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Systematic Review

The Role of Active Breaks and Curriculum-Based Active Breaks in Enhancing Executive Functions and Math Performance, and in Reducing Math Anxiety in Primary School Children: A Systematic Review

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Abstract: Physical activity is recognized as crucial for children's development in many aspects. However, its integration into the classroom remains a challenge, particularly in STEM subjects, despite this area being a central component of school curricula worldwide. This systematic review investigates the characteristics and the relationships between active breaks (AB) and curriculum-based active breaks (CB) interventions on executive functions, attention, on-task behavior, performance in STEM, and math anxiety in primary school children. A database search, following the PRISMA 2020 guidelines, was conducted in March 2024, identifying 19 eligible studies for descriptive analysis and assessed for risk of bias. A total of 13 studies focused on AB, four on CB, and two compared the two conditions. Only one paper considered math anxiety. The results revealed mixed effects on executive functions and attention, with some studies reporting improvements and others finding no significant changes. Math performance improved with both AB and CB interventions, especially when AB lasted 10 to 20 min. Most interventions were led by teachers, though few studies incorporated intervention fidelity. Overall, the inconsistent findings highlight the need for further research to determine the optimal characteristics for effective interventions and reliable assessment methods and to explore long-term effects and the appropriate level of teacher involvement.

Keywords: active breaks; curriculum-based active breaks; attention; executive functions; STEM performance; math anxiety; on-task behavior; primary education; classroom interventions; systematic review

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1. Introduction

The importance of physical activity (PA) for children's healthy psychophysical development is well-documented. Among these, notably, the latest version of the "Guidelines on Physical Activity and Sedentary Behavior" (WHO, 2020), published in 2020 by the World Health Organization, reports that children and adolescents aged between 5 and 17 should dedicate at least 60 min a day to moderate-to-vigorous physical activity (MVPA). Additionally, this document highlights, for the first time, the specific needs of young people with disabilities, who may face unique challenges in accessing physical activities, and encourages further exploration of how to support them. The WHO, in a subsequent document (WHO, 2022), reaffirms the significance of PA for all individuals, particularly within primary and secondary educational environments. It highlights various evidence-based strategies to promote PA, including the implementation of physically active learning environments. These active learning strategies can manifest in diverse forms. Notable among these are active breaks (AB), which are interludes of generic PA, and curriculum-based active breaks (CB), which integrate PA with specific curricular content.

To the best of our knowledge, there is a strong body of literature investigating the effects of PA in the classroom on executive functions (EFs) and academic performance (Daly-Smith et al., 2018; Haverkamp et al., 2020; Norris et al., 2020). For example, a systematic review by Monacis et al. (2020) underlined the importance of AB on the physical, cognitive, and psychological aspects of primary school children. The innovative aspect of AB programs is the introduction of physical, visual, and auditory stimuli in school lessons, producing various benefits (Mullender-Wijnsma et al., 2016).

Research on the impact of classroom-based physical activity on EFs and attention has yielded mixed results. While some studies reported positive effects, others showed no significant changes (de Greeff et al., 2018). Specifically, improvements have been observed in inhibition, one of the core EFs components, following acute bouts of PA (Ludyga et al., 2016). However, results for working memory and cognitive flexibility are less consistent (Diamond & Ling, 2016). Interestingly, Schmidt et al. (2015) observed that cognitively engaging physical activities, which combine motor coordination with cognitive challenges, may be particularly effective in enhancing both EFs and attention in children. These discrepancies in findings might be attributed to variations in the intervention duration, intensity, and type of physical activity employed. Moreover, the specific aspects of attention being measured (e.g., sustained attention, selective attention, or attention shifting) may influence the observed outcomes (Melguizo-Ibáñez et al., 2024).

Concerning on-task behavior, a systematic review by Watson et al. (2017a) found that classroom-based physical activity interventions generally improved on-task behavior, with effect sizes ranging from small to large. For instance, Ma et al. (2014) reported that 4 min high-intensity interval activities integrated into lessons increased on-task behavior by 9–16%. However, the long-term sustainability of these improvements remains under-researched. It is worth noting that the relationship between PA, EFs, attention, and on-task behavior is complex. Some researchers posited that improvements in on-task behavior might be mediated by enhancements in EFs and attention control (Melguizo-Ibáñez et al., 2024).

The possibility of integrating PA into the school curriculum offers an opportunity to involve both the quantitative aspect of PA, such as increasing the time dedicated to daily movement, and the qualitative aspect, concerning the student's learning process. In fact, it facilitates the development of deep connections between cognition and movement and exploits the potential of PA to integrate motor, physiological, emotional, cognitive, and relational aspects (d'Arando et al., 2024).

The potential of AB to support Science, Technology, Engineering, and Mathematics (STEM) learning is particularly intriguing given the cognitive demands of these subjects. STEM disciplines often require sustained and selective attention, problem-solving skills, and the ability to integrate complex concepts—cognitive processes that may be enhanced by PA (Kelley & Knowles, 2016). The importance of STEM education in primary schools cannot be overstated, as it lays the foundation for future scientific literacy and innovation (Roehrig et al., 2021), preparing students for future careers that increasingly demand interdisciplinary knowledge and skills (English, 2016). Moreover, the integration of STEM disciplines reflects the interconnected nature of real-world problems. The potential synergy between AB and STEM learning is rooted in the embodied cognition theory, which posits that cognitive processes are deeply rooted in the body's interactions with the world (Weisberg & Newcombe, 2017; Wilson, 2022). This aligns well with the hands-on, experiential nature of many STEM activities. The theory suggests that embodying knowledge through movement, such as arm movements or postures, aids in building higher-quality mental representations, facilitating recall, and enhancing memory (Wilson, 2022). Research has shown that children's physical growth, motor development, and cognitive development are closely linked, with cognitive skills essential, for instance, for math—such as visuospatial skills and rapid memory retrieval—with them being particularly responsive to embodied learning approaches (Weisberg & Newcombe, 2017). By providing opportunities for movement and embodied learning experiences, AB may, therefore, create a more engaging and effective learning environment for STEM subjects, potentially benefiting a diverse range of learners, including those with special educational needs (SEN). In essence, this approach to integrating PA with STEM education offers a promising avenue for enhancing both cognitive development and academic performance in primary school children.

While many previous reviews have examined the impact of PA interventions on academic performance (Daly-Smith et al., 2018; Haverkamp et al., 2020; Masini et al., 2020; Norris et al., 2020; d'Arando et al., 2024), including the meta-analysis by Sneck et al. (2019) focusing on math, there remains a gap in understanding how these interventions specifically affect STEM subjects as a whole. Furthermore, existing reviews have often excluded studies involving students with SEN, limiting our understanding of how these interventions might benefit diverse learner populations.

In addition to cognitive and academic outcomes, the potential effect of AB on math anxiety deserves special consideration. Math anxiety, defined as feelings of tension and apprehension that interfere with the manipulation of numbers and the solving of mathematical problems (Ashcraft, 2022), is a widespread concern in primary education that can significantly hinder STEM learning and performance. Recent research suggests that PA may play a role in reducing anxiety and stress in educational settings (Margulis et al., 2021). The incorporation of active breaks in STEM lessons, particularly in math, could potentially alleviate math anxiety by creating a more relaxed and engaging learning environment (Hraste et al., 2018). Moreover, the embodied cognition approach underlying AB may help students develop a more positive relationship with mathematical concepts by associating them with enjoyable physical activities (Mavilidi et al., 2016). This potential reduction in math anxiety could be especially beneficial for students with SEN, who often experience higher levels of academic anxiety (Nelson & Harwood, 2011). By addressing both cognitive performance and emotional well-being, AB offer a holistic approach to enhancing STEM education in primary schools, potentially breaking the cycle of math anxiety and poor performance that can persist into later academic years (Maloney & Beilock, 2012).

