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Systematic review of acute physically active learning and classroom movement breaks on children's physical activity, cognition, academic performance and classroom behaviour: understanding critical design features

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ABSTRACT

Objective To examine the impact of acute classroom movement break (CMB) and physically active learning (PAL) interventions on physical activity (PA), cognition, academic performance and classroom behaviour.

Design Systematic review.

Data sources PubMed, EBSCO, Academic Search Complete, Education Resources Information Center, PsycINFO, SPORTDiscus, SCOPUS and Web of Science.

Eligibility criteria for selecting studies Studies investigating school-based acute bouts of CMB or PAL on (PA), cognition, academic performance and classroom behaviour. The Downs and Black checklist assessed risk of bias.

Results Ten PAL and eight CMB studies were identified from 2929 potentially relevant articles. Risk of bias scores ranged from 33% to 64.3%. Variation in study designs drove specific, but differing, outcomes. Three studies assessed PA using objective measures. Interventions replaced sedentary time with either light PA or moderate-to-vigorous PA dependent on design characteristics (mode, duration and intensity). Only one study factored individual PA outcomes into analyses. Classroom behaviour improved after longer moderate-to-vigorous (>10 min), or shorter more intense (5 min), CMB/PAL bouts (9 out of 11 interventions). There was no support for enhanced cognition or academic performance due to limited repeated studies.

Conclusion Low-to-medium quality designs predominate in investigations of the acute impacts of CMB and PAL on PA, cognition, academic performance and classroom behaviour. Variable quality in experimental designs, outcome measures and intervention characteristics impact outcomes making conclusions problematic. CMB and PAL increased PA and enhanced time on task. To improve confidence in study outcomes, future investigations should combine examples of good practice observed in current studies.

PROSPERO registration number CRD42017070981.

What is already known on this topic?

- ► Acute bouts of exercise have small positive effects on cognition.
- ► Previous studies combining acute and chronic designs have found variable effects of classroom movement breaks (CMBs) and physically active learning (PAL) on physical activity (PA), cognition, academic performance and classroom behaviour.
- ► Individuals' PA is highly variable within translational PA interventions.

What are the new findings?

- ► Low-to-medium quality designs dominate the investigations of acute impact of CMB and PAL on PA, cognition, academic performance and classroom behaviour.
- ► At the individual level few studies confirm treatment fidelity using objective PA measures.
- ► Interventions displace sedentary time with either light PA or moderate-to-vigorous PA dependent on initial design characteristics (mode, duration and intensity).
- ► Classroom behaviour improves after longer moderate-to-vigorous (>10 min), or shorter more intense (5 min), CMB/PAL bouts (9 out of 11 interventions).
- ► There was no support for enhanced cognition or academic performance due to limited repeated studies.

INTRODUCTION

Segmented day physical activity (PA) research consistently identifies classroom lessons as the most sedentary and least active segment of a young person's day.[1 2] For pupils, classroom lessons are teacher directed and, therefore, non-discretionary, providing an ideal opportunity for increasing PA levels.[3] With governments requiring that schools provide 30 min of in-school moderate-to-vigorous physical activity (MVPA),[4] introducing activity into the most sedentary part of the day offers attractive opportunities for intervention.[5] Classroom movement breaks (CMBs) and physically active learning (PAL) represent class-time movement strategies receiving substantial contemporary attention.[6] CMB involves short bursts of activity, often moderate to vigorous in nature, between periods of academic instruction.[7] PAL promotes PA by teaching (new) information through PA games or drill and practice of factual information.[3]

Recent systematic reviews and meta-analyses have investigated the impact of CMB or PAL interventions on PA,[7–9] cognition,[7] academic performance[7 9] and classroom behaviour.[7 10] Focused on generating singular outcomes, reviews of CMB and PAL combine acute and chronic study results[7 8 10] or exclusively focus on chronic studies.[9] This is problematic due to different underlying mechanisms of change. Acute effects are premised on the physical arousal hypothesis where PA of a certain duration and intensity causes an increase in blood flow, brain-derived neurotrophic factor and plasma catecholamines.[11 12] Chronic PA has been shown to alter brain structure and function through synaptogenesis, neurogenesis and angiogenesis.[13] Therefore reviews should treat these interventions independently. To date, no review has solely reviewed acute PAL or CMB studies.

Previous systematic reviews on acute exercise, not exclusive to the school environment, have found mixed results. Some find small positive effects on cognition, academic achievement or classroom behaviour,[14–16] others find limited or no effect.[17 18] Differing results have been attributed to varying study quality and differences in important design characteristics.[16–18] To generate trustworthy singular outcomes requires robust experimental methods and outcome assessments. In addition, due to the variability in PA responsiveness in real-world settings, treatment fidelity must be confirmed at the individual level.[19] This paper will systematically review studies on the acute effects of CMBs and PAL in children on PA, cognition, academic performance and classroom behaviour; focusing on intervention outcomes and critical design features.

METHODS

The systematic review protocol was registered with International Prospective Register of Systematic Reviews on 1 July 2017 (CRD42017070981) and adheres to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P).[20]

Search strategy

First, a keyword search was conducted within the PubMed database (online supplementary file 1). Searches were then amended for EBSCO, Academic Search Complete, Education Resources Information Centre, PsycINFO, SPORTDiscus, SCOPUS and Web of Science.

Eligibility criteria

The keyword search strategy was informed by Donnelly *et al*,[14] and refined to meet the specific requirements for the current study. Key search terms and their derivatives were pooled in five separate themes prior to being combined for the final searches. The final search was conducted on 5 July 2017.

Search themes

1. Population: children, young people and adolescents (ages 4–17)
2. Environment: school and/or classroom
3. Intervention type: acute CMB or acute PAL
4. Activity outcome measure: PA, MVPA or time spent sedentary
5. Cognition, executive function, academic performance, classroom behaviour or time-on-task (ToT) outcome measures.

A sixth criterion excluded irrelevant studies on disease, illness, participants with learning and/or developmental disorders, animals and nutritional interventions. Following searches, reference lists of identified articles and previous systematic reviews were reviewed to identify further relevant studies.

The review considered studies published in English; no date limits were set. To confirm translational impact, CMBs had to take place in classrooms, whereas PAL was required to take place in the school environment. Both randomised controlled trials (RCTs) and non-RCTs were included. Studies were excluded when they did not meet key inclusion criteria. Grey literature was not consulted using the idea that most rigorous studies will include peer-reviewed consideration.

