49,51], and one study measured
254 leisure time PA [50], using validated instruments (see Table 1).

255

256 **Study outcomes - PAB/SB and determinants**

257 RCT

258 Six conceptually different determinants were targeted in the RCT, of which four belonged to
259 the individual (psychological) category and two belonged to the interpersonal (psychological
260 category) [50]. The psychometric properties of all determinant measurements were
261 referenced (Table 1). There was no significant change in determinants at immediate post-
262 intervention and at follow-up (d 's ranged from -0.17 to 0.28), except a small effect on
263 students' perception of teachers' controlling behaviour at follow-up ($d=0.25$, 95% CI 0.12 to
264 0.37), indicating teacher's behaviour was perceived to be more controlling which is against
265 what the intervention aimed to achieve. Additionally, there was non-significant effect on
266 PAB ($d = -0.02$)

267

268 CTs

269 Five distinct individual (psychological) determinants were targeted in all four studies. The
270 psychometric properties of all determinant measurements were referenced (see Table 1). Only
271 self-efficacy from one study showed a small effect at post-intervention ($d = 0.40$; 95% CI

272 0.09 to 0.73) [51], however, when it was pooled in a meta-analysis with another study [44],
 273 there was moderate evidence against an effect on self-efficacy (Table 2; Fig 2a). Narratively,
 274 there was moderate intervention effect on commitment to PA ($d = 0.68$; 95% CI 0.50 to 0.87)
 275 [49]. However, none of the determinants that could only be analysed narratively reported
 276 notable intervention effect (d 's ranged from -0.17 to 0.28 ; for determinants that showed small
 277 effects, the 95% CI's crossed the estimate threshold).

278 Table 2. Results of the meta-analyses under the school setting and the corresponding
 279 heterogeneity and publication bias assessments. The effect size estimates for meta-analyses
 280 and heterogeneity are expressed in d (95%CI) and τ respectively.

	Effect size estimates	BF ₀₁	
Self-efficacy for PAB (2 CTs) (Fig 2a)	0.08 (-0.39, 0.40)	4.85*	281
Heterogeneity (τ)	0.15 (0.04, 0.45)	-	282
Publication bias	-	0.48	283
PAB (4 CTs) (pre-post) (Fig 2b)	0.00 (-0.41, 0.23)	8.08*	284
Heterogeneity (τ)	0.12 (0.03, 0.29)	-	285
Publication bias	-	0.46	286
PAB (2 CTs) (pre-follow up) (Fig 2c)	0.15 (-0.39, 0.60)	2.91	287
Heterogeneity (τ)	0.21 (0.04, 0.73)	-	288
Publication bias	-	0.63	289
			290
			291

292 Note: *denotes moderate evidence, **denotes strong evidence for absence of an effect/
 293 publication bias.

294
 295 Fig 2. Forest plots depicting intervention effect on (a) self-efficacy, (b) overall PAB pre-
 296 /post- effect and (c) overall PAB pre-/follow-up effect in CTs under school setting.
 297

298 For the individual study that showed a small effect on self-efficacy at post intervention, there
 299 was a corresponding small effect on PAB at the same time point [51]. For the study that
 300 measured commitment to PA, there was no corresponding effect on PAB. When all CTs were
 301 pooled for meta-analysis, there was moderate evidence against an effect on PAB at post-
 302 intervention (Fig 2b), however, there was insufficient evidence to suggest presence or
 303 absence of an effect on PAB at follow-up, or publication bias (Table 2; Fig 2c).

304 Heterogeneity for all meta-analyses seem small, but due to limited number of studies in each
 305 meta-analysis, the degree of heterogeneity is highly uncertain.

306

307 **Quality assessment**

308 For the four CTs, they were all deemed high risk of bias overall. Notable contributors to the
309 judgement were three domains - domain 1 (bias due to confounding), domains 6 and 7 (bias
310 due to measurement of outcomes – PAB/SB and determinants respectively). Judgement for
311 domain 1 primarily stemmed from the fact that not all pre-defined confounders were
312 accounted for in all studies, while judgement for domains 6 and 7 was because participants
313 were unlikely to be blinded in most interventions involving self-report measurements
314 (PAB/SB and determinants) (Fig 3a). Nonetheless, the one RCT in this setting explicitly
315 mentioned blinding of the participants and researchers (Fig 3b) [50].