The successful implementation of AB in STEM education heavily relies on teachers' competencies and attitudes. Primary school teachers play a pivotal role in integrating PA with academic content, requiring a unique set of skills that blend pedagogical knowledge with an understanding of movement-based learning. However, research indicates that many teachers feel unprepared to effectively incorporate PA into their lessons, citing a lack of training and resources as primary barriers (Michael et al., 2019). Enhancing teachers' self-efficacy and providing them with practical strategies for implementing AB are crucial steps in maximizing the potential benefits for students (Daly-Smith et al., 2020). As highlighted by the meta-analysis conducted by Martin and Murtagh (2017), professional development programs that focus on the integration of movement and STEM learning can significantly improve teachers' attitudes towards and implementation of AB. Moreover, collaborative approaches where teachers co-design AB interventions with researchers have shown promise in increasing both the fidelity and sustainability of these practices (Routen et al., 2018). As primary education evolves to meet the challenges of 21st-century learning, equipping teachers with the skills to effectively integrate PA into STEM instructions becomes increasingly important. This not only enhances student outcomes but also contributes to teachers' professional growth and job satisfaction.

Drawing from the theoretical and empirical evidence presented above, several key aspects emerge as critical for investigation. The embodied cognition theory (Weisberg & Newcombe, 2017; Wilson, 2022) suggests that PA can enhance learning through the integration of movement and cognitive processes, particularly in mathematics, where abstract concepts can be made concrete through physical experience. This is especially relevant when considering both generic AB that may refresh cognitive resources and CB that directly embody mathematical concepts. Additionally, the documented effects of PA on anxiety reduction (Margulis et al., 2021) and the importance of teacher involvement in successful implementation (Michael et al., 2019; Daly-Smith et al., 2020) point to the need for a comprehensive examination of these interventions.

Therefore, this systematic review aims to address the following research questions:

(a) What is the relationship between in-classroom AB and CB interventions and EFs, attention, on-task behavior, STEM performance, and math anxiety in primary school children?
(b) What are the characteristics of AB and CB interventions associated with positive effects on these outcomes?
(c) What is the nature and extent of teacher involvement in AB and CB interventions, and how does this involvement relate to intervention fidelity?

Furthermore, primary studies involving students with SEN will be considered, given the potential advantageous effects on this population.

This systematic review contributes to existing literature in three distinct ways. First, while previous reviews have examined PA interventions in educational settings (Daly-Smith et al., 2018; Haverkamp et al., 2020; Masini et al., 2020; Norris et al., 2020; d'Arando et al., 2024), this is the first systematic review to specifically compare both AB and CB in relation to EFs and mathematics learning. Second, by examining intervention fidelity and teacher involvement across different types of AB, this review provides practical insights for implementing these interventions effectively in primary school settings. Third, this review is unique in its consideration of math anxiety alongside cognitive and academic outcomes, offering a more comprehensive understanding of how movement-based interventions might support mathematics learning.

Our findings aim to inform both educational practice and policy, offering insights into effective strategies for integrating PA with STEM learning in primary school settings. Moreover, by examining the role of teacher involvement, we hope to contribute to the ongoing dialogue on enhancing teacher competencies in this innovative pedagogical approach.

2. Methods

For this systematic review study, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach was employed for the reviewing process (Page et al., 2021).

2.1. Search Strategy

The bibliographic search was carried out in March of 2024 by two independent reviewers. We used a combination of keywords and Boolean operators (see Appendix A for query string) on the EBSCOhost platform, selecting the following databases: APA PsycArticles, APA PsycInfo, CINAHL Complete, Education Source, Family Studies Abstracts, Gender Studies Database, Mental Measurements Yearbook, and Sociology Source Ultimate. As limiters, the publication date was set between January 2011 and March 2024. The year 2011 was chosen based on a prior search for systematic review or meta-analyses and the assumption that, from that point onwards, literature on the subject has grown. In fact, to the best of our knowledge, the first systematic review on the integration of PA in the classroom was conducted in 2011 (Mahar, 2011). Only studies carried out in English, Spanish, French, or Italian were considered based on languages known by the research team. Reference lists of included articles and previous systematic review were searched using a snow-ball technique to identify further relevant studies.

2.2. Eligibility Criteria

Key search terms addressing the primary search objective were organized in separate themes, following the PICOS (Population, Intervention, Comparator, Outcome, Study Design) criteria.

- Population—inclusion: primary school children; age 5–12 (UNESCO, 2012); children with disabilities, impairments, or health issues; exclusion: preschool children; age < 5, age > 12, adults.
- Intervention—inclusion: in-classroom active breaks as (1) short bouts of PA performed as a break from academic instruction (AB) or (2) short bouts of PA that include curriculum content (CB) (Ma et al., 2014); exclusion: physical education lessons; intervention out of school and out of classroom; multicomponent interventions.
- Comparators—a comparison or control group, is not required but will be used when available to compare effects.
- Outcomes—inclusion: at least one of the following outcomes or a combination of two or more: (1) EFs (higher-order cognitive functions responsible for initiating, adapting, regulating, monitoring and controlling information processes and behavior); (2) attention (focused or selective attention, referring to the ability to concentrate on relevant stimuli while ignoring distractions); (3) on-task behavior (any behavior in which a child is attentive to the academic instruction or actively engaged in the appropriate task, as assigned by the teacher); (4) academic performance in STEM (students achievements in STEM, often reported via classroom grades, national standardized tests or progress monitoring tools); (5) math anxiety (already described as "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations"; Weisberg & Newcombe, 2017); exclusion: academic outcomes unrelated to STEM fields (e.g., language arts, history, or social studies), such as research examining improvements in reading comprehension or literature analysis; outcomes related to generalized anxiety (e.g., studies primarily focused on broad measures of anxiety without specific connections to school or academic contexts); outcomes related to physical health and increased PA (e.g., studies emphasizing physical health improvements such as reduced Body Mass Index or enhanced cardiovascular fitness, or interventions aimed solely at increasing PA levels without assessing academic-related outcomes).
- Study design—both qualitative (e.g., case studies) and quantitative (e.g., Randomized Controlled Trials, Quasi-Experimental Design); exclusion: no studies were excluded based on design.
- Additional criteria—both peer-reviewed papers and grey literature were consulted.

2.3. Identification of Relevant Studies

After downloading from databases and search engines, citations were uploaded into Covidence, a web-based collaboration software platform for conducting systematic reviews as a team (Pellegrini & Marsili, 2021). A total of 312 studies were initially included. A total of 13 duplicates were removed. Applying the inclusion criteria, 299 studies were screened independently by two reviewers, first by title and abstract, then by reading full texts. At each stage, studies were recorded as "yes", "no", or "maybe". When a conflict occurred, a discussion was held to reach an agreement, or a third researcher was contacted. A total of 19 studies were included in this paper, which specifically prioritized AB and CB interventions, as defined in detail above. Figure 1 shows the flowchart illustrating the study inclusion process through the stages of the systematic review and includes a list of reasons for exclusion (for the sake of completeness, it should be noted that the results presented in this paper are part of a larger systematic review that included 35 studies more broadly related to classroom-based PA interventions and mindfulness activities; Sorrentino et al., 2024).