Study selection

After downloading citations into EndNote, duplicates were removed. The final results were independently reviewed by two authors (AD-S and SZ), first by title, then by abstract. At each stage, studies were recorded as include, exclude or maybe. Studies progressed if either reviewer recorded include or maybe; ensuring no papers were accidentally excluded. Next, full papers were reviewed independently prior to a discussion between the two reviewers to agree inclusion/exclusion. Where ambiguity arose over key study details (eg, location of the CMB), authors were contacted. A list of the inclusion/exclusion outcomes of each study was recorded.

Data extraction

Key study details were recorded in Google Sheets including participant characteristics, study design, assessment methods and outcomes for PA, cognitive function, academic performance and classroom behaviour. The lead author (AD-S) extracted information from the full papers. Tables were then independently reviewed by SZ, resolving discrepancies through face-to-face discussions.

Study quality and risk of bias

Consistent with PRISMA-P guidelines, two independent reviewers (AD-S and SZ) assessed overall and subdomain risk of bias using the Downs and Black[21] checklist for the assessment of the methodological quality of both randomised and non-randomised studies of healthcare interventions. Interpretations of the checklist criteria were informed by a refined understanding for acute translational studies.[18] Study authors developed the criteria to address specific issues discussed in previous reviews (online supplementary file 2).[11 19] The following questions were amended:

- Question 13: a trained teacher was required to deliver the intervention;
- Question 17: required a specific post-test time for cognitive outcomes;
- Question 19; extended to include direct observation, accelerometers and pedometers as suitable PA measurement tools[22];
- Question 23: randomisation, the authors graded this criteria conservatively, requiring details of the randomisation process;
- Question 25: a two-point scale was introduced that required studies to include the amount of PA accumulated within the CMB or PAL session in analyses.

The strength of the body of evidence was assessed using the risk of bias outcome. Overall scores determined the planned analysis approach. A low–medium outcome resulting in a review of methodological process. A meta-analysis would be conducted if there were sufficient high-quality studies (>4 per primary outcome) so not to compound the risk of bias.[23]

RESULTS

Overview of study characteristics

Initial searches returned 2929 papers, plus 5 papers identified through manual searches (figure 1). After removing duplicates, 2540 papers were reviewed by title and abstract. Sixty-one full-text articles were then retrieved. Seventeen articles—featuring 18 experimental studies—met the inclusion criteria. To aid understanding, two independent studies were conducted within one paper[24]; these are cited as A and B. Figure 1 shows reasons for rejection at full paper stage. Of the 18 included studies, 10 featured PAL interventions, 8 implemented CMB.

Physically active learning

Most included PAL studies (60%) were published in the last 4 years[24–28] with the first published in 1965[29] (table 1). Six studies were conducted in the USA,[25 28–32] two in Germany,[24] and one each in the UK[27] and the

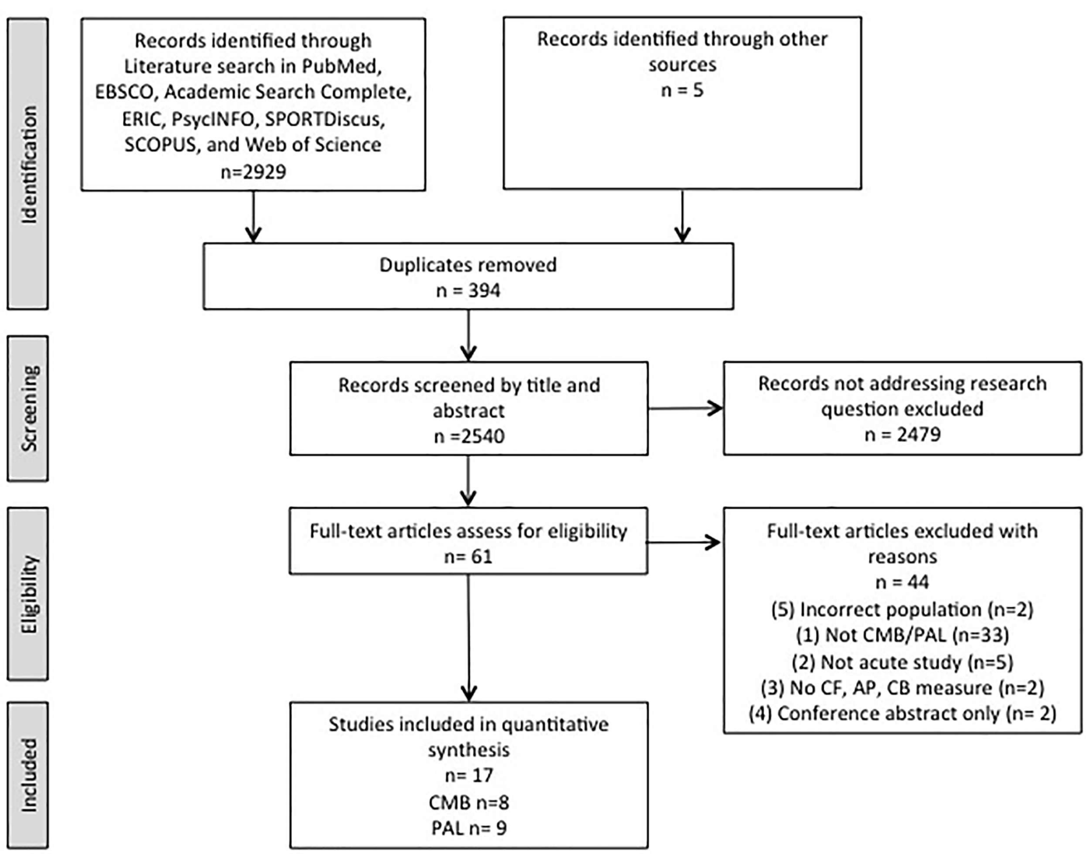

Figure 1 PRISMA flow chart illustrating study inclusions through the stages of the systematic review. AP, academic performance; CB, classroom behaviour; CF, cognitive function; CMB, classroom movement break; PAL, physically activie learning ; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Table 1 PAL study characteristics