316

317 Fig 3. Risk of bias assessments of CTs using (a) Robins-I and risk of bias assessments of the
318 RCT using (b) RoB2.0 in school setting.

319

320 **Certainty of evidence and intervention effect**

321 We conducted GRADE for the meta-analysis of self-efficacy in two CTs (Table 3a) [47,51],
322 and the meta-analysis with PAB as an outcome in four CTs at post-intervention [47-
323 49,51]and the two CTs at follow-up [49,51] (Table 3b). The certainty of evidence was high
324 for the absence of intervention effect on PAB at post-intervention, whereas for the other two
325 meta-analyses, the certainty of evidence was deemed low mainly due to imprecision of effect
326 estimate.

Table 3a. Overview of quality of evidence (GRADE) and intervention effect on self-efficacy for two CTs in school setting.

Certainty assessment								№ of participants at baseline		Intervention effect (<i>d</i> , 95%CI) Heterogeneity (τ)	Certainty	Importance
№ of studies	Authors, year	Study design	(1)	(2)	(3)	(4)	(5)	Intervention	No intervention			
Outcome: Self-efficacy (intervention duration: 8 weeks to 64 weeks)												
2	Boyle-Holmes et al. (2010)[47] Wang et al. (2017)[51]	Controlled trials	NS	NS	NS	VS ^A	none	855	788	<i>d</i> = 0.07; 95%CI = -0.36, 0.39 τ - CBD	⊕⊕○○ Low	IMPORTANT

Table 3b. Overview of quality of evidence (GRADE) and intervention effect on physical activity for 4 CTs in school setting.

Certainty assessment								№ of participants at baseline		Intervention effect (<i>d</i> , 95%CI) Heterogeneity (τ)	Certainty	Importance
№ of studies	Authors, year	Study design	(1)	(2)	(3)	(4)	(5)	Intervention	No intervention			
Outcome: Physical Activity (intervention duration: 8 weeks to 64 weeks)												
4	Boyle-Holmes et al. (2010)[47] Gabriel et al. (2011)[49] Grasten & Yli-Piipari (2019)[48] Wang et al. (2017)[51]	Controlled trials	NS	NS	NS	NS	none	1,407	1,774	<i>d</i> = 0.00; 95%CI = -0.41, 0.23 τ - CBD	⊕⊕⊕⊕ High	CRITICAL
Outcome: Physical Activity (follow-up: 10 weeks to 5 months)												
2	Gabriel et al. (2011)[49] Wang et al. (2017)[51]	Controlled trials	NS	NS	NS	VS ^A	none	685	371	<i>d</i> = 0.15; 95%CI = -0.39, 0.60 τ - CBD	⊕⊕○○ Low	IMPORTANT

Note:

As three risk of bias domains for CTs (bias due to confounding and outcome measurement bias) and two domains for RCTs (outcome measurement bias) are almost inevitable in the nature of the interventions conducted, it was decided that they should be treated more leniently in GRADE; (1) = risk of bias, (2) = inconsistency, (3) = indirectness, (4) = imprecision, (5) = other considerations; *d* = Cohen's *d*, 95%CI = 95% confidence interval; CBD = Cannot be determined as there is little evidence of presence or absence of heterogeneity; NS = Not serious; VS^A = very serious concern with a relatively wide 95%CI.

326 **(II) Family/home setting**

327 Only one intervention was conducted in the family/home setting (see Table 1) [52]. It was a
328 theory-based 24-week RCT with no follow-up assessment, and both habitual PAB and SB
329 were examined (n=251). Three determinants were measured using validated instruments –
330 two belonged to individual (psychological) and one belonged to interpersonal (behavioural)
331 categories. No significant intervention effects were reported for all outcomes (*d*'s ranged
332 from -0.17 to 0.10). The risk of bias was deemed high due to bias in the measurement of
333 outcomes (domain 4 and 5 – PAB/SB and determinants respectively) (Fig 4).

334
335 Fig 4. Risk of bias assessment of an RCT using RoB2.0 in family/home setting
336

337 **(III) School with family/home settings**

338 We identified seven studies of which one was a CT [53], and all interventions were theory-
339 informed (see Table 1). Sample sizes ranged from 51 to 3,147. Intervention period ranged
340 from six weeks to 20 months, and only 1 study included follow-up (10 weeks post-
341 intervention) [53]. Four interventions indirectly involved parents in the form of homework
342 completion with children or remote knowledge provision [54-57], two interventions actively
343 involved parents in workshops or information sessions [53,58], and one intervention relied on
344 children adhering to the home intervention [59]. Habitual PAB [53,55,56] and habitual
345 MVPA [53] were measured in the respective studies, and SB was measured in four studies
346 [54,57,58,59].