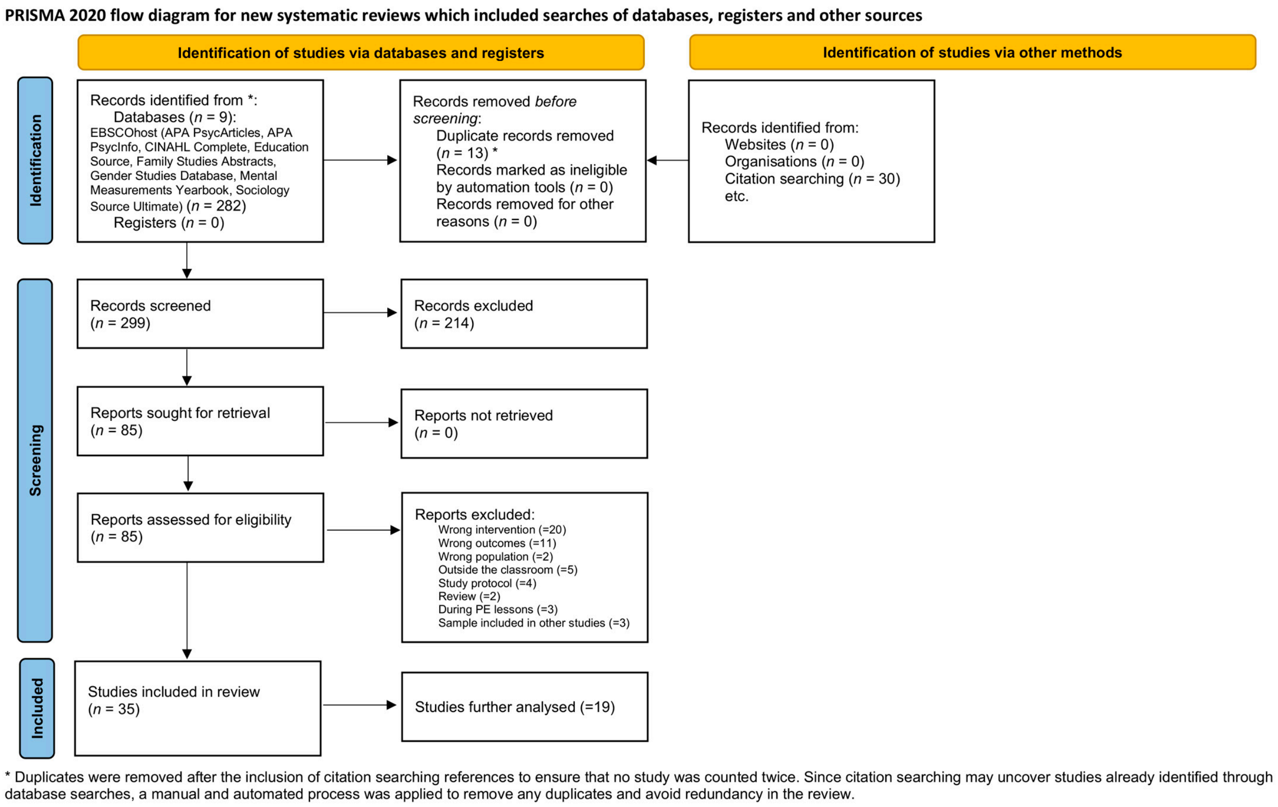

Figure 1. PRISMA flow diagram.

2.4. Codification of Results and Data Extraction

In order to extract data across studies, a coding process was carried out using a Google Form to record key study details. A coding protocol was developed, and data were extracted from full papers by the team. In Table 1, the most relevant details are summarized and organized by type of intervention (AB, CB, or comparative studies), following a thorough review of the Google Sheet generated from the Google Form, which was used to systematically code all the data and check for inaccuracies. Discrepancies between reviewers were resolved through discussion or by consulting a third reviewer. We decided not to proceed with the use of Covidence for data extraction because of the settings of this application, which we found more applicable to the screening phases.

We conducted a descriptive analysis of the studies, focusing on some characteristics such as the year of publication; country; study design; population; duration of intervention; type, intensity, duration in min, and frequency of each break; outcomes and tools of assessment (the whole codebook can be found at Supplementary Materials). Data were coded systematically to allow for a comprehensive comparison of study characteristics and outcomes.

Table 1. Overview of study characteristics.

Author(s) ** (Year) Country	Design (as Declared by the Authors)	Population	Intervention Characteristics and Teachers Involvement	Fidelity	Duration (in min) Frequency Total Duration	Assessment	Outcome(s) (of Interest for this SR)	Effects
				ACTIVE BREAKS (AB)				
Howie (2014) USA	WSD no CG yes CC	*n*: 96 GR4, GR5 age: 9–12 SN: N/A	Led by R TECH yes	No	5/10/20 min consistent time/week 4 weeks	Coded video footage, momentary time sampling protocol	OB	0 (5 min) + (10/20 min)
Howie et al. (2015) USA	WSD no CG yes CC	*n*: 96 GR4, GR5 age: 9–12 SN: N/A	Led by R TECH yes (Brain BITES videos) moderate-to-vigorous intensity marching, jumping, running in place, arm movements aerobic activity warm-up, cool-down	Yes checklist	5/10/20 min consistent time/week 4 weeks	Timed math test (1 min) Trail Making Test (TMT)	MP EFs	+ $d = 0.24$ (10 min) $d = 0.27$ (20 min) 0
van den Berg et al. (2016) Netherlands	mixed WSD BSD no CG yes CC	*n*: 184 GR5, GR6+ age: 10–13 SN: N/A	Led by R TECH yes (pre-recorded videos) moderate-to-vigorous intensity Aerobic, coordination, strength exercises	No	12 min 1 per day 2 weeks	d2 test of attention self-evaluation of difficulty and enjoyment	A	0
Huddleston (2017) USA	E no CG yes CC	*n*: 50 GR2, GR3, GR4 age: 7–10 SN: N/A	Led by R TECH yes(GoNoodle videos)	Yes videotape	3–4 min 2 times 2 weeks	Direct observation	OB	+ less time-off task
Egger et al. (2018) Switzerland	BSD 2 × 2 yes CG RA	*n*: 216 (combo = 59, cognition = 53, aerobic = 50, CG = 54) GR2 age: 7–9 SN: N/A	Led by R TECH yes(music) moderate intensity combo (high CE, high PE), cognition (high CE, low PE), aerobic (low CE, high PE), control (low CE, low PE)	No	18 min (3 games/6 min each) 3 per week 9 months	Two tablet-based tasks Backward Colour Recall; child-adapted Eriksen Flanker task; "mixed" block within the Flanker task	EFs	− shifting 0 updating, inhibition negative effects of "cognitively engaging" AB

Table 1. *Cont.*

Author(s) ** (Year) Country	Design (as Declared by the Authors)	Population	Intervention Characteristics and Teachers Involvement	Fidelity	Duration (in min) Frequency Total Duration	Assessment	Outcome(s) (of Interest for this SR)	Effects
ACTIVE BREAKS (AB)								
Watson et al. (2019) Australia	RCT pilot yes CG	*n*: 341 (IG: 123; CG: 218) GR3, GR4 age: 8–10 SN: EXCL (e.g., ADHD, autism)	Led by R and T (via assisted roll-out from week 1 to week 3) TECH no ACTI-BREAK protocol (Watson et al., 2017a) 30 activities designed to involve teachers in the development	no	5 min 3 per day (implemented 2 per day) 6 weeks	Timed math test (1 min) individual: tool adapted from Direct Behaviour Rating Scale; classroom: modified version of Classroom Behaviour and Assets Survey-Teacher	MP OB	0 + classroom behavior
Schmidt et al. (2019) Switzerland	E no CG yes CC RA	*n*:104 (EL: 34; PA: 37; CG: 33) GR3 age: 9 SN: N/A	Led by R moderate intensity embodied learning (EL), physical activity (PA), without PA included	yes videotape	10 min 2 per week 2 weeks (instruction phase)	d2-R test of attention	A	0 due to intensity and/or to cognitive demand load
van den Berg et al. (2019) Netherlands	RCT yes CG	*n*: 512 (IG: 249; CG: 263) GR5, GR6+ age: 9–12 SN: INCL	Led by T TECH yes (JustDance videos) moderate-to-vigorous intensity 3 videos in each break, chosen for reason of feasibility and teachers' preferences	yes % of integrity (ABs per week)	10 min 1 per day 9 weeks	d2 test of attention, Attention Network Task (ANT)	A	0 it is possible that exercise sessions of longer duration (min and weeks) are needed to have beneficial effects on cognitive outcomes
Mavilidi et al. (2020) Australia	RCT BSD, 2 × 2 yes CG	*n*: 68 (IG: 33; CG:35) GR6+ age: 11–12 SN: N/A	Led by R TECH no push-ups, star jumps, penguin movements, burpees, and running on the spot, performed as a group	no	10 min no frequency or duration in weeks	Cognitive Anxiety Test Questionnaire 7 open-ended test problems based on national curricula	MA MP	Not able to distinguish MA from test anxiety (TA) 0 using an AB before test does not deteriorate TA and MP
Müller et al. (2021) Germany	PP yes CG RA	*n*: 162 (IG: 93; CG: 69) GR 4 age: 9–10 SN: N/A	Led by R TECH no 4 phases: 2 min warming up, 4 min interval based medium cardiovascular, 2 min exercises with a partner, 2 min cool down	no	10 min 1 per day 5 per week 2 weeks	d2-R test of attention	A	+ side-effects on motivation