Study	Design and population	PAL	Control	PA assessment	PA outcome	Performance assessment	Performance main outcome
Author, location	Design, n, girls, age	Deliverer, type, DUR, INT	Deliverer, type, DUR, INT		Percentage of lesson time in MVPA	Type, timings	
Graham *et al*,[28] USA	Between-S n=21, girls=48%, age: NR, 7–8 years	TL, *Jump In*, active answer mats in maths lesson, DUR and INT: NR	TL, classroom maths lesson, DUR and INT: NR	No assessment	–	AP: maths quiz on session content; no pre, post at NR	No sig differences in postlesson quiz marks between conditions (p=0.65).
Grieco *et al*,[30] USA	R* by class—Within-S n=97, girls=54.7%, age=8.7±0.4 years, NR	TL, Texas I-Can, classroom-based combined PA and learning, DUR: 15 min, INT: MVPA	TL, classroom usual lesson, DUR and INT: NR	No assessment	–	CB: ToT; pre, post at 5 min	Sig three-way interaction between time × lesson type × BMI category (p<0.05). No change in ToT after PAL. ↓ after CON. Normal weight (d=−0.39), overweight (d=−1.28).
Grieco *et al*,[25] USA	R* by class—Between-S n=320, girls=51.3%, age=9.5±0.9 years, 7 to 12 years	(1) RL active spelling relay, DUR: 15 min, INT: MVPA (2) RL, competitive spelling relay, DUR: 15 min, INT: LPA	(3) RL, classroom non-competitive spelling. DUR: 15 min, INT: SED (4) RL SED competitive spelling relay, DUR: 15 min, INT: SED	GT1M accelerometer	(1) 83.8% 12.57 min (2) 67.8% 10.17 min (3) 2.6% 1.40 min (4) 9.3% 0.39 min	CB: ToT; pre, post at 10 min	Sig interaction between time and condition for ToT (p<0.001). (4) sig ↓ in ToT pre to post (d=−0.61); (3) no change, (2) sig ↑ (d=0.43), (1) sig ↑ (d=1.22).
Humphrey,[29] USA	Between-S n=20, girls=NR, age: 7–9 years	TL, active spelling games, DUR and INT: NR	TL, language workbook, DUR and INT: NR	No assessment	–	COG: spelling recognition test; no pre, post at NR	Sig ↑ in test scores for both conditions, control (p<0.05) and PAL (p<0.01). PAL significantly higher post-test score (p<0.05).
Lucht and Heidig (A),[24] Germany	Within-S n=55, girls=NR, age: 10.7±0.3 years	TL, HOPSCOTCH exer-learning sensor mat for spelling 13 foreign words, DUR: 15 min, INT: NR	TL, classroom language spelling lesson 13 words, DUR: 45 min, INT: NR	No assessment	–	AP: visual and written cued recall spelling test; no pre, post at 1 week	No sig difference between the total score achieved for the spelling of the 13 words in each condition (p=0.51).

Continued

Table 1 Continued

Study	Design and population	PAL	Control	PA assessment	PA outcome	Performance assessment	Performance main outcome
Author, location	**Design, n, girls, age**	**Deliverer, type, DUR, INT**	**Deliverer, type, DUR, INT**		**Percentage of lesson time in MVPA**	**Type, timings**	
Lucht and Heidig (B),[24] Germany	Within-S n=58, girls=NR, age: 9.68±0.3 years, NR	TL, HOPSCOTCH exer-learning sensor mat for spelling 10 words. DUR and INT: NR	TL, classroom foreign language spelling lesson, 10 words, DUR: 45 min, INT: NR	No assessment	–	AP: visual recognition and visual cued recall; no pre, post at 3 days	Recognition: CON remembered more words compared with PAL (p=0.006, ES=0.46). Cued recall task: PAL performance was better compared with CMB (p=0.011, d=0.42). Improvement in both remembering and spelling.
Mahar *et al*,[31] USA	Within-S n=62, girls=NR, age: 9.1±0.9 years (8–11)	TL, Energizers Combined movement and learning in the classroom, DUR: 10 min, INT: NR	TL, classroom usual instruction, DUR: 20 min, INT: NR	Pedometers	Reported from wider programme, not specific session	CB: ToT; pre, post at 0 min	A sig interaction time x condition (p<0.05). PAL: ToT ↑ from pre to post (+8.3%, p<0.017, d=0.60). Control no change. For least on task students: PAL significant ↑ (19.9%, p<0.05, d=2.20).
Mullender-Wijnsma *et al*,[26] Netherlands	Within-S n=81, girls=51%, age=8.2±0.65 years, NR	TL classroom basic exercise and learning at desk, DUR: 30 min, INT: MVPA	TL, classroom usual instruction, DUR and INT: inactive	Heart rate MVPA=60%–90% Max heart rate	PAL: 60% 14 out of 23 min CON: not assessed	CB: ToT; no pre, post at NR	Sig effect of condition on ToT favouring PAL (p<0.05; d=0.41). No sig correlations were found between the % of MVPA during the PAL lesson and TOT postlesson.

Continued

Table 1 Continued

Study	Design and population	PAL	Control	PA assessment	PA outcome	Performance assessment	Performance main outcome
Author, location	**Design, n, girls, age**	**Deliverer, type, DUR, INT**	**Deliverer, type, DUR, INT**		**Percentage of lesson time in MVPA**	**Type, timings**	
Norris *et al*,[27] UK	R* by class— Between-S n=85, girls=42.2%, age=NR 9–10 years	TL, classroom, active VFT, active at chair. DUR: 30 min, INT: NR	TL, classroom seated VFT, DUR: 30 min, INT: SED	GT1M Accelerometer	PAL: 3.5% 1.07±0.81 min CON: 2.0% 0.61±0.80 min	COG: immediate facts recall; no pre, post at NR	No sig differences in post VFT quiz marks between conditions (p=NR).
Valle *et al*,[32] USA	Within-S n=40, girls=57.5%, age: NR 12–13 years	TL, classroom walking around tables learning words, DUR and INT: NR	TL, classroom learning words from board, DUR: NR, INT: SED	No assessment	–	COG: immediate word recall; no pre, post at 0 min	No sig difference between the number of correct word pairs recalled between conditions (p>0.05).

*Randomisation procedure not reported. Two independant studies were conducted within Lucht and Heidig; these are cited as A and B in this table.
a

AP, academic performance; Between-S, between subjects; BMI, body mass index; CB, classroom behaviour; CMB, classroom movement break; COG, cognition; CON, control; DUR, duration; INT, intensity; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; n, number; NR, not reported; PA, physical activity; PAL, physically active learning; R, randomised; RL, researcher led; SED, sedentary; sig, significant; TL, teacher led; ToT, time on task; VFT, virtual field trip; Within-S, within subjects; ↑, increase; ↓, decrease.