347

348 **Study outcomes - PAB/SB and determinants**

349 RCTs

350 Twenty-three conceptually different determinants were targeted in these interventions (see
 351 Table 1). Fifteen determinants belonged to the individual (psychological) category, one
 352 belongs to individual (behavioural) category, five belonged to the interpersonal
 353 (psychological) category, one belongs to the interpersonal (behavioural) category and one
 354 belonged to the institutional category.

355

356 Out of all RCTs, determinants that showed positive effects were – i) parental support
 357 ($d=0.24$, 95%CI (0.09, 0.40)) [52], external motivation ($d = -0.23$, 95%CI -0.38 to -0.07) [55]
 358 and parental modelling on SB ($d=0.25$, 95%CI 0.18 to 0.32) [57] – small effect; ii)
 359 knowledge ($d=0.50$, 95%CI 0.31 to 0.68) [58] – moderate effect, and iii) self-efficacy
 360 ($d=0.90$, 95%CI (0.31, 1.57)) and exercise intention ($d=0.87$, 95%CI 0.30 to 1.45) [56] –
 361 strong effect (Table 1). Other determinants showed non-significant intervention effect (d 's
 362 ranged from -0.44 to 0.52; for determinants that showed small to moderate effects, the 95%
 363 CI's crossed the estimate threshold) [54-59].

364

365 Five determinants were targeted in more than one study – self-efficacy [56,57,59], attitude
 366 [56,57], subjective norm [56,57], knowledge [56,58] and parental practice in SB regulation
 367 [54,57], hence we conducted a meta-analysis for each (Fig 5a-5e). Results of meta-analyses
 368 showed moderate evidence against an effect on self-efficacy, attitude, subjective norm and
 369 parental practice (Table 4). There is moderate evidence of presence of publication bias for the
 370 meta-analysis on self-efficacy ($BF_{10}=5.88$). Evidence for presence or absence of an effect on
 371 knowledge and publication bias for other meta-analyses cannot be determined.

372 Table 4. Results of the meta-analyses under the school with family/home setting, with the
 373 corresponding heterogeneity and publication bias assessments. The effect size estimates for
 374 meta-analyses and heterogeneity are expressed in d (95%CI) and τ respectively.

	Effect size estimates	BF_{01}
--	-----------------------	-----------

Self-efficacy for PAB/SB (3 RCTs) (Fig 5a)	0.05 (-0.31, 0.52)	7.63*	375 376
Heterogeneity	0.15 (0.03, 0.56)	-	377
Publication bias	-	0.17*	378
Attitude for PAB/SB (2 RCTs) (Fig 5b)	0.04 (-0.41, 0.49)	7.46*	379 380
Heterogeneity	0.14 (0.03, 0.47)	-	381
Publication bias	-	1.12	382
Subjective norm for PAB/SB (2 RCTs) (Fig 5c)	0.04 (-0.04, 0.57)	7.63*	383 384
Heterogeneity	0.15 (0.03, 0.56)	-	385
Publication bias	-	0.99	386
Knowledge for SB (2 RCTs) (Fig 5d)	0.16 (-0.05, 0.78)	2.89	387
Heterogeneity	0.32 (0.05, 1.01)	-	388
Publication bias	-	0.64	389
Parental practice for SB (2 RCTs) (Fig 5e)	-0.06 (-0.43, 0.32)	7.67*	390 391
Heterogeneity	0.14 (0.06, 0.46)	-	392
Publication bias	-	1.79	393
PAB (4 RCTs) (pre-/post) (Fig 5f)	0.10 (-0.29, 0.36)	3.70*	394 395
Heterogeneity	0.14 (0.04, 0.38)	-	396
Publication bias	-	0.13*	397
SB (4 RCTs) (pre-/post)(Fig 5g)	0.00 (-0.14, 0.13)	19.67**	
Heterogeneity	0.08 (0.03, 0.19)	-	
Publication bias	-	1.98	

Note:

398 *denotes moderate evidence, **denotes strong evidence for absence of an
399 effect/heterogeneity/publication bias.