Table 1. *Cont.*

Author(s) ** (Year) Country	Design (as Declared by the Authors)	Population	Intervention Characteristics and Teachers Involvement	Fidelity	Duration (in min) Frequency Total Duration	Assessment	Outcome(s) (of Interest for this SR)	Effects
ACTIVE BREAKS (AB)								
Layne et al. (2021) USA	RCT yes CG	*n*: 40 (IG: 19; CG: 21) age: 8–9 SN: N/A	TECH yes (active video game) moderate-to-vigorous intensity	no	10 min 1 per day (before math class) 4 weeks	d2 test of attention Letter Digit Substitution Test	MP EFs	0 +
Fiorilli et al. (2021) Italy	BSD, PP mixed 3 × 2 yes CG RA	*n*: 141 (CREAT: 40, FIT: 51, CG: 205) GR3, GR4, GR5 age: 8–10 SN: N/A free from injury, which could preclude PA practice	Led by R TECH no moderate-to-Vigorous intensity creativity: improvisations, dramatization, simulation or imitation; fitness: strength and aerobic activities (squat, jumps, lunges or running on the spot)	no	15 min 3 per day, same day	Validated math test 6–11 AC-MT; Stroop Color and Word Test (SCWT)	MP A	+ (FIT) + Effects are more pronounced when AB enhance motivation and enjoyment
Riese (2023) USA	WSD (ABC design) no CG yes CC RA	*n*: 36 GR3 age: 8–9	Led by T TECH yes (GoNoodle videos) each class was exposed to the three conditions: (A) class as usual (B) 4 min AB, (C) 8 min AB	No	4/8 min same time of the day, after 20 min of instruction time 8 weeks	Direct Behavior Rating	OB	+
CURRICULUM-BASED ACTIVE BREAKS (CB)								
Goh et al. (2016) USA	O no CG	*n*: 210 GR3, GR4, GR5 age: 8–12 SN: N/A	Led by T TECH no Take 10! (Goh et al., 2016) "Invisibile Jump Rope", in this activity students pretends to hold a jump rope and verbalize the answers to math addition problems posed by their teacher while jumping	Yes follow-up with T, direct observation	10 min 1 per day 4 + 8 weeks (baseline + intervention)	Systematic direct observation strategy	OB	+ ES = 0.928 (large)
Vazou and Skrade (2016) USA	QED 2 × 2 yes CG	*n*: 284 (IG: 157; CG: 127) GR4, GR5 SN: N/A	Led by T Move4Thoughts (Vazou & Smiley-Oyen, 2014) based on appropriate fundamental motor skills	Yes T reports	10–12 min 1 per day 3 per week 8 weeks	Standardized math test	MP	+ post-test d = 0.68

Table 1. *Cont.*

Author(s) ** (Year) Country	Design (as Declared by the Authors)	Population	Intervention Characteristics and Teachers Involvement	Fidelity	Duration (in min) Frequency Total Duration	Assessment	Outcome(s) (of Interest for this SR)	Effects
CURRICULUM-BASED ACTIVE BREAKS (CB)								
Have et al. (2018) Denmark	RCT yes CG	*n*: 505 (IG: 294; CG: 211) GR1 age: 7 SN: EXCL (physical disability)	Led by T training course, provide T with the skills to implement task-relevant PA into the math teaching, own abilities to design active math lessons TECH no protocol (Have et al., 2016)	Yes daily log	15 min (of PA spread over the 45 min lesson) 6 per week 9 months	Standardized math test (easyCMB) Eriksen Flanker task	MP EF	+ 0 due to absence of intensity requirement and short duration
Bartholomew et al. (2018) USA	RCT yes CG	*n*: 2716 (IG = 10 math + 9 spelling, CG = 9) GR4 age: 9–11 SN: N/A	Led by T TECH no moderate intensity I-CAN! Program (Bartholomew et al., 2018) general games on math academic material	No	10–15 min 1 per day 5 days/week I-CAN! study 3 years	Momentary time sampling	OB	+ students in IG spent significantly more time-on-task than CG
Comparative of AB and CB								
Fedewa et al. (2018) USA	E no CG RA	*n*: 460 (AB = 284, CB = 176) GR3, GR4, GR5	Led by T teachers had flexibility on time to provide AB and can create curriculum-based Q&A sets TECH yes (GoNoodle videos)	Yes daily reports	5 min 2 per day 5 day/week 9 months	Standardized assessment FastBridge learning	MP	+ (AB) it may be important for children to take actual cognitive breaks from academic tasks
Mavilidi and Vazou (2021) USA	QED three-group convenient sample, voluntary not RA	*n*: 560 (M4T: 221, AB: 134, CG: 205) GR4, GR5 age: 9–11 SN: N/A	Led by T autonomy of implementation TECH no Move4Thoughts (Vazou & Smiley-Oyen, 2014) moderate intensity	Yes daily logs	10 min 3 per week (at least) 8 weeks	Timed comprehensive grade-level appropriate and standardized math tests (easyCMB)	MP	+ (CB) among GR4 more than GR5, due to crowded curriculum

RCT: randomized control trial; QED: quasi-experimental; O: observational; E: experimental; PP: pre-test post-test; WSD: within-subjects; BSD: between-subjects; AB: active breaks; CB: curriculum-based active breaks; CE: cognitive exertion; PE: physical exertion; CG: control group; CC: control condition; RA: randomly assigned; IG: intervention group; GR: grade; SN: special needs; INCL: included; EXCL: excluded; N/A: not applicable (neither included nor excluded); T: teachers; R:researchers; TECH: technologies; EFs: executive functions; A: attention; OB: on-task behavior; MP: math performance; MA: math anxiety; +: positive effects; 0: no effects; -: negative effects; ES: effect size. ** only the first author is cited due to space limitations.