Table 2 Results of the Downs and Black[21] methodological quality assessment ranked by overall quality percentage score

	Reporting	External validity	Internal validity (bias)	Internal validity (confounding)	Power	Total
Question numbers	**1–7, 9, 10**	**11–13**	**14, 15, 17–20**	**21–26**	**27**	
Maximum score	**10**	**3**	**6**	**7**	**1**	**27 (%)**
PAL studies						
Grieco *et al*[25]	7	0	6	4	0	17 (63)
Norris *et al*[8]	8	1	4	3	0	16 (59)
Mullender-Wijnsma *et al*[26]	7	1	3	4	0	15 (56)
Grieco *et al*[30]	7	1	4	2	0	14 (52)
Lucht and Heidig[24] (A)	7	1	2	3	0	13 (48)
Lucht and Heidig[24] (B)	7	1	2	3	0	13 (48)
Graham *et al*[28]	6	1	1	3	0	11 (41)
Mahar *et al*[31]	4	1	3	2	0	10 (37)
Valle *et al*[32]	2	1	2	4	0	9 (33)
Humphrey[29]	3	1	1	3	0	8 (30)
CMB studies						
Schmidt *et al*[33]	9	0	4	4	1	18 (67)
Howie *et al*[34]	9	0	4	4	0	17 (63)
Howie *et al*[35]	9	0	3	5	0	17 (63)
van den Berg *et al*[36]	9	0	4	2	0	15 (56)
Kubesch *et al*[37]	8	0	3	3	0	14 (52)
Ma *et al*[38]	6	0	3	3	1	13 (48)
Hill *et al*[39]	5	1	4	2	0	12 (44)
Ma *et al*[40]	6	0	3	2	0	11 (41)

CMB, classroom movement break; PAL, physically active learning.

Netherlands.[26] Study quality ranged from 30%[29] to 63%[25] with an average of 47% (table 2). Within the three most recent studies, quality averaged 59.3%, suggesting improving quality.[25–27] Sample sizes ranged from 20[29] to 320[25] with an average of 84. All 10 trials focused on pre-adolescent children aged between 7 and 13.

Three studies randomised participants at the class level; two used within-subject designs[25 30] and one used a between-subject design[27]; no study reported the randomisation process. Of the remaining non-randomised studies, five used within-subject designs[24 26 31 32] with two remaining studies using a between-subject design.[28 29] Blinding is rare; two blinded the evaluators[25 30] and one blinded the participants.[27] Only Mahar *et al*[31] reported pretesting familiarisation sessions for both intervention and assessments. Other studies used outcome assessments familiar to the participants but offered no test familiarisation.[24 27]

Classroom movement break

Most CMB studies (75%) were published in the last 3 years[33–38] with the first published in 2009[39] (table 3). Two studies were conducted in Canada[35 36] and the USA[33 34] with one study in the following countries: Germany,[39] Netherlands,[38] Switzerland[37] and the UK.[40] Study quality ranged from 41%[35] to 67%[37] with an average of 54%. Study quality within the three most recent studies averaged 64.3%; suggesting improving quality. Sample sizes ranged from 36[39] to 1224[40] with an average of 230. All but one trial focused on children aged 8 to 12; the exception recruited participants aged 13 to 14 years.[39]

Two studies randomised at the individual level, one using a within-subjects design[39] and the other a between-subjects design.[37] Of the five studies reporting class-level randomisation, all used within-subject designs.[33 34 36 38 40] Only Howie *et al*,[33 34] reported the randomisation process. The final study used a non-randomised between-subject design.[35] Two studies deployed blinding procedures; Hill *et al*,[40] blinded participants to the purpose, while Howie *et al*,[33] videotaped the classroom observations blinding evaluators to the condition. Familiarisation featured in most studies although only Ma *et al*,[35 36] familiarised participants with both the intervention and outcome measures. Three further studies familiarised participants to the assessment tools.[37–39] One study familiarised the participants to the intervention.[33] Two studies used no familiarisation.[34 40]

Intervention design and delivery (ecological validity)

Physically active learning

Three studies involved classroom-based aerobic exercises combined with learning,[26 30 31] two used active spelling

Table 3 Main characteristics of the CMB studies

Study	Design & population	CMB	Control	PA assessment	PA outcome	Performance assessment	Performance Main Outcome
Author, location	Design, n, girls, age	Deliverer, type, DUR, target INT	Deliverer, type, DUR, INT		Percentage of lesson time in MVPA	Type, timings	
Hill *et al*,[39] UK	R* by class Within-S n=1224, girls=NR, age=NR 8–11 years	TL, stretching and aerobic exercise (running and hopping to music) at desk, 10–15 min, INT: MPA	Classroom normal lesson. DUR and INT: NR	No assessment	–	COG: paced serial addition, size ordering, listening span, digit-span backwards and digit–symbol encoding. No pre, post at 60 min	Overall:+ve sig effect for CMB (p=0.009; h_p^2=0.006); sig two-way interaction intervention × group (p<0.001; h_p^2=0.193).
Howie *et al*,[34] USA	R by class Within-S n=75, girls=NR, age=NR 9–12 years	RL, Brain BITES, aerobic exercise (marching and running in place with arms). (1) 5 min, (2) 10 min and (3) 20 min. INT: MVPA	(4) RL, classroom activity, DUR: 10 min, INT: SED	Modified SOFIT, 10 s observation. Scale 1–5; 1 lying down, 5 very active	(1) 87% 4.35±0.47 min (2) 43.7% 4.37±0.32 min (3) 21.5% 4.29±0.33 min (4) NR	CB: ToT Pre, post at NR	+ve sig effect on ToT after (2) CMB:10 min (p<0.01, d=0.50). Approaching sig (3) CMB: 20 min (p=0.56, d=0.32) compared with (4) control.
Howie *et al*,[35] USA	R by class Within-S n=96, girls=NR, age=10.7±0.6 years 9–12 years	RL, Brain BITES, aerobic exercise (marching, jumping and running in place with arms). (1) 5 min, (2) 10 min and (3) 20 min. INT: MVPA	(4) RL, classroom, lesson on exercise science classroom activity, DUR: 10 min, INT: SED	Modified SOFIT, 10 s observation. Scale 1–5; 1 lying down, 5 very active	(1) 80% 4.00±0.43 min (2) 43.5% 4.35±0.33 min (3) 21.3% 4.26±0.37 min (4) 20% 2.01±0.05 min	COG: Trail-making test, digit recall, pre, post at NR AP: timed maths test, pre, post at NR	COG: no difference CMB vs CON. AP:+ve sig effect of (2) CMB: 10 (+1.07, 95% CI (0.03 to 2.12), p=0.04, d=0.24) and (3) CMB: 20 (+1.2, 95% CI (0.15 to 2.26), p=0.02, d=0.27) on maths scores vs (4) control.
Kubesch *et al*,[37] Germany	R* individual Within-S n=36, girls=42%, age=NR 13–14 years	TL, virtual Berlin Marathon, jogged on spot with arm movements, DUR: 5 min, INT: NR	Watched students complete virtual Berlin Marathon	No assessment	–	COG: Flanker, dots task, pre, post at immediate, post at after next lesson	COG: no sig effect of the CMB.