400

401 Fig 5. Intervention effects on (a) self-efficacy in studies targeting PAB and/or SB; (b) attitude
402 in studies targeting PAB and/or SB; (c) subjective norm in studies targeting PAB and/or SB;
403 (d) knowledge in studies targeting SB; (e) parental practice in SB regulation in studies
404 targeting SB; (f) PAB at post-intervention; (g) SB at post-intervention, in RCTs under school
405 and family/home settings.

406

407 For intervention effect on PAB/SB, meta-analyses showed moderate evidence against an
408 effect on PAB (Fig 5f) and strong evidence against an effect on SB (Fig 5g). There was
409 moderate evidence for publication bias for PAB ($BF_{10}=7.69$). In one study included in the
410 meta-analysis for PAB and for knowledge [58], moderate effect on knowledge (the only
411 determinant measured) and small effect on PAB ($d=0.30$, 95%CI 0.12 to 0.48) [58] was
412 found, however, the psychometrics of knowledge measurement was not referenced.
413 Therefore, despite that some interventions showed promise on narratively analysed

414 determinants (i.e., external motivation [55], exercise intention [56], and parental modelling
415 [57]), corresponding change on the pooled PAB/SB effect is not evident. Again, the
416 magnitude of heterogeneity of all meta-analyses appeared small, but this remains
417 inconclusive due to small number of studies in each meta-analysis (Table 4). Together with
418 other results that did not see any corresponding changes in determinants and PAB/SB, we
419 could only suggest that associations between these determinants and PAB/SB were possible,
420 and that the interventions had not been successful in changing either.

421

422 CT

423 The only CT under this setting showed small effect on perceived barriers to PA ($d=0.43$,
424 95% CI 0.06 to 0.80) at post-intervention and self-management ($d=0.43$, 95% CI (0.06, 0.81))
425 at follow-up. There was a moderate effect on social support from schools at follow-up
426 ($d=0.53$, 95% CI 0.16 to 0.91). However, PAB notably decreased at post-intervention ($d = -$
427 0.51, 95% CI -0.88 to -0.13) and there was negligible intervention effect on PAB at follow-up
428 ($d=0.00$) [53].

429

430 **Quality assessment**

431 All studies are deemed high risk of bias, mainly due to bias in the measurement of outcomes
432 (PAB/SB and determinants) (Fig 6).

433

434 Figure 6. Risk of bias assessments of (a) RCTs and (b) CT in school with family/home
435 settings.

436

437 **Certainty of evidence and intervention effect**

438 We conducted GRADE for the seven meta-analyses on self-efficacy, attitude, subjective
439 norm, knowledge, parental practice, PAB and SB (all RCTs; Table 5a-5b). The certainty of

440 evidence was downgraded to low or very low for all meta-analyses due to risk of bias and/or
441 imprecision.

442 Table 5a. Overview of quality of evidence (GRADE) and intervention effect on self-efficacy, attitude, subjective norm, knowledge and parental
 443 practice for RCTs in school with family/home setting.
 444

Certainty assessment							№ of participants at baseline		Intervention effect (<i>d</i> , 95%CI) Heterogeneity (τ)	Certainty	Importance	
№ of studies	Authors, year	Study design	(1)	(2)	(3)	(4)	(5)	Intervention				No intervention
Outcome: Self-efficacy of physical activity/sedentary behaviour (intervention duration: 8 weeks to 64 weeks)												
3	Salmon et al. (2011)[59] Vik et al. (2015)[57] Zhang et al. (2020)[56]	Randomised controlled trials	S ^A	NS	NS	VS ^A	none	2,154	2,179	<i>d</i> = 0.04; 95%CI = -0.29, 0.44 τ - CBD	⊕○○○ Very low	CRITICAL
Outcome: Attitude towards physical activity/sedentary behaviour (intervention duration: 6 weeks to 8 weeks)												
2	Vik et al. (2015)[57] Zhang et al. (2020)[56]	Randomised controlled trials	NS	NS	NS	VS ^A	none	1,687	1,689	<i>d</i> = 0.04; 95%CI = -0.41, 0.49 τ - CBD	⊕⊕○○ Low	CRITICAL
Outcome: Subjective norm towards physical activity/sedentary behaviour (intervention duration: 6 weeks to 8 weeks)												
2	Vik et al. (2015)[57] Zhang et al. (2020)[56]	Randomised controlled trials	NS	NS	NS	VS ^A	none	1,687	1,689	<i>d</i> = 0.16; 95%CI = -0.52, 0.78 τ - 5.35 (based on BF ₀₁)	⊕⊕○○ Low	CRITICAL
Outcome: Knowledge on sedentary behaviour (intervention duration: 6 weeks to 12 weeks)												
2	Vik et al. (2015)[57] Moitra et al. (2021)[58]	Randomised controlled trials	NS	VS ^B	NS	VS ^A	none	1,955	1,868	<i>d</i> = 0.04; 95%CI = -0.47, 0.57 τ - CBD	⊕○○○ Very low	CRITICAL
Outcome: Parental practice on sedentary behaviour (intervention duration: 6 weeks to 80 weeks)												
2	Vik et al. (2015)[57] Bergh et al. (2014)[54]	Randomised controlled trials	S ^B	S ^C	NS	VS ^A	none	2,172	2,571	<i>d</i> = -0.06; 95%CI = -0.43, 0.32 τ - CBD	⊕○○○ Very low	CRITICAL