2.5. Quality Assessment and Risk of Bias

Consistent with PRISMA guidelines, two independent reviewers assessed the methodological quality and risk of bias of the included studies. The Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (Kmet et al., 2004) was used to evaluate the quality of each study included in this systematic review. The measure consists of 14 domains. Reviewers assigned a score to each domain based on whether the criteria were met (2 = yes, 1 = partially, 0 = no) or marked as 'N/A' if the domain was not applicable to the study. These scores were used to calculate an overall percentage score. To calculate the quality percentage, we summed the scores (2 or 1) across all applicable domains for a given study (excluding N/A). We then divided this sum by the maximum possible score (the total score if all applicable domains were fully met, namely 28) and multiplied by 100 to obtain a percentage. Equal weight was given to each domain, with higher percentages indicating higher quality. The quality score assignation and percentage calculation are available at Supplementary Materials. Interrater reliability across the quality assessment criteria for the 19 studies was over 95%**.**

3. Results

3.1. Overview of Study Characteristics

In analyzing the study designs, we identified six Randomized Controlled Trials (Bartholomew et al., 2018; Have et al., 2018; van den Berg et al., 2019; Watson et al., 2019; Mavilidi et al., 2020; Layne et al., 2021), two Quasi-Experimental studies (Vazou & Skrade, 2016; Mavilidi & Vazou, 2021), and one observational study (Goh et al., 2016), as reported by the authors. No longitudinal studies were identified. Eleven papers reported characteristics of a control group (Vazou & Skrade, 2016; Bartholomew et al., 2018; Egger et al., 2018; Have et al., 2018; van den Berg et al., 2019; Watson et al., 2019; Mavilidi et al., 2020; Fiorilli et al., 2021; Layne et al., 2021; Mavilidi & Vazou, 2021; Müller et al., 2021), five included a control condition (Howie, 2014; Howie et al., 2015; van den Berg et al., 2016; Huddleston, 2017; Schmidt et al., 2019), while three explicitly stated that no control group was used (Goh et al., 2016; Fedewa et al., 2018; Riese, 2023). Refer to Table 1 for further details.

The countries in which studies were conducted are as follows: the USA (10), the Netherlands (2), Switzerland (2), Australia (2), Germany (1), Italy (1), and Denmark (1). The distribution, spanning from 2014 to 2023, reveals notable fluctuations in the number of publications over the years, with two peaks in 2018 and 2021 (4 studies each). In general, most included studies (68%) were published in the last seven years.

The total number of participants in the intervention and control groups ranged from 36 to 2716 children, with an age ranging from 6 to 12 years. The school grade where the interventions were implemented ranges from grade one to grade six, with the majority of research conducted in grades four (11) and five (10).

Students with SEN or health issues were explicitly excluded in three studies (Watson et al., 2019; Fiorilli et al., 2021; Have et al., 2018), included in one study (van den Berg et al., 2019), and not mentioned in sixteen studies. However, the results never specifically analyze these subgroups of students who are also in the papers in which they are included.

3.2. Quality Assessment Results

Based on the calculated percentage scores, we applied the following cut-offs to categorize the studies into quality levels: a study percentage score of <50% is deemed poor quality, 50–69% is fair quality, 70–79% is good quality, and a score of >80% is a strong quality rating. These thresholds helped us classify the studies systematically, providing a clear framework to interpret the overall quality.

While the total quality assessment scores of the studies ranged from 42% to 93%, most studies were of high quality, with 12 scoring above 70%. Most studies (n = 12) clearly demonstrated an appropriate study design, had a well-defined and robust outcome and exposure measures, and reported results in sufficient detail (Howie et al., 2015; van den Berg et al., 2016; Vazou & Skrade, 2016; Huddleston, 2017; Bartholomew et al., 2018; Have et al., 2018; Schmidt et al., 2019; van den Berg et al., 2019; Watson et al., 2019; Mavilidi et al., 2020; Mavilidi & Vazou, 2021; Müller et al., 2021). Most studies (n = 13) also described appropriate analytic methods (Howie, 2014; Howie et al., 2015; Goh et al., 2016; Vazou & Skrade, 2016; Bartholomew et al., 2018; Fedewa et al., 2018; Egger et al., 2018; van den Berg et al., 2019; Watson et al., 2019; Fiorilli et al., 2021; Have et al., 2018; Müller et al., 2021; Riese, 2023), while only three studies provided partial information (Huddleston, 2017; Mavilidi et al., 2020; Layne et al., 2021). Despite the relatively high-quality ratings, some weaknesses were identified. For example, the blinding of subjects and/or investigators was often not reported, even if it was possible. Additionally, one-third of the studies reported only partial information about the method of subject/comparison group selection or described a strategy that was only somehow appropriate (Howie, 2014; Howie et al., 2015; Goh et al., 2016; Fedewa et al., 2018; van den Berg et al., 2019; Riese, 2023). Refer to Table 2 for overall quality assessment results.

Table 2. Quality assessment scores and levels.

Author(s), Year	Type of Publication *	Mean Score (in %)	Quality
Howie (2014)	D	77.78%	Good
Howie et al. (2015)	J	77.27%	Good
van den Berg et al. (2016)	J	70.83%	Good
Huddleston (2017)	D	78.41%	Good
Schmidt et al. (2019)	J	80.30%	Strong
van den Berg et al. (2019)	J	89.01%	Strong
Egger et al. (2018)	J	93.18%	Strong
Watson et al. (2019)	J	79.97%	Good
Mavilidi et al. (2020)	J	89.58%	Strong
Müller et al. (2021)	J	89.58%	Strong
Layne et al. (2021)	J	42.31%	Poor
Fiorilli et al. (2021)	J	86.25%	Strong
Riese (2023)	D	72.22%	Good
Goh et al. (2016)	J	72.73%	Good
Vazou and Skrade (2016)	J	88.64%	Strong
Have et al. (2018)	J	86.54%	Strong
Bartholomew et al. (2018)	J	85.84%	Strong
Fedewa et al. (2018)	J	70.83%	Fair
Mavilidi and Vazou (2021)	J	68.75%	Fair

* D: dissertation; J:journal.

3.3. Intervention Design and Delivery

The content of the interventions varied greatly. Out of the 19 papers, 13 implemented AB, and only 4 implemented CB. Two studies (Mavilidi & Vazou, 2021; Fedewa et al., 2018) compared the effects of these two types of breaks.

3.3.1. Active Break Intervention Characteristics

Studies focusing on AB incorporated fundamental motor skills and aerobic movements such as stationary marching, arm movements, jumping, and running in place, with some specifying animal-like walking (seven studies). Technologies that involved dancing (van den Berg et al., 2016) or pre-recorded exercise videos (Howie et al., 2015; van den Berg et al., 2016) and active video games (Layne et al., 2021) were used to demonstrate the movements or to motivate students to engage in integrated PA. Two studies (Howie et al., 2015; Müller et al., 2021) highlighted the importance of the following phases during the break: a warm-up, MVPA, and cool-down. When intensity was mentioned, it was mainly defined as MVPA (in five studies) or moderate (in three studies).

Only one research study, by Watson et al. (2019), referred to the use of a specific protocol called ACTI-BREAK, consisting of activities incorporating drama, games, following instructions, and the use of technology. The children involved in this protocol engaged in more than 3 min per day of MVPA compared to students in control classrooms (Watson et al., 2017b).

Interventions also varied in duration and frequency. The total duration of implementation varied significantly, ranging from as short as one day (in one study) (Fiorilli et al., 2021) to as long as nine months (in one study) (Egger et al., 2018). Specifically, seven studies implemented the intervention within less than one month (including durations of one day and two weeks), four studies spanned between one and eight months, and one study lasted nine months. In particular, the latter research compared the effects of four different interventions of AB, investigating how much the three core EFs can be influenced by physically and cognitively challenging PA, both of which were systematically manipulated.

The duration of each break showed significant variability, ranging from 4 to 20 min. The most represented weekly frequency of AB is once a day for at least three days a week (six studies). One study showed no indication of duration in months or frequency (Mavilidi et al., 2020).

3.3.2. Curriculum-Based Active Break Interventions Characteristics

In CB interventions, PA was integrated with academic content. All four studies referred to a protocol or a program related to CB interventions: I-CAN! (Bartholomew et al., 2018); Move4Thoughts (Vazou & Skrade, 2016); Take10! (Goh et al., 2016); Have et al. (2016) protocol. When examples of integration with curriculum were provided in the paper, they were most likely an answer to a math operation, given by the repetition of a given movement (eg., jumping 20 times for 5×4 or skipping forward for addition and backward for subtraction (Goh et al., 2016; Have et al., 2018).