Continued

Table 3 Continued

Study	Design & population	CMB	Control	PA assessment	PA outcome	Performance assessment	Performance Main Outcome
Author, location	Design, n, girls, age	Deliverer, type, DUR, target INT	Deliverer, type, DUR, INT		Percentage of lesson time in MVPA	Type, timings	
Ma *et al*[40] Canada	Within-S Grade 2 n=20, irls=25%, age=NR 7–8 years Grade 4 n=27, girls=58.3%, age=NR 9–10 years	Leader NR, FUNterval, 20 s VPA, 10 s rest. squats, jumping jacks, scissor kicks, jumping and running on the spot. DUR: 4 min (10 min session), INT: VPA	RL, lecture on healthy eating, physical activity and history of sport, DUR: 10 min, INT: non-active	No assessment	–	CB: TofFT No pre, post at NR	Grade 2: sig ↓ in TofFT CMB vs CON; passive (↓9%, p<0.01, d=0.74), verbal (↓3%, p<0.05, d=0.45), motor (↓15%, p<0.01, d=1.076) Grade 4: sig ↓ in TofFT CMB vs CON; passive (↓4%, p<0.05, d=0.31), motor (↓7%, p<0.01, d=0.48). Greatest effect of CMB for those in lowest quartile for TofFT.
Ma *et al*[38] Canada	R* class Within-S n=88, girls=50%, age=NR 8–11 years	Leader NR, FUNterval, 20 s VPA, 10 s rest. squats, jumping jacks, scissor kicks, jumping and running on the spot. DUR: 4 min (10 min session), INT: VPA	RL lecture on kinesiology, DUR: 10-min, INT: non-active	No assessment	–	COG: d2-test: (TN) total characters processed, (E) number of errors, (Eo) number of errors of omission, (Ec) mistakes including relevant symbols, (E%) per cent of TN that were errors. No pre, post at 10 min	COG: sig ↓ for CMB vs CON on d2-test; ↓E (–4, p<0.01, d=0.29), ↓Eo (–3, p=0.01, d=0.18), ↓Ec (–2, p=0.03, d=0.16), ↓E% (–1%, p<0.01, d=0.23), Sig ↑TN control vs CMB (+9, p=0.04, d=0.12).

Continued

Table 3 Continued

Study	Design & population	CMB	Control	PA assessment	PA outcome	Performance assessment	Performance Main Outcome
Author, location	Design, n, girls, age	Deliverer, type, DUR, target INT	Deliverer, type, DUR, INT		Percentage of lesson time in MVPA	Type, timings	
Schmidt *et al*,[33] Switzerland	R* individual Between-S n=92, girls=45.7%, Age=NR 11–12 years	Leader NR, DUR: 10 min, INT: NR (1) High-PA high-COG load. Number connection test. (2) High-PA low-COG load, running at different speeds like a car	Leader NR, DUR: 10 min, INT: NR. (3) SED with high-COG load, trail-making test. (4) SED with low-COG load, listened to age appropriate story	Heart rate (note: presented as mean for session DUR)	(1) 154.05±25.73 (2) 144±63±35.40 (3) 102.92±21.07 (4) 87.93±9.81	COG: d2-R test; (FA) number of correct responses minus commission errors, (TN) total number of symbols processed, (E%) per cent of TN that were errors. Pre, post at 0 min	High-COG (1 and 3) performed better than low-COG (2 and 4) for FA ($p=0.044$, $h_p^2=0.046$) but not TN or E% ($p>0.05$). Attention: no sig effects of physical exertion or interaction of COG exertion and physical exertion were found ($p>0.05$).
van den Berg *et al*,[36] The Netherlands	R* by class Within-S (1) n=66, girls=47%, age=11.6±0.7 years, NR (2) n=71, girls=44%, age=11.7±0.8 years, NR (3) n=47, girls=49%, age=12.1±0.5 years, NR	ML, DUR: 12 min, INT: MPA, (1) aerobic exercise: marching and running in place. (2) Coordination exercises: dance steps, bilateral exercises. (3) Resistance exercises: squats, shoulder raises	RL seated lesson on exercise and movement, DUR: 12 min, INT: NR	Heart rate MVPA=64%–94% Max HR	(1) 39.5%±27.0% 3.95 min (2) 14.1%±17.3% 1.41 min (3) 18.8%±20.9% 1.88 min	COG: LDST, d2-test of attention. Pre, post at 0 min	No sig acute effects of CMB (combined) vs CON on LDST performance ($p=0.40$) or d2-test ($p=0.34$). CMB mode did not moderate effects on LDST ($p=0.18$) or d2-test ($p=0.55$).

*Randomisation procedure not reported.