445
 446 Table 5b. Overview of quality of evidence (GRADE) and intervention effect on physical activity and sedentary behaviour in school with
 447 family/home setting.
 448

Certainty assessment							№ of participants at baseline		Intervention effect (<i>d</i> , 95%CI) Heterogeneity (τ)	Certainty	Importance	
№ of studies	Authors, year	Study design	(1)	(2)	(3)	(4)	(5)	Intervention				No intervention
Outcome: Self-efficacy of physical activity/sedentary behaviour (intervention duration: range 8 weeks to 64 weeks)												
4	Salmon et al. (2011) Quaresma et al. (2014) Zhang et al. (2020) Moitra et al. (2021)	Randomised controlled trials	S ^B	NS	NS	S ^D	none	1,199	924	<i>d</i> = -0.10; 95%CI = -0.29, 0.36 τ - CBD	⊕○○○ Very low	CRITICAL
Outcome: Sedentary behaviour (intervention duration: range 6 weeks to 80 weeks)												
4	Salmon et al. (2011) Bergh et al. (2014) Vik et al. (2015) Moitra et al. (2021)	Randomised controlled trials	S ^B	NS	NS	S ^D	none	2,931	3,267	<i>d</i> = 0.00; 95%CI = -0.14, 0.13 τ - 11.49 (based on BF ₀₁)	⊕⊕○○ Low	CRITICAL

449

450

Note:

451

As three risk of bias domains for CTs (bias due to confounding and outcome measurement bias) and two domains for RCTs (outcome measurement bias) are almost inevitable in the nature of the interventions conducted, it was decided that they should be treated more leniently in GRADE; (1) = risk of bias, (2) = inconsistency, (3) = indirectness, (4) = imprecision, (5) = other considerations; *d* = Cohen's *d*, 95%CI = 95% confidence interval; CBD = Cannot be determined as there is little evidence of presence or absence of heterogeneity; NS = Not serious; S^A = High risk of bias in randomisation, deviation from intended intervention, bias in reporting in three studies, and moderate evidence of the presence of publication bias; S^B = A combination of some concerns and high risks in a few domains in the risk of bias assessment; S^C = Marginal overlap of 95%CI (not including point estimates); S^D = Imprecision mainly comes from one study with lowest weight, 95%CI of overall estimate includes small to moderate effects in both directions; S^E = Relatively long tails of CI; Estimates of two studies closer to 0.0, estimates of the other two studies are on either side further away from 0.0 VS^A = point estimate is near 0, but 95%CI of overall effect includes small to moderate effect in both directions; VS^B = no overlap in 95%CI and very different estimates.

461

462

463 **(IV) Community with/without other settings**

464 Two RCTs were identified (see Table 1). One intervention was conducted in a community
465 setting only with an active control group [60], and one was in the community with
466 family/home and school setting (where parents were indirectly involved in the intervention
467 and active policy/environmental adaptation was in place) [61]. Sample sizes ranged from 71
468 to 1,348. Interventions lasted from four weeks to two years, and follow-up periods ranged
469 from three to six months. Only one intervention was theory-informed [60]. One study
470 measured habitual PAB and SB [60] and one targeted transportation PA [61], only the former
471 measurement instruments was referenced.

472

473 **Study outcomes - determinants and PAB/SB**

474 Within the two studies, six determinants were targeted – five were individual (psychological)
475 and the other one was interpersonal (psychological). The measurements, and measurement
476 properties, of three determinants within one study were unspecific [56] (see Table 1).

