### REVIEW

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# Effects of flexible learning spaces, active breaks, and active lessons on sedentary behaviors, physical activity, learning, and musculoskeletal health in school-aged children: a scoping review



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### Abstract

**Background** Children aged 6 to 17 spend long periods of sitting at school. Reducing these behaviors and increasing physical activity has been linked to improvements in cognitive functions and decreased musculoskeletal issues. The purpose of this scoping review was to describe interventions implementing flexible learning spaces, active breaks, and active lessons and their effects on sedentary behaviors as well as on physical activity, learning, and musculoskeletal health.

**Methods** A search on databases (EDUCATION SOURCE, ERIC, SPORTDISCUS, MEDLINE, EMBASE, and WEB OF SCIENCE) was carried out in April 2021 and updated in June 2022 according to the guidelines of the "PRISMA-ScR". Studies on flexible learning spaces and physical activity in elementary and secondary school classes were retained. These also had to measure the effects of the interventions on sedentary behaviors, physical activity, learning (e.g., academic achievement), and musculoskeletal health outcomes.

**Results** Ninety-two articles were identified; twenty-four from the initial screening, thirty-two from the update, and thirty-six were manually included. Among these 92 articles, twenty-one studies used only flexible learning spaces, twenty-three used only active breaks, thirty-six used only active lessons, four used both flexible learning spaces and active breaks separately in different classes, five combined active breaks and active lessons, and three combined flexible learning spaces and active breaks. Analyses show positive changes in sedentary behaviors (32 articles/40) and physical activity (52 articles/74) including sitting time, sit-to-stand transitions, number of steps, and moderate-to-vigorous physical activity. Positive effects were also observed on learning (13 articles/26) or musculoskeletal health outcomes (3 articles/8). Although many studies found no effect of these interventions, no studies report harmful

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interventions on these variables. The most effective strategy to reduce sedentary behaviors seems to be flexible learning spaces with adapted teaching approaches.

**Conclusions** Results indicate that flexible learning spaces, active breaks, and active lessons effectively reduce sedentary behaviors and increase physical activity without negatively influencing academic achievement. Further studies are needed to understand better the effects of combining these interventions and their effects on children's learning and musculoskeletal health outcomes.

**Keywords** Flexible learning spaces, Active breaks, Active lessons, Sedentary behaviors, Physical activity, Academic achievement, Musculoskeletal disorders

### Background

Characterized as activities involving sitting or lying down with a metabolic equivalent  $\leq 1.5$  (METs) [1], sedentary behaviors can have a negative impact on several aspects of children's health regardless of physical activity [2]. They also have been associated with detrimental effects on body composition, social behaviors, physical fitness, and self-esteem [3]. Decreasing sedentary behavior is associated with increased cognitive functions and decreased musculoskeletal disorders [4]. The latest recommendations for children suggest limiting recreational screen time to less than two hours a day, reducing prolonged periods of sedentary behavior, and promoting regular physical activity, although there are no specific guidelines for overall sedentary time [1]. Despite this, Canadians aged 5 to 17 accumulate an average of eight hours of sedentary time daily [5, 6], with half of them spending more than 2 h a day on leisure screen use [7], and only a quarter of them achieving an average of 60 min of moderate-to-vigorous physical activity per day [8].

Children and adolescents demonstrate suboptimal habits regarding both sedentary behaviors and physical activity, which is particularly problematic given that the longest periods of sitting occur during school hours [9]. Despite school being an environment encouraging healthy lifestyles, it has been shown that 63% of the time children and adolescents spend at school is sedentary [10]. Confronted with this problem, educational systems worldwide are undergoing a shift in their pedagogical approach, aiming not only to enhance student academic achievement and promote physical activity, but also to reduce sedentary behaviors [11]. Given the substantial impact of educational environments on sedentary behaviors, it becomes evident that innovative solutions are necessary to address these trends. Classrooms are increasingly recognized as promising, with initiatives like flexible learning spaces [12], active breaks [13], and active lessons gaining attention [14].

Among innovative solutions, "flexible learning spaces" involve completely or partially transforming classrooms with flexible layouts, integrating fixed or movable furniture to create individual and collaborative workspaces. These physical changes are also often implemented with personalized teaching approaches by teachers [12]. Other interventions will incorporate short, teacher-led "active breaks" lasting 5 to 15 min within classrooms or nearby areas [13], with some integrating elements of the school curriculum into these breaks to transform them into "active lessons" where physical activity is utilized in various ways [14]. The key difference between the two is that in active breaks, physical activity serves primarily as a pause from academic learning, whereas in active lessons, physical activity is directly integrated into the learning process to support the curriculum. These strategies are employed individually or in combination and can be integrated into a comprehensive health promotion program within the school.