AP, academic performance; Between-S, between subjects; BMI, body mass index; CB, classroom behaviour; CMB, classroom movement break; COG, cognition; CON, control; DUR, duration; INT, intensity; LDST, letter–digit substitution test; LPA, light physical activity; ML, movie led and researcher supported; MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; n, number; NR, not reported; PA, physical activity; PAL, physically active learning; RL, researcher led; SED, sedentary; sig, significant; SOFIT, System for Observing Fitness Instruction Time; TL, teacher led; ToffT, time off task; ToT, time on task; VPA, vigorous physical activity; Within-S, within subjects; .

games,[25 29] two used a digitally active HOPSCOTCH spelling game with sensor mat,[24] one used a *Jump In!* answer mat,[28] one engaged students through a classroom-based virtual active field trip,[27] while the final study used an active memory game which involved walking around the classroom and remembering words.[32] All interventions, except Grieco *et al*,[25] were delivered by teachers. Interventions varied in duration and intensity (table 2). The protocols of two studies by Grieco and colleagues lasted 15 min with one targeting MVPA[30] and the other with two experimental conditions comparing moderate PA and light PA.[25] Two studies stated 30 min durations, one targeting MVPA[26] and the other not stating an intensity.[27] The study by Mahar *et al*[31] reported the shortest intervention duration of 10 min, while both Lucht and Heidig[24] studies reported the longest duration of 45 min; neither stated a target intensity. Three studies reported neither duration nor intensity.[28 29 32]

Classroom movement break

All interventions were based in classrooms. Six studies involved basic, whole-body movements such as running and jumping with arm movements on the spot.[33–36 39 40] Schmidt *et al*,[37] compared a high-active high-cognitive load group who performed a running number connection test with a high-active low-cognitive load group who ran at different speeds simulating a car changing gear. Van den Berg[38] compared three conditions, (i) Whole-body aerobic exercise movements, and (ii) coordination exercises involving bilateral movements and movements crossing the body midline, and (iii) strength-based dynamic and static exercises like squats. Two interventions were delivered by teachers[39 40] with two led by researchers[33 34] and one where students followed a movie, encouraged by researchers.[38] Three did not identify the session deliverer.[35–37]

Duration of the CMB interventions ranged from 4[35 36] to 20 min.[33 34] Two studies investigated a variety of CMB durations: 5, 10 and 20 min.[33 34] All but two studies[37 39] reported a target intensity; moderate PA,[38 40] MVPA[33 34] and vigorous PA.[35 36]

PA assessment and outcomes

Physically active learning

Of the 10 PAL interventions, three assessed the duration and intensity of the intervention using objective measures; two utilised GT1M accelerometers[25 27] and one heart rate monitor.[26] Of these, only two assessed the control condition.[25 27] All presented results at the group level. Only Mullender-Wijnsma *et al*[26] addressed individual engagement in the PAL condition in the analysis. Results at the group level revealed variation in the duration and intensity of the different trials. The researcher-led MVPA competitive relay elicited the highest proportion—83.8% (12.57 min)—of lesson time in MVPA.[25] Desk-based exercise and learning resulted in the most minutes of MVPA; 14 min of 23 min, 60% of PAL time.[26] Norris *et al*[27] achieved a marginal increase in MVPA in the active virtual field trip with only 3.5% of the lesson time in MVPA compared with 2% in the seated control condition. Greater differences (>5 min) were observed in the accumulation of light activity (14.97±6.18 min vs 9.92±6.11 min, p<0.001).

Classroom movement break

Two studies assessed and presented PA in the control and CMB conditions[34 37] and two in the intervention conditions only.[33 38] Howie *et al*[33 34] used the System for Observing Fitness Instruction Time (SOFIT) tool to assess group-level MVPA. Heart rate, presented at group level, was used in the remaining two studies.[37 38] No studies reported results at the individual level or factored these into analyses.

In Howie *et al*,[33 34] the MVPA accumulated in the 5, 10 and 20 min conditions was similar (~4.3 min), despite the increasing duration of the CMB. The 5 min CMB resulted in the highest proportion of MVPA in both studies (80%–87%). The control condition within Howie *et al*[34] resulted in 20% of the 10 min spent in MVPA. In Schmidt *et al*,[37] heart rates during the two high PA conditions were significantly greater than the two sedentary conditions (p<0.0005, h_p^2=0.800). No statistical comparison was made between the two high PA conditions. In the final study, aerobic exercise elicited at least twice the MVPA time (39.5%±27.0%) compared with the coordination (14.1%±17.3%) and resistance (18.8%±20.9%) groups.[38]

Cognition, academic achievement and classroom behaviour assessment and outcomes

Physically active learning

Four PAL trials assessed ToT performance within 10 min of the end of the bout.[25 26 30 31] All found a positive outcome in favour of the PAL condition. These differences were driven by varied responses to the intervention and control conditions. In Grieco *et al*,[30] the difference was driven by a reduction in ToT in the control condition, pre to post; obese children (d=−1.28) compared with normal weight children (d=−0.39). In Mahar *et al*.[31] controls showed no change compared with a significant improvement in the PAL condition (+8.3%, p<0.017, d=0.60). Grieco *et al*[25] showed a reduction in ToT for the control condition with improvements in the two PAL conditions, the largest effect size being observed in the moderate spelling relay (d=1.22) compared with the light PA spelling relay (d=0.43). In Mullender-Wijnsma *et al*,[26] only a post-test, which immediately followed the lesson, was used. Students in the PAL condition had a higher ToT compared with controls (p<0.05, d=0.41).

Five trials assessed cognition; immediate visual recognition,[29 32] immediate fact recall,[27] and delayed recognition and delayed cued recall[24] (table 4). Comparing PAL with control, studies investigating immediate visual recognition identified one positive (effect size not reported)[29] and one no difference[32] result. For immediate fact recall, no difference was observed between conditions.[27] For

Table 4 Cognitive processes and corresponding tests drawn from the included studies

Cognitive process	Test	Study	Summary outcome
Reaction time	Dots task	Kubesch *et al*[39]	↔
Attention	d2	Ma *et al*[36]	↑
		van den Berg *et al*[38]	↔
	d2-R	Schmidt *et al*[37]	↔
Inhibition	Flanker	Kubesch *et al*[39]	↔
	Dots task	Kubesch *et al*[39]	↔
Working memory	Digit-span backwards	Hill *et al*[40]	↔
	Digit recall	Howie *et al*[34]	↔
	Dots task	Kubesch *et al*[39]	↔
	Size ordering	Hill *et al*[40]	↔
Executive function	Trail-making task	Howie *et al*[34]	↔
Speed and memory	Digit–symbol encoding	Hill *et al*[40]	↔
	Letter–digit substitution	van den Berg *et al*[38]	↔
Immediate word recall	Listening span	Hill *et al*[40]	↑
Information processing speed	Paced serial addition	Hill *et al*[40]	↔
Immediate visual recognition	Word recognition	Humphrey[29]	↑
		Valle *et al*[32]	↔
Immediate fact recall	Knowledge quiz	Norris *et al*[27]	↔
Delayed recognition	Word recognition	Lucht and Heidig[24] (B)	↓
Delayed cued recall	Word recall and spelling	Lucht and Heidig[24] (A)	↔
		Lucht and Heidig[24] (B)	↑