The total duration of implementation showed more inconsistency than in AB, ranging from two months (Vazou & Skrade, 2016) to three years, this being the longest intervention, as reported by Bartholomew et al. (2018).

The length of each break was fairly consistent across the four studies presented, ranging between 10 and 15 min. The frequency was once per day, three to six times per week, each time there was a math lesson in the two long-term programs (Bartholomew et al., 2018; Have et al., 2018).

3.3.3. Comparative Studies of AB and CB Interventions Characteristics

Only two studies out of 19 compared AB and CB.

Fedewa et al. (2018) conducted a study comparing aerobic-based and curriculum-based breaks over a nine-month period. The aerobic-based group engaged in PA, such as aerobic exercises, while the curriculum-based group participated in dancing to music while simultaneously answering math questions. Both groups took part in 5 min sessions twice daily, five days a week. Teachers had flexibility in scheduling the breaks. Those in the curriculum-based group were given full access to the platform (GoNoodle), allowing them to create custom question-and-answer sets.

Mavilidi and Vazou (2021) compared three groups: Move4Thoughts (M4T CB), aerobic-based (AB), and a control group (CG). The CB group used the M4T program, where teachers had autonomy in implementation, integrating moderate-intensity movement into classroom instruction. The aerobic-based group focused on traditional physical activities. The interventions were 10 min long and conducted at least three times per week over a period of 2 months.

3.4. Outcomes

Of the 19 studies reviewed, several main outcome domains were identified, although many studies investigated multiple outcomes simultaneously.

3.4.1. Active Break interventions Outcomes

Of the AB interventions, three assessed EFs (Howie et al., 2015; Egger et al., 2018; Layne et al., 2021), while three others evaluated on-task behavior (Howie, 2014; Watson et al., 2019; Riese, 2023). Five studies measured attention (van den Berg et al., 2016; Schmidt et al., 2019; van den Berg et al., 2019; Fiorilli et al., 2021; Müller et al., 2021), though none focused on it as the sole outcome. Math performance was evaluated in five AB interventions (Howie et al., 2015; Watson et al., 2019; Mavilidi et al., 2020; Fiorilli et al., 2021; Layne et al., 2021), with math anxiety also considered in one of them (Mavilidi et al., 2020).

EFs were measured using several standardized tests administered individually (e.g., Stroop Test, Trail making, working or semantic memory, fluency task, Go/No-Go test), as well as attention: d2 test (van den Berg et al., 2016; van den Berg et al., 2019); d2-R test (Schmidt et al., 2019; Müller et al., 2021); the Attention Network Test (van den Berg et al., 2019); Stroop Color and Word Test (Fiorilli et al., 2021). The effectiveness of the AB interventions on math performance was also commonly assessed using standardized math tests, typically aligned with the national syllabus or adapted from various sources. In one study (Fiorilli et al., 2021), there is a specific mention of a validated math test (Cornoldi et al., 2012).

On-task behavior was assessed by teachers or research staff both through direct classroom observations using different tools for coding and by reviewing recorded videotapes.

Improvements in EFs were observed in Layne et al. (2021), where authors found a positive effect on reaction time and response inhibition control after a cognitively engaging 10 min break. Egger et al. (2018), on the contrary, reported an "inverse effect of cognitive engagement", showing a negative impact of cognitive engagement (CE) during classroom PA on one core EFs (shifting) and no effects on updating or inhibition. The authors speculated that this outcome might be due to the length of the PA break (20 min), which may have been too long for second graders. Two other studies found that daily exercise breaks neither improved nor worsened the children's selective attention, inhibition, or semantic memory retrieval compared to the control group (Howie et al., 2015; van den Berg et al., 2019). However, van den Berg et al. (2019) stated that AB sessions of longer duration (exceeding 10 min and lasting more than 9 weeks) may be necessary to achieve beneficial effects on cognitive outcomes.

Positive effects and improved on-task behavior were observed in programs lasting between 4 and 6 weeks, but the optimal duration of each break remains unclear (Howie, 2014; Watson et al., 2019). For example, Watson et al. (2019) reported improvements in classroom behavior at the individual level after implementing 5 min breaks. In contrast, Howie (2014) found that AB improved students' on-task behavior after 10 min of exposure, with a trend to increase after 20 min, while no effects were found after shorter breaks.

Out of the studies that assessed attention, two reported a positive effect (Fiorilli et al., 2021; Müller et al., 2021), while three found no beneficial impact (van den Berg et al., 2016; Schmidt et al., 2019; van den Berg et al., 2019). Schmidt et al. (2019) hypothesized that this lack of effect may be due to the moderate intensity of the AB, the cognitive demand load of the condition of embodied learning, and the short duration of the program only (two weeks for the instruction phase).

Of the five studies that considered math performance, two found positive effects (Howie et al., 2015; Fiorilli et al., 2021); for example, in Howie et al. (2015), math scores were highest after the 10 min (ES = 0.24) and 20 min (ES = 0.27) active break conditions. The other three did not observe improvements in this area. In Watson et al. (2019), students in the intervention group showed, as mentioned before, a positive effect in on-task classroom behavior, but no intervention effect was found for math.

Only one study (Mavilidi et al., 2020) considered math anxiety in its analysis, using the Cognitive Anxiety Test Questionnaire as the assessment tool, administered before a high-difficulty math test. In addition, the children rated their perceived task difficulty and mental effort. The authors found that while anxiety levels fluctuated during the test and were associated with lower math performance, the activity break condition did not significantly affect the children's anxiety, mental effort, or perceived task difficulty compared to the control group. Furthermore, the authors noted that there was no evidence to distinguish math anxiety from general test anxiety.

Neither a short duration (5 min) nor an extended one (20 min) appeared to produce a positive effect on the observed outcomes, though there was some inconsistency in the results (Howie, 2014; Howie et al., 2015; van den Berg et al., 2016; Schmidt et al., 2019).

3.4.2. Curriculum-Based Active Break Interventions Outcomes

Among these studies, two assessed the impact of integrating CB into lessons (e.g., language and arts, geography, math) on academic-related outcomes, compared to traditional lessons, even though our focus was solely on CB into math lessons, as per the inclusion criteria of the SR. The other two studies examined cognitive factors (on-task behavior, EFs).

Of the CB interventions, two assessed math performance, Vazou and Skrade (2016) as the only outcome, and Have et al. (2018) combined with EFs, using timed and standardized math tests. The other two measured on-task behavior using a systematic direct observation strategy (Goh et al., 2016) and compared the time-on-task pre- and post-lesson (Bartholomew et al., 2018).

In Vazou and Skrade (2016), the intervention demonstrated medium-to-large effect sizes on math performance (post-test $d = 0.68$), especially when compared to the control group that followed a traditional curriculum without PA. Similarly, the study by Have et al. (2018) found positive effects ($d = 0.38$) on math skills but did not observe significant improvements in EFs. This lack of improvement in EFs may be attributed to the short duration of the PA (15 min) and the absence of intensity requirements in the intervention.

Evidence in the two studies incorporating CB into math and assessing on-task behavior reported an increase in on-task behavior both with an intervention that was short but intense (10 min per session, once a day over a period of four weeks; ES = 0.928) (Goh et al., 2016) and with a long-term intervention (10–15 min once a day over three years; $d = 0.32$) (Bartholomew et al., 2018). Overall, the results showed positive effects of CB on both math performance and on-task behavior, and no detrimental effects were observed.