Certain reviews have already summarized the outcomes of school-based interventions focusing specifically on classroom interventions like flexible learning spaces, active breaks, or active lessons [12, 13, 15-22]. However, an exhaustive review on the effects of all interventions related to flexible learning spaces, active breaks, and active lessons or their combined effects has not been performed. Furthermore, while existing reviews mainly outline the individual effects of interventions on sedentary behaviors or physical activity, they do not comprehensively evaluate their effects on sedentary behaviors, physical activity, learning, and musculoskeletal health outcomes, particularly when combining multiple intervention approaches. The purpose of this scoping review was: (1) to describe the characteristic of the interventions involving flexible learning spaces, active breaks, active lessons, and their combinations; (2) to summarize their effects on sedentary behaviors as well as on physical activity, learning, and musculoskeletal health; and (3) to identify the best practices for future interventions in classrooms aimed to decrease sedentary time.

#### Methods

#### Design

This review was prospectively registered on the Open Science Framework (October 29, 2024; https://doi.org/1 0.17605/OSF.IO/HVKXA). This scoping review was done following the preferred reporting items for systematic

reviews and extending meta-analyses for scoping reviews (PRISMA-ScR) list [23]. The research was conducted in two times (i.e., initial screening and update) focusing on the following themes: (1) flexible learning spaces, active breaks, and their effects on sedentary behaviors and physical activity; and (2) flexible learning spaces, active breaks, active lessons, and their effects on sedentary behaviors, physical activity, learning outcomes, and musculoskeletal health. This scoping review adheres to the framework proposed by Arksey and O'Malley to describe the interventions and their effects to establish guidelines without considering the quality of the studies [24].

#### **Research questions**

The research questions were: (1) What are the characteristics of the interventions incorporating flexible learning spaces, active breaks, and active lessons, either individually or in combination, that have been implemented in elementary and secondary school settings; (2) What are the effects of these interventions on sedentary behaviors as well as on physical activity, learning, and musculoskeletal health outcomes in children; and (3) What are the best practices for future interventions in classrooms aimed to decrease sedentary time?

#### Literature search

A literature search was conducted with support from a librarian (MDL). A first search was carried out in April 2021 and was updated in June 2022 based on the concepts "students/children/adolescents", "classroom/ school/ergonomic", "activity break/physical activity/sedentary behaviors", and "teaching/pedagogy" with variants adapted for each database if applicable. During the update of the first search, other concepts were added to capture more articles on flexible learning spaces and active breaks, as well as on active lessons and their effects on sedentary behaviors, physical activity, learning, and musculoskeletal health. The following databases were accessed: SPORTDiscus, ERIC, EDUCATION SOURCE, MEDLINE, EMBASE, and WEB OF SCIENCE [See Additional file 1 for detailed search methodology].

To be included in the review, studies must meet the following criteria: (a) quantitative research; (b) related to flexible learning spaces and/or active breaks and/or active lessons; (c) conducted in elementary or secondary school classrooms; (d) focused on sedentary behaviors and/or physical activity and/or learning (i.e., academic achievement) and/or musculoskeletal health (i.e., disorders, discomfort, and ergonomics); and (e) written in English or French. Studies were excluded if they: (a) focused on the layout of the schoolyard; (b) were specific to interventions outside the classroom (logistical differences between indoor and outdoor interventions (e.g., supervision, access to spaces)); (c) involved a specific clinical population (e.g., obesity, diabetes); (d) were conducted in non-traditional educational settings; (e) were conducted in daycare centers or higher education institutions; and (f) were unpublished.

#### **Study selection**

All references were imported into EndNote 20 software (Clarivate Analytics, Philadelphia, USA). After removing duplicates, the remaining titles and abstracts were screened on Covidence by two independent reviewers (DL and CLM) according to the inclusion/exclusion criteria. Full texts of the remaining articles were subsequently screened using the same criteria. Discrepancies were resolved by a third reviewer (ASA, VBP, or EB) and consensus was reached regarding all articles included. Reference lists of included articles and other review articles were also manually examined, leading to the identification and inclusion of thirty-six additional studies.

#### Data charting

The research team created a data extraction table in Microsoft Excel by identifying different variables aligned with the objectives of the scoping review. Then, two reviewers independently extracted information from relevant articles consistently and organized the data accordingly. The key variables included citation details, behaviors targeted by the intervention, objectives, sample population, research design, intervention specifics, data collection methods and measures, and main results (i.e., primary results related to sedentary behaviors, physical activity, learning, or musculoskeletal health).