↑, statistically significant improvement in physically active learning (PAL)/ classroom movement break (CMB) compared with control; ↔, no statistically significant difference between PAL/CMB and control; ↓, statistically significant improvement in control compared with PAL/CMB.
CMB, classroom movement break; PAL, .

delayed cued recall, 1 week postintervention, no difference was observed between groups,[24] yet in the second study, 3 days postintervention revealed higher scores for the PAL group in delayed cued recall and a lower score in delayed recognition compared with the control condition.[24] Overall, the cognition outcomes revealed two positive results, three no difference results and one negative result when comparing the performance of the PAL with control conditions. One study assessed academic performance using a post-test maths quiz, finding no difference between PAL and control conditions.[28]

Classroom movement break

Two CMB studies assessed time on/off task,[34 40] six assessed cognition[33 35–39] and one assessed academic performance.[35] For time on/off task, the study by Ma *et al*[40] found improvements after the 4 min High-intensity interval intervention (d=0.31 to 1.076). Howie *et al*[34] found varying results with improvements after 10 min (d=0.50) but no differences after 5 or 20 min; although the results for the latter were approaching significance. In the only study assessing academic performance, Howie *et al*[35] found an improvement in the number of maths problems answered correctly after the 10 and 20 min conditions (d=0.24 and d=0.27), but not the 5 min condition, suggesting a possible threshold effect.

Eight cognitive processes were assessed across six studies; reaction time, attention, inhibition, working memory, executive function, speed and memory, word recall and processing speed. Table 4 outlines the tests and associated processes. Overall, results suggest no change in cognition due to engagement in the CMB with only two positive results at the independent test level (attention, d=0.16–0.29[36]; word recall, h_p^2=0.006[40]), and one positive result when the tests were combined as a battery (h_p^2=0.006).[40] In 13 of 15 results, no differences were found between conditions.

DISCUSSION

A systematic search of the literature identified 10 acute PAL and eight acute CMB studies. Overall, quality was low-to-medium (33%–67%). The three most recent PAL and CMB studies achieved 59.3% and 64.3%, respectively, indicating improving study quality. Dependent on intervention characteristics—mode, duration and intensity—CMB and PAL interventions displaced sedentary time with light PA or MVPA. Consistent with previous acute school-based systematic reviews of PAL/

CMB studies, classroom behaviour improved following exercise.[7 10] Contrary to previous reviews reporting small effects,[11 14–16] evidence did not indicate enhanced cognition. Academic performance, assessed in two studies, resulted in two positive and two no difference outcomes.

The outcomes of the current review, relative to the small positive effects (g=0.097,[11] effect size=0.37[15]) seen in previous meta-analyses, raise interesting issues. Previous meta-analyses included studies combining laboratory-based and field-based studies. In laboratory-based studies, the acute exercise bout and testing battery are typically tightly controlled,[41] which limit the external influence on test outcomes . Exerting such control in school-based studies is not only problematic, but also defeats the purpose of translational research—to test the application of basic science in the real world. Therefore, it is likely that the variations in design features, and their deployment within the school environment, explain the differing cognitive outcomes.

While it may be tempting to conclude that acute CMB and PAL studies have limited or no impact on academic performance and cognition, outcomes must be considered in tandem with study quality. While improving, studies have yet to combine the key design features that would result in high-quality designs. Combining the strongest facets from current studies, a Downs and Black risk of bias score of 85% could be achieved; a substantial increase on the highest reported score of 67%.[33] Study designs are now discusssed with reference to critical design features, highlighting examples of good practice within the current field.

Design features likely to have influenced study outcomes included lack of randomisation at the individual level, not reporting the randomisation process, limited blinding of participants and the research team, and intervention and testing battery familiarisation. Regarding acute bouts, the mode, duration and intensity varied greatly, making it difficult to confirm a universal effect, especially within PAL studies. Objective assessment of the PA (ie, the treatment dose) only occurred in one study at the individual level, and in 39% of studies at the group level. Therefore, the majority of these studies lacked confirmation of treatment fidelity.

Randomisation, blinding and familiarisation

Randomisation reduces outcome bias by controlling all known and unknown factors.[42 43] The majority of studies randomised by class. While more feasible within translational research, this presents issues with the distribution of potential confounding variables.[44] While it may be argued that the treatment is a class-level intervention, variability in the individual experience of an intervention and the application of individual-level statistical analysis questions this approach. Only two studies reported the randomisation process.[33 34] Reporting is key to ensure true randomisation has occurred. Within medical research, 25% of studies reporting randomisation demonstrated faulty procedures.[45]

Blinding prevents differential treatment of particpants that may result in bias .[46] It is challenging to deploy blinding with school-based translational research. Strategies used to blind participants included not informing participants of the experimental hypothesis or masking the intervention within the week-to-week variability of curriculum delivery.[39] Another viable strategy is to match intervention and control conditions while ensuring they differ only by the active component.[27] Blinding the research team and/or independent researchers to the treatment condition was deployed to conduct outcome assessments.[25 30 34] To further reduce study bias, future studies may combine these strategies to achieve double blinding.

Familiarisation with the intervention, prior to data collection, is essential to maximise movement time and reduce novelty effects. Familiarising participants with testing batteries and procedures reduces learning effects.[47 48] Typically, familiarisation sessions are conducted 1 week prior to the experimental day.[36] Familiarisation with ToT assessments, to reduce teacher and pupil reactivity, involved observers practising within the classroom for 1 week before data collection.[31 40]

Intervention design and delivery

PAL interventions varied from light-intensity movements within the classroom[32] to moderate-to-vigorous active spelling relays.[25] Such diversity in the mode, duration and intensity of the intervention makes it difficult to deduce universal PA outcomes. Establishing universal outcomes void of critical design features risks misinforming practitioners. PAL is currently defined as teaching (new) information through PA games or the drill and practice of factual information.[3 7] From the current review, it appears that while this covers the majority of current studies, more nuanced classifications are warranted. Such classifications may combine the pedagogical approach with the delivery environment; both impact PA outcomes. The majority of CMB interventions involved whole-body movements behind a desk enabling comparison of the quantitative characteristics. Recent studies have investigated the qualitative characteristics of CMB.[49] These included interventions comparing bilateral movements[36] and cognitively enhanced exercise using a running number connection test.[33]