3.4.3. Comparative Studies of AB and CB Interventions Outcomes

Those two studies primarily aimed to evaluate whether there were differences in the impact of academic-based breaks compared to aerobic-only movement breaks and/or traditional lessons. Both assessed math performance using standardized tests, and both showed positive but conflicting results. Fedewa et al. (2018) reported a small effect size ($d = 0.07$) in the group that implemented aerobic-only breaks. The authors emphasized the importance of providing genuine breaks from learning and cognitive effort rather than using PA solely to review academic content. On the contrary, the study conducted by Mavilidi and Vazou (2021) showed significant group-by-time effects on students' math performance in favor of the M4T group that implemented CB. This group performed better than the AB group (d = 0.44) and control group (d = 0.38), showing improvements in math achievement. Additionally, age was identified as a significant moderator, indicating that the intervention's impact varied depending on the students' ages.

3.5. Teacher Involvement and Intervention Fidelity

Of the 19 studies included in this systematic review, 11 (five of the AB interventions, all CB interventions, and both comparative studies) were led by teachers either from the start or at some point during the implementation. However, in eight studies implementing AB, the interventions were led by researchers (Howie, 2014; Howie et al., 2015; van den Berg et al., 2016; Egger et al., 2018; Schmidt et al., 2019; Mavilidi et al., 2020; Müller et al., 2021; Fiorilli et al., 2021). Of the studies led by teachers, one reported a specific collaborative approach (Watson et al., 2019), with both researchers and teachers participating through an "assisted roll-out".

Several studies also referenced training sessions for teachers and ongoing support from researchers. Varying levels of teachers' autonomy in implementation and involvement in the development and design of activities were highlighted. For example, regarding the AB interventions, the pilot program by Watson et al. (2019) was notably strengthened by involving teachers in the development phase of the intervention protocol. In some studies, teachers chose exercise breaks based on their preferences among pre-recorded videos (van den Berg et al., 2019; Riese, 2023), while in others, teachers were only responsible for turning on and off an active video game (Layne et al., 2021). It is worth noting that a key limitation of the latter study, pointed out by the authors, was the low involvement of teachers, as they had few opportunities to interact with the video game system or to choose the activities.

Interestingly, in all of the CB studies, the interventions were led by classroom teachers. Two studies noted a higher degree of teacher involvement, where teachers were either allowed to select activities that best suited the mathematical content of the lesson (Vazou & Skrade, 2016) or were trained to design physically active tasks or active math lessons in alignment with the curriculum (Have et al., 2018).

Teacher engagement and preferences played a significant role and should be explored further (Watson et al., 2019). According to findings of some studies, teachers reported favoring PA integration in the classroom to be curriculum-based because it was simple to implement, required minimal preparation time (van den Berg et al., 2016), and also due to time constraints and curriculum pressure.

Intervention fidelity was reported only in ten studies (6 led by teachers, 4 led by researchers) and was measured utilizing various tools, such as daily logs, checklists, the coding of videotaped sessions, and following up with the teachers.

Few studies provided information on adherence and compliance with the program. In Have et al. (2018), we found a comprehensive description of how intervention fidelity was assessed by teachers, recording many kinds of information (e.g., frequency and duration, name of the activity that was used, when it was used during the school day, the perception of the teachers as well as the experience of their students).

When the intervention was administered by research staff, high fidelity was noted (Schmidt et al., 2019), even if this type of program (researcher-led) can have some limitations in terms of sustainability (Howie et al., 2015).

4. Discussion

This systematic review examined the effects of AB and CB on EFs, attention, math performance, and math anxiety in primary school children. The analysis of 19 studies revealed several key findings and important considerations for future research and practice while also highlighting significant methodological challenges and areas for improvement.

The results pertaining to EFs and attention were inconsistent, reflecting the complexity of these cognitive processes and the variability in intervention approaches. Notably, Layne et al. (2021) reported improvements in reaction time and response inhibition control. Conversely, some studies found no significant effects of AB on selective attention, inhibition, or semantic memory retrieval compared to control groups (Howie et al., 2015; van den Berg et al., 2019). More significantly, Egger et al. (2018) observed a negative impact of cognitive engagement during classroom PA on shifting ability, a core executive function, while noting no effects on updating or inhibition. The authors posited that this outcome might be attributed to the duration of the AB (20 min), which may have been excessive for second-grade students.

The optimal duration of breaks remains contentious, with studies reporting varied outcomes. Positive effects were observed in AB programs lasting 4–6 weeks, with break durations ranging from 5 to 20 min (Howie, 2014; Layne et al., 2021). However, the ideal duration for each break remains unclear. van den Berg et al. (2019) suggested that longer interventions, exceeding 10 min per session and extending beyond 9 weeks, might be necessary for significant cognitive benefits. This result is consistent with the findings from the moderator analysis conducted by Sneck et al. (2019), which indicated that longer duration of intervention (e.g. 21 weeks) was negatively associated with effect sizes, suggesting that longer interventions are not necessarily more effective than shorter ones.

Despite the inclusion criteria encompassing STEM disciplines, it is noteworthy that the studies primarily analyzed results pertaining to math performance, neglecting outcomes in science, technology, and engineering. This narrow focus limits the comprehensive understanding of STEM performance as a whole.

The specific impact on math performance was varied, with some studies reporting positive effects (Howie et al., 2015; Fiorilli et al., 2021) and others finding no significant improvements. Notably, CB showed more consistent positive effects on math performance compared to non-curriculum-based interventions. This suggests that integrating PA with academic content may be particularly beneficial for enhancing math learning. These findings corroborate the results reported in the previous systematic review and meta-analysis conducted by Sneck et al. (2019), which demonstrated the positive effects of PA interventions on math performance in school-aged children. However, the limited research on math anxiety (Mavilidi et al., 2020) prevents drawing firm conclusions about the impact of active breaks on this outcome.

The comparative studies of AB and CB interventions yielded conflicting results, highlighting the need for more research directly comparing different types of break condition. These divergent findings also point to the importance of considering two main approaches in the literature on the effect of PA on academic achievement, as noted by Have et al. (2018). One approach investigates task-irrelevant whole-body movements not integrated into the learning task, focusing on health-related variables and their association with cognitive and academic improvements. The other approach examines task-relevant part-body movements integrated into the learning task based on the idea that cognitive functions are grounded in action and perception.

4.1. Methodological Considerations and Limitations

The studies included in this review offer valuable insights into the effects of AB and CB on EFs, math performance, and math anxiety in primary school children. A key strength of many studies lies in their rigorous design, with several employing randomized controlled trials or quasi-experimental methods, thus enhancing the reliability of the findings.

Nevertheless, several limitations were evident across the studies. The considerable heterogeneity in intervention designs, durations, and outcome measures posed a significant challenge for direct comparisons. While some interventions were short-term implementations of a few weeks, others spanned multiple years (Bartholomew et al., 2018), with varying frequencies of break condition. This diversity, although potentially enriching, complicates the synthesis of results.

Moreover, the assessment tools used varied widely across studies. Some researchers relied on standardized tests for EFs and math performance, while others employed more subjective measures or self-reports. This variability in assessment methods not only contributes to inconsistent findings but also limits the comparability of results across studies. Future research should consider using more ecologically valid measurement instruments, such as systematic observations, teacher logs, and tasks that mimic curricular activities, to provide a more appropriate representation of real-world effects (Watson et al., 2017a).

Another critical issue pertains to the fidelity of implementation, which was not consistently reported. When reported, fidelity measures varied widely, from teacher reports to objective measures of PA intensity. This inconsistency in reporting obscures the degree to which interventions were implemented as intended, potentially influencing the observed outcomes. The lack of consistent reporting on intervention fidelity limits our ability to draw firm conclusions about the relationship between implementation quality and outcomes. Future studies should prioritize clear reporting of fidelity measures to enhance the interpretability and comparability of results.