#### Summarizing and reporting the results

The selection process and the number of rejected articles were illustrated using PRISMA diagrams for the initial search and the update incorporating articles included manually (Fig. 1). Tables were used to summarize the articles retained (Additional files 2, 3, 4, 5). In preparing this manuscript, the authors utilized OpenAI's GPT-4 language model for English editing.

#### Results

One thousand eight hundred fifty-eight articles were initially identified and imported into the Endnote software. After removing duplicates, one thousand three hundred eighty-six peer-reviewed articles were screened based on title and abstract. Among these, one hundred two articles underwent full-text assessment, and twenty-four studies met our inclusion criteria. The main reasons for exclusion were study design (e.g., interventions limited to playground settings), study outcomes (e.g., emphasis on time-on-task rather than academic achievement), and population (e.g., focusing on preschool or university populations instead of elementary or secondary school



Fig. 1 PRISMA flow diagram of study selection process. The left section represents the initial research, while the right section illustrates the updates with new keywords, and the isolated square indicates the studies that were manually added

levels). In the second research (update), four hundred seventy-six articles were screened based on title and abstract, followed by a full-text assessment of ninetynine articles. Thirty-two studies met our inclusion criteria, with exclusion reasons like the initial screening. Additionally, thirty-six articles were manually included from the references of selected articles and via targeted searches. Overall, ninety-two articles were selected: seventy-four reported intervention outcomes exclusively conducted within the classroom (referred to as "classroom-based physical activity (CBPA)") and eighteen presented outcomes of interventions within the classroom complemented by other interventions in the school settings (referred to as "school-based physical activity (SBPA)"). The study sizes ranged from 8 to 4 905 participants, with 47 502 students across the ninety-two included studies. Specifically, 12 175 participants were tested for sedentary behaviors, 28 313 for physical activity, 6 686 for learning, and 328 for musculoskeletal health outcomes.

## What are the characteristics of the interventions? *Flexible learning spaces*

Twenty-five studies implemented interventions that modified classes into flexible learning spaces [25–49]

(Additional file 2). Seventeen interventions involved replacing all traditional desks with either sit-stand desks or standing desks [25-27, 30-32, 35-38, 41-47], of which fourteen also replaced the chairs [25-27, 31, 32, 35-37, 41-43, 45-47]. Eight interventions, presented across nine articles, rather modified the classes by adding different types of flexible furniture while retaining traditional desks and chairs [28-30, 33, 34, 39, 40, 48, 49]. In addition to standing desks, the main features of flexible learning spaces included Swiss balls [25, 33-36, 39, 40], stools [26, 28, 29, 42, 45, 46], mats [25, 27, 35, 36, 39, 49], fidget bars [32, 41], mobile whiteboards [37, 39], beanbags [36], or height-adjustable bicycle desks [47]. Beyond adding or replacing furniture, it was also arranged in a way to allow a collaborative learning approach in four interventions [27, 35, 37, 49] and the teaching method was adapted in nine interventions (ten studies) to allow changes of sitting (e.g., with a rotation system) [28–31, 38, 42, 43, 46, 48, 49]. Nine of the twenty-five studies using flexible learning spaces indicated teacher training [27-31, 36, 38, 42, 43, 48], five of which were focused on education (e.g., the importance of healthy lifestyle habits and how to adopt good posture) [27, 31, 38, 42, 48] and four also enhanced pedagogical skills (e.g., use of goal settings, problem-solving sessions) [28-30, 43]. For example, in

addition to informing teachers about flexible learning spaces, Chen et al. 2021 first introduced teachers and students to behavior change techniques such as goal setting and then supported teachers in modifying the classroom and developing a rotation plan [28]. Within the studies that modified classroom settings, some chose simple interventions such as changing furniture, while others undertook more comprehensive environmental changes. A notable example is the study by Lanningham-Foster et al. 2008, which implemented a two-week activity-permissive environment followed by eight weeks of standing classes. The activity-permissive environment, which included miniature golf and basketball hoops, featured standing desks, mobile whiteboards, anti-fatigue mats, and stability balls [39]. Thus, most interventions aiming to create flexible learning spaces did not train the teachers or use alternative pedagogical strategies like collaborative approaches or rotation plans. Instead, most flexible learning space interventions focused on transforming classroom furniture, primarily using sit-stand desks.