Confirmation of treatment fidelity: PA

Recent studies objectively assessed PA levels in control and intervention participants, confirming treatment fidelity at the cohort level.[25 27 34 37] Only one study factored individual PA accumulation into the analysis.[26] Not confirming the treatment dose at the individual level is problematic, given the high degree of variability reported in a previous narrative review.[19] Given acute exercise is hypothesised to affect cognition through increased physiological arousal, it is also important to ascertain the duration and intensity at the individual level to confirm the dose(s) impacting arousal. A recent meta-analysis found an activity threshold of ≥20 min of MVPA was required for enhanced cognition.[11] Therefore, future studies may deploy relationship analyses[26] or use a minimum required level of PA accumulation seen in previous school-based studies.[50]

PA outcomes highlighted the intermittent nature of PAL and CMB. When CMB interventions were assessed over 5, 10 and 20 min, the same MVPA accumulation was achieved despite increased session duration. This may indicate a threshold limit for activity accumulation from CMB, or a limitation of the intervention to engage individuals for extended periods of time. The most active CMB activities appeared to be whole-body aerobic exercises when compared with coordination and resistance exercises.[38] PAL studies elicited highly varied levels of PA. Virtual field trips led to increases in light PA rather than enhancing MVPA. Competitive spelling relays were the most active PAL intervention, with 84% of the session in MVPA. Such insights are essential to informing future intervention design and the practical application of PAL. Where the primary outcome is to reduce sedentary time, virtual field trips and similar pedagogical strategies may be deployed. Conversely, if the primary outcome is to increase MVPA, activities combining relay-type activities and learning content are more appropriate.

Cognition, academic performance and classroom behaviour

Consistent with previous reviews,[7,10] time on/off task improved in 9 out of 11 PAL/CMB interventions. Specifically, results revealed the importance of exercise volume (duration × intensity). Short-duration interventions of 5 min were successful if vigorous in nature but not moderate to vigorous.[33,35] Ten to 15 min bouts demonstrated consistent improvements; larger effects were observed in more intense interventions,[25,33] whereas longer durations found mixed effects. Based on these outcomes, to improve acute time on/off task, teachers should implement 5 min vigorous CMB interventions or longer interventions of moderate-to-vigorous intensity. The largest effect size was observed in the 15 min MVPA PAL spelling relay.[25]

While CMB and PAL interventions improve ToT, this evidence should be interpreted cautiously. While studies consistently demonstrated high inter-rater reliability of ToT measures, their discriminant validity is rarely reported.[51] The method appears to originate from a study that assessed academic performance in children with special educational needs,[52] questioning its relevance to modern classrooms. Prior to future use, ToT assessments require confirmation of construct and discriminant validity. Without this, it is questionable if assessment outcomes truly reflect ToT. As much as gazing away from work—a definition used in most studies— may represent distraction, it may equally indicate mentally processing information, an essential component of academic performance.

Evidence on the effect of acute PAL/CMB on academic performance is weak. Two studies, both assessing maths performance, found mixed results.[28,34] Ten and 20 min MVPA CMB had small positive effects on math fluency. Given 5 min bouts caused no change, this suggests a possible threshold effect. Yet, no difference was observed in the MVPA accumulated across the different bout lengths using the SOFIT tool. SOFIT, like most observational tools, assesses PA by monitoring select participants, which may lead to inaccurate outcomes for the whole class. To improve accuracy, future studies should assess PA dose through individual measures such as accelerometry.[22]

Assessing math performance is complex. Math fluency may be best identified by assessing recall and application of facts and methods, because fluency relies on improved processing speed and accuracy.[34] Tests requiring increasingly complex procedural knowledge, knowing action sequences, and conceptual knowledge, the explicit or implicit understanding of the principles, are less likely to detect change unless content is taught within a PAL session.[53] Assessing acute math fluency is problematic because of the lack of psychometric evidence for contemporary multiple version tests. Within both studies, no validity figures were reported for math assessments; one reported reliability.[34] Where pre–post assessments were conducted, it was not clear if different versions were utilised,[34] meaning that outcome scores may be susceptible to learning effects. Future studies will be improved by using multiple version tests of math fluency with established validity and reliability. Studies assessing the effect of acute bouts of exercise on other curriculum areas, beyond maths, are also required.

As previously identified, moving beyond a universal cognitive outcome is essential due to varied responses to exercise of each underlying process.[19] Only two processes, attention and working memory, were assessed across three or more studies. Surprisingly, attention was shown to improve with 5 min vigorous-intensity CMB but not with longer bouts of 10–12 min of moderate-to-vigorous intensity. Working memory, assessed through four different tests, showed no improvement—compared with controls—across a range of intervention durations (5–20 min) and intensities.

In summary, cognitive outcomes indicate small non-significant effect sizes, which may be explained by substantial variations in experimental design. Fifty per cent of studies failed to use pre–post test designs; essential to account for intraindividual variation in daily cognition.[37] Except for delayed recall assessments, post-test timing varied from 0 to 60 min across studies, with three studies not reporting exact test timings. Only one study attempted to investigate duration effects by deploying post-tests immediately after the acute bout and following the next lesson.[39] With cognitive improvements highest within 10 min of the acute bouts and reducing after,[11] future studies should clearly state and justify timings within the methodology. While there may be a temptation to select more fruitful post-test timings, these should be justified in relation to practical implications within the classroom learning context.

Limitations

While the current study did not include a meta-analysis of key outcome measures, the large variability in critical design features warranted a focus on methodological design as opposed to establishing singular outcomes. Forming outcomes based on highly varied intervention designs and outcome assessments risks misinforming practice. While we did not consult the grey literature, it is possible that there are studies that have been overlooked.

CONCLUSION

Studies on the acute effects of PAL and CMB on PA, cognition, academic performance and classroom behaviour are of low-to-medium quality. Recent studies use higher-quality designs. Due to high variability in critical design features, intervention mode, duration and intensity, and outcome measures, results should be interpreted with caution. Few studies confirmed treatment fidelity at the group level, with only one confirming treatment fidelity at the individual level. PA outcomes varied greatly dependent on intervention design, duration and expected intensity. CMB and PAL of ≥10 min MVPA showed greatest consistency of effect on ToT; shorter timeframes required vigorous-intensity activities. At present, cognition and academic performance outcomes are inconclusive. We recommend that future studies should assess the PA dose at the individual level and factor this within the outcome analysis for cognition, academic performance and classroom behaviour.

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