Additionally, the cognitive demands of the exercises used in interventions varied considerably. The inconsistent results regarding cognitive tasks in PA interventions, as noted by Layne et al. (2021), suggest that more research is needed to understand the optimal design of these activities. Schmidt et al. (2019) concluded that task-relevant activities that embody learning content can improve memory and attentional outcomes, likely due to the reduced cognitive load when actions and academic content are aligned. Future studies should systematically examine how different types of exercises and their cognitive demands impact learning outcomes, especially by exploring the symbolic alignment between movement and academic content.

Furthermore, the predominant focus on short-term effects in most studies limits our understanding of the sustained impact of these interventions over time. The scarcity of long-term studies examining the enduring effects of break condition on academic and cognitive outcomes represents a significant gap in the current research landscape.

4.2. Implementation and Sustainability

The review revealed important insights regarding the implementation and sustainability of PA interventions. Teacher involvement varied across studies, with some interventions led by researchers and others by classroom teachers. The level of teacher autonomy and involvement in designing activities appeared to be higher in CB interventions, suggesting that integrating PA into academic content may facilitate greater teacher engagement.

However, the sustainability of these interventions in real-world classroom settings remains a concern. As noted by Watson et al. (2017a), teacher preferences and the feasibility of implementing active breaks within busy classroom schedules are crucial factors to consider. Future research should explore strategies to enhance the sustainability of these interventions, including investigating optimal durations that balance effectiveness with practicality, and examining ways to efficiently integrate movement into existing curricular activities.

4.3. Practical Implications

Despite the mixed findings, this review suggests several valuable implications for educational practice. Incorporating short active breaks into the primary school day appears to be generally beneficial and does not detract from academic performance. The positive effects on on-task behavior and the potential for enhancing math learning through CB are particularly promising.

When implementing active breaks, teachers should consider several key factors. The duration and frequency of these breaks play a crucial role, with sessions of 10–12 min appearing most effective and feasible within classroom schedules. This timeframe seems to strike a balance between providing sufficient PA and maintaining instructional time. Additionally, the integration of PA with academic content, as seen in curriculum-based active breaks, may enhance both student engagement and learning outcomes. This approach not only maximizes the use of classroom time but also reinforces academic concepts through kinesthetic learning experiences, highlighting the advantages of task-relevant PA on learning outcomes and aligning with the embodied cognition theory (Schmidt et al., 2019).

The success of these interventions heavily relies on teacher involvement and support. Providing adequate training and ongoing support for teachers is crucial for successful implementation. This includes not only initial instruction on how to conduct active breaks but also continuous guidance on integrating movement into various subject areas, particularly math.

Furthermore, interventions should be designed with flexibility in mind, allowing for adaptation to different classroom environments and student needs. This adaptability ensures that active breaks can be effectively implemented across diverse educational settings, accommodating varying space constraints, student abilities, and curricular demands.

Careful consideration should also be given to the cognitive load of active break activities. While some cognitive engagement may be beneficial, overly demanding activities might lead to cognitive fatigue and potentially negative outcomes. Striking the right balance in this regard is essential for maximizing the benefits of active breaks. By thoughtfully implementing these practices, schools can more effectively integrate AB and CB into their daily routines. This approach has the potential to yield improvements in EFs, enhance on-task behavior, and boost math performance among primary school students. The key to success lies in a thoughtful implementation strategy that considers duration, curriculum integration, teacher support, and contextual adaptability.

4.4. Areas for Future Research

Several areas for future research emerge from this review. Longitudinal studies are needed to understand the long-term effects of active break conditions on academic and cognitive outcomes. These studies are necessary to establish if the accumulated benefits of daily improvement in attention, impulse control, and executive functions after each lesson integrated with PA are related to long-term academic performance.

More research is also required on the impact of these interventions on students with SEN, as this population was underrepresented in the current literature. Examining how AB and CB impact students with Attention-Deficit/Hyperactivity Disorder (ADHD), learning disabilities, or other special educational needs and whether tailored approaches are necessary for these populations would fill a significant gap in the current literature.

Additionally, teacher engagement and preferences play a significant role and should be explored further (Watson et al., 2017a). Understanding how teachers perceive and implement AB and CB, as well as their preferences for different types of activities, could provide valuable insights for designing more effective and sustainable interventions. Along with this, investigating the factors influencing teacher adoption and sustained implementation of active breaks in real-world classroom settings is crucial. This could involve exploring teacher preferences, identifying barriers to implementation, and developing strategies for seamlessly integrating active breaks into existing curricula.

According to Sneck et al. (2019), despite the promising results, further replication studies are necessary to establish a potential causal relationship between AB and/or CB and EFs and STEM performance. These studies should employ consistent measurement techniques, ensure adequate sample sizes, and incorporate carefully designed control groups. Moreover, future studies should prioritize clear reporting of intervention fidelity measures. This emphasis on fidelity would enhance the interpretability and comparability of results and provide valuable insights into the relationship between implementation quality and outcomes. Future studies should aim to standardize measures and intervention protocols to facilitate more direct comparisons across studies. Additionally, research should explore the optimal balance of cognitive engagement and PA in these interventions, as well as investigate the most effective strategies for integrating movement into the primary school curriculum.

5. Conclusions

This systematic review makes several important contributions to our understanding of movement-based interventions in primary education. Comprehensively analyzing both AB and CB provides educators and researchers with a clearer picture of how different types of movement integration might support children's learning, particularly in mathematics. While the evidence is mixed, the overall trend suggests that these interventions can be valuable tools for promoting PA and potentially enhancing cognitive and academic outcomes. The analysis of intervention characteristics and implementation factors offers practical guidance for teachers and school administrators.

Furthermore, by highlighting the limited research on math anxiety and other STEM subjects beyond mathematics, this review identifies crucial gaps in the literature that need to be addressed. Indeed, although mathematics represents a crucial component of STEM education, the evidence base for other STEM subjects remains limited, suggesting a pressing need to expand research beyond mathematics, especially considering the growing importance of these disciplines in education and future careers.

The potential impact of active break conditions on both math performance and wider STEM learning is intriguing, especially considering the diverse cognitive demands these subjects place on young learners. While the current evidence for math is encouraging and provides a solid foundation for understanding the relationship between physical activity and learning, it also underscores the necessity for continued investigation to fully understand and optimize the benefits of AB and CB across all STEM fields.

These contributions are particularly timely given the increasing emphasis on STEM education and the growing recognition of physical activity's importance for children's holistic development. By building upon the positive findings in math and addressing the gaps in other STEM areas, future research can provide more comprehensive insights into how movement-based interventions can support children's academic development from an inclusive perspective. This ongoing work is crucial for developing evidence-based practices that enhance both PA and cognitive performance across the full spectrum of STEM disciplines. As research in this field progresses, it will play a vital role in shaping educational policies and practices that holistically support all children's development and academic success in an increasingly STEM-focused world.

Supplementary Materials: The codebook (S1) and the table containing quality score assignation (S2) and percentage calculation (S3) are available at the following link. https://drive.google.com/file/d/1FSyFToJ5hPj3DlCcwOJyE95ns2EpsaIw/view?usp=sharing, accessed on 29 September 2024.

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Appendix A

Query string: "primary school" OR "elementary school" OR "primary education" OR "elementary education" AND "active break" OR "physical activity" OR "brain break" OR "movement break" OR "physically active lesson" OR "exercise break" OR mindfulness OR yoga OR meditation AND "executive functions" OR attention OR "cognitive outcomes" OR cognition OR "attention deficit hyperactivity disorder" OR adhd or "attention deficit" OR "on-task behaviour" OR "on-task behaviour" OR "off-task behaviour" OR "off-task behaviour" OR "educational outcomes" OR "academic outcomes" OR assessment OR evaluation OR performance OR "math anxiety" AND mathematics OR math OR "math education" OR "mathematics education" OR "stem education" OR "steam education" OR science OR technology.

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