477

478 Due to difference in the type of PAB/SB measured [60,62], PAB/SB outcomes can only be
479 analysed descriptively. The community-based intervention showed a moderate post-
480 intervention effect on SB ($d = -0.74$, 95%CI -1.22 to -0.26), with trivial effects on all
481 determinants (d 's ranged from 0.18-0.33; for determinants that showed small effects, the
482 95%CI's crossed the threshold). However, the small effect on MVPA/SB expectations at
483 follow-up ($d = 0.39$, 95%CI 0.04 to 0.75) did not see any changes to PAB or SB [60]. For the
484 other study, there were only trivial effects for perceived safe route to school, parental
485 encouragement for cycling to school, attitude towards cycling and % active trips to school
486 (d 's ranged from -0.14 to 0.14) [61].

487

488 **Quality assessment**

489 Similar to other studies included in this review, the main reason for the overall high-risk
490 decision on study bias was due to measurement bias [61]. However, the study with an active
491 control group could contribute to blinding of participants, as such, the study was deemed low
492 risk (Fig. 7).

493 Fig 7. Risk of bias assessment of studies that conducted RCTs in a community setting alone
494 or with other settings (family/home and/or school).
495

496 **Sensitivity analyses**

497 Sensitivity analyses were performed for studies that required estimations of composite scores.
498 No difference in the effect sizes was detected when r was set at 0.2, 0.5 and 0.8.
499

500 **Discussion**

501 The main aims of this review were to identify modifiable determinants that have been
502 targeted in interventions that followed the RCT/CT designs and to assess their association
503 with self-report PAB/SB in children in different settings. To our knowledge, it is the first
504 study to apply Robust Bayesian meta-analyses to examine the effects of interventions on
505 modifiable determinants, and to infer the associations between the determinants and PAB/SB
506 where possible. Out of the 37 distinct determinants targeted across all settings, 68% were
507 individual (psychological) determinants, 5% were individual (behavioural) determinants,
508 20% were interpersonal (psychological) determinants, 5% were interpersonal (behavioural)
509 determinants and there was only one institutional determinant. Common determinants across
510 settings were self-efficacy, family support, school support, peer support, motivation based on
511 self-determination theory, PA enjoyment, caregivers' PA, perceived competence and attitude.
512 Of all determinants, only six can be pooled for meta-analyses by settings. PA/SB self-

513 efficacy was targeted in the *school* setting (CTs) and *school with family/home* setting (RCTs),
514 and there was moderate evidence *against* an intervention effect. Attitude, subjective norm
515 and parental practice under *school with family/home* setting (RCTs) also showed moderate
516 evidence *against* an effect, while the strength of evidence for knowledge cannot be
517 determined. This is surprising as some of these determinants have been widely targeted in
518 PAB/SB interventions [17,19,24].

519

520 Regarding PAB/SB, results of the meta-analyses showed moderate evidence of absence of
521 post-intervention effect on PAB (CTs) in the *school setting* and moderate-strong evidence
522 *against* post-intervention effect on PAB and SB (RCTs) in the *school with family/home*
523 *setting*. The certainty of evidence was either low or very low, except for the absence of
524 intervention effect on PAB in the *school* setting (high certainty). Taken together, the lack of
525 intervention effects on the modifiable determinants might have contributed to unsuccessful
526 PAB/SB change in children.

527

528 Considering all studies that showed no corresponding changes between determinants and
529 PAB/SB, we could only conclude that associations between these determinants and PAB/SB
530 were possible, as no change in determinants would not lead to any change in PAB/SB given
531 the assumed association between the targeted determinants and PAB/SB [13]. However,
532 concrete evidence of the associations was not found (i.e. moderate-large effect sizes on both
533 determinants and PAB/SB). Interestingly, we found changes in some determinants but
534 corresponding positive changes in PAB/SB were not evident, namely, perceived barriers to
535 PA at post-intervention [53], self-management and school support at follow-up [53], parental
536 social support [55], external motivation [55], exercise intention [55] and parental modeling
537 in SB [57] (under school and family/home settings) as well as MVPA/SB expectations at

538 follow-up [60] (under community setting). Future research should carefully consider if and
539 how these determinants should be targeted in interventions.

540

541 The majority of interventions in the current review were theory-based - as advocated by
542 behaviour change researchers [62] - common theories used being the self-determination
543 theory, goal achievement theory, social cognitive theory and theory of planned behaviour.
544 However, the intervention effect on determinants and PAB/SB was not significant across
545 settings, despite that most determinants and PAB/SB measurements were evidenced to be
546 psychometrically sound. In fact, our results echoed previous findings on the weak association
547 between some self-determination theory tenets and PAB in the youth population [63].

548 However, contrary to the results of a recent umbrella reviews of PAB/SB interventions in
549 children, we did not find family support to be associated with behaviour change [64], nor
550 intention or self-efficacy from earlier reviews [26,27]. Nonetheless, direct comparisons with
551 existing systematic reviews should be cautioned, as the inclusion criteria of different reviews
552 and the analytic strategies are likely to differ. Additionally, the efficacy of theory-based PAB
553 interventions could be compromised by the methodological weakness of the included studies
554 [65], which is potentially applicable to the current review. Whilst every included study
555 inevitably has its limitations, crucially, our results highlighted a bigger picture problem on
556 how the physical inactivity problem is understood, whether it is an individual-level or a
557 population-level issue. Two main factors may have contributed to the failure in changing the
558 determinants and/or (associated) PAB/SB. First and foremost, behaviour change theories that
559 advocate individual-level change solely (including in the context of interpersonal
560 determinants) have long been criticized for their overestimation of people's self-regulatory
561 ability [66]. Through these theories, individual and interpersonal determinants are derived. A
562 study of Cochrane reviews, from 1993 to 2019, investigating the effect of RCTs on obesity in

563 the youth population shows that consistently, about 57% of interventions target individual
564 and interpersonal determinants only [67]. However, over-reliance on individual agency may
565 have led to failure of policies in tackling the obesity crisis [68] and exacerbated health
566 inequity [69]. This also begs the question – are these determinants as modifiable, or as
567 effective in changing PAB/SB as researchers thought? [14,15] Perhaps changes in policy and
568 the environment will facilitate change in individual and interpersonal determinants, which
569 will in turn enact the desired behaviour [22]. Such consideration is imperative as different
570 geographical regions have their own PA policies and environmental concerns in place which
571 are likely to affect population-level PAB/SB differently. While there is growing emphasis on
572 targeting policy and environmental determinants through understanding the interactions
573 between actors and determinants within a system (e.g. priority of education policy; a systems-
574 based approach), their changes are challenging to quantify [70]. Nonetheless, realist synthesis
575 can help address the mechanistic associations between the determinants, and enhance our
576 understanding of what works for who, how and in what context [71]. The spirit of realist
577 synthesis can also contain the common problem with heterogeneity in PAB/SB interventions
578 [8,72]. As such, researchers and public health practitioners should involve stakeholders in
579 developing intervention content specific to a setting that is unique to their needs and
580 political/physical environment [73]. While the systems-based approach might compromise
581 the internal validity of uniform individual-centered interventions, the resulting interventions
582 might see a higher level of buy-in, adherence and ultimately, effectiveness [74].

583

584 Another potential explanation for the largely ineffective interventions could be due to an
585 oversight in relatively unconscious motivation that hinders behaviour change [75]. Based on
586 the COM-B model that encapsulates the main ingredients for successful behaviour change
587 [62], all interventions included in this review have targeted individuals' psychological and/or

588 physical capability (C), have provided social and/or physical opportunities (O), and reflective
589 motivation (M) (referring to the individual/interpersonal psychological determinants), but
590 arguably, automatic motivation to disengage from behaviour change is overlooked. Important
591 to note is that PAB/SB interventions target inactive individuals who are likely to favour being
592 sedentary over being active at a behavioural level [75]. However, PAB promotion seldom
593 considers such inherent resistance to behaviour change [76]. Currently, research into this dual
594 process in behaviour change is largely experimental, so the need for this area of research to
595 be incorporated in applied settings is urgently called for [13]. Not only will such effort
596 benefit intervention design, but also health messaging in the promotion of PAB.

597

598 Some limitations of the current review warrant attention. First, this review was based on self-
599 report PAB/SB which is subject to various types of bias, including but not limited to social
600 desirability and recall bias, based on the PAB/SB tools used in the included studies [77].
601 However, this is not to say that self-reports are inferior to device-based measurements when
602 its usage is fit for purpose [78]. Additionally, the small number of studies included in all
603 meta-analyses makes it challenging to determine the degree of heterogeneity and publication
604 bias, despite that RoBMA was conceptualized to offset the lack of power [43]. Nevertheless,
605 if followed the frequentist approach, publication bias should only be assessed when there are
606 10 or more studies in a meta-analysis , which all our meta-analyses fall short on [79].
607 Besides, adopting the Bayesian approach to meta-analysis has benefited our interpretation of
608 the findings, as it can indicate the strength of evidence of the likelihood of the presence or
609 absence of an effect, unlike the all-or-nothing interpretation from the frequentist approach
610 [44]. Another issue with a small study number within a meta-analysis might have contributed
611 to imprecision in the GRADE process even though the total sample is relatively sizable. This
612 has inevitably impacted our assessment of the certainty of evidence. Regarding the risk of

613 bias assessment, as blinding of participants is inherently challenging, if not impossible, due to
614 ethical considerations, the relevant domains related to outcome assessment were deemed
615 ‘high risk’ for all studies. We have thus examined all domains in the risk of bias assessment
616 in the GRADE process instead of relying on the overall risk. Future interventions should
617 consider including an active control group, so that the status of the intervention group can be
618 more easily masked, and any efforts in blinding participants should be made more explicitly
619 clear. Importantly, due to the lack of mediation analyses in the included studies, the
620 association between the determinants and PAB/SB could only be inferred. Whilst the call for
621 mediation analysis to examine the causal pathways was made more than a decade ago [80],
622 many interventions still do not adopt this analytic approach. A potential reason could be the
623 sheer number of determinants (some more modifiable than others) included in some
624 interventions hinder meaningful mediation analyses [81]. For example, in one of the included
625 studies, there are altogether 44 determinants for PAB/SB, and some of these determinants are
626 conceptually similar (e.g., both determinants ‘parents let child watch TV’ and ‘parents
627 remind child about rules’ can fall under one umbrella determinant ‘parental practice on
628 SB’)[57]. Additionally, contradictory evidence exists in the association between determinants
629 and PAB/SB, and researchers ought to monitor their unconscious bias in selecting the
630 determinants to intervene. Without a clearer understanding of the context through which
631 determinants operate and interact with each other, incorporating even evidence-based
632 determinants into an intervention would not guarantee intervention success. Lastly, due to the
633 restrictions of our eligibility criteria, interventions that implemented policy/environment
634 change (as determinants themselves), but without quantifying the magnitude of change, had
635 been excluded from the review. However, these interventions may provide valuable
636 qualitative information regarding the interactions between different levels of determinants
637 within the socio-ecological model. Future research should also review interventions and real-

638 life public health initiatives that targeted policy and environmental change, to examine the
639 extent to which they can effectively modify individual and interpersonal determinants.

640

641 **Conclusion**

642 The current systematic review set out to examine modifiable determinants in interventions
643 following the RCT and CT design that target children and their association with self-report
644 PAB/SB in different settings. However, the lack in intervention effect on determinants and
645 the corresponding PAB/SB in all settings led us to conclude that the associations between any
646 modifiable determinants and PAB/SB remain uncertain. Specifically, almost all modifiable
647 determinants identified belonged to individual or interpersonal categories according to the
648 socio-ecological model. None of the meta-analyses showed evidence for the presence of
649 intervention effect on the determinants and PAB/SB. These results made us question the
650 modifiability of individual and interpersonal determinants in different settings, and whether
651 they would be more modifiable if policy and/or environment conducive to PAB/SB change
652 were in place. Additionally, for determinants that have seen an intervention effect, but
653 without corresponding changes in PAB/SB, if and how they should be targeted in future
654 interventions should be carefully considered. Crucially, to accelerate our understanding of
655 what determinants might work for who and how, and in what settings, realist synthesis should
656 be conducted in order to inform the design of interventions, and interventions should adopt a
657 system-based approach. With more careful consideration of determinants to target in
658 interventions, conducting mediation analysis between determinants and PAB/SB could
659 provide a clearer picture of their causal pathways. Lastly, design of interventions for children
660 should also consider the automatic motivation that hinders behaviour change.

661

662 **Supporting information**

- 663 S1 Checklist. PRISMA Checklist.
- 664 S1 Calculation. Effect size and composite score calculation.
- 665 S1 Frequentist Analysis. Frequentist approach to the meta-analyses.
- 666 S1 Appendix. Effect sizes and CIs for all outcomes.
- 667

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