#### Active breaks

Twenty-seven studies used interventions in which physical activity was employed to implement active breaks [40, 50–75] (Additional file 3). The active breaks ranged in duration from 5 [40, 52, 55-59, 66-68, 71, 74, 75], 10 [51, 53, 54, 59, 61, 64, 66, 69, 71, 72, 75], 15 [50, 58, 62, 70], or 20 min [60, 64, 66] and, when specified, were of moderate-to-vigorous intensity [52, 62, 63, 66, 68, 72, 74]. Twenty-three interventions were previously developed and provided activities to teachers [40, 50-52, 54-64, 68–75], while one study allowed teachers to create activities instead [53]. In preparation for active breaks, nine interventions solely provided training on these activities [50, 52, 56, 58, 61, 63, 70, 73, 74], and six interventions additionally developed skills on active breaks (i.e., how to promote physical activity in the class and how to present active breaks) and classroom management [51, 54, 55, 59, 60, 65]. The interventions were mainly led by teachers [40, 50, 51, 53–56, 58–62, 65–67, 69, 70, 73, 75]. However, in eight cases, videos or PowerPoint documents prepared beforehand by the research team were used to implement the active breaks with the students [52, 57, 63, 64, 68, 71, 72, 74]. Active breaks included a variety of physical activities such as exercises (e.g., push-ups, squats, stretching, running in place, jumping) or dancing conducted either on-site [40, 56, 58, 61, 62, 66, 69, 73] or in the entire class [54, 55]. Finally, beyond active breaks, eight studies reported interventions outside the classroom which also aimed to reduce sedentary behaviors and increase physical activity [50, 54, 55, 67, 70, 71, 73, 75]. Among these, four proposed variations for physical education classes (e.g., increasing the number of classes per week or using different learning approaches to increase physical activity) [54, 55, 67, 75], three studies implemented interventions in the playground to encourage physical activity among students [54, 55, 71], one intervention used active homework [67], and another encouraged parental support with newsletters [73]. In summary, most active break interventions consisted of 5-to-10-minute moderate-to-vigorous physical activities designed by the research team and provided to teachers who led the intervention after specific training.

#### Active lessons

Thirty-six studies used interventions in which physical activity was used directly in lessons.

[39, 61, 68, 76-108] (Additional file 4). The duration of active lessons ranged from 5 [68, 105], 10 [61, 76, 77, 79, 81-84, 86, 87, 89, 90, 95, 97, 99, 106, 107], 15 [77, 86, 102], 20 min or more [88, 91–94, 98, 100, 101, 104]. Teachers received training before giving active lessons in twenty-one studies [61, 77-84, 87, 89, 90, 92, 93, 95, 96, 98, 101-103, 108] and six of these also reported integrating skill development sessions for managing and enhancing active lessons within the classroom [77-81, 101]. Studies where classes did not receive training were either already familiar with the active lessons [76], the intervention was done by the research team [68, 86, 100, 104], or it was not mentioned [39, 85, 88, 91, 94, 97, 99, 105–107]. Activities were provided to teachers in all the studies except for four cases [39, 76, 91, 100]. Ten interventions additionally provided material/furniture such as jump ropes, balls, mats, bean bags, posters, and mats [39, 77, 78, 80, 85, 87, 88, 91, 101, 104]. The targeted intensity of physical activity was moderate-to-vigorous [68, 76, 79, 82-84, 86, 92-95, 97, 102, 106, 107], except for two interventions that implemented light physical activities [96, 104]. Certain studies incorporated technology either to enhance lessons [78, 80, 85, 88, 92-95, 104, 105] or as a tool (e.g., interactive whiteboard, mats for mathematics activities, audio kit device) [85, 88, 92, 93, 104]. Twenty-six studies outlined the timing of the active lessons, with twenty-two specifying their integration during mathematics classes [61, 68, 76-79, 81-85, 90, 92, 93, 96, 98, 100, 101, 103, 105-107], twelve interventions occurring within literature lessons (i.e., language arts, English, Portuguese, Spanish) [61, 79, 82-84, 88, 90, 92, 93, 96, 97, 103], five during social studies classes [82–84, 96, 98], four during science courses [82-84, 103], three during geography classes [94, 95, 103], two during art classes [77, 103], and one during history lessons [103]. Lastly, apart from active lessons, three studies reported influencing sedentary behaviors and physical activity outside of class [78, 102, 108]. Among these, two studies implemented interventions in physical education classes (e.g., strategy to emphasize moderate-to-vigorous physical activity) [78, 108], two during recess [78, 102], and two

beyond school hours, either through active homework [102] or by involving parents with specific resources [78]. While half of the interventions lasted 10 min, longer sessions (i.e., 20 min and beyond) were more prevalent for active lessons than active breaks. Most active lessons included activities aimed at moderate-to-vigorous physical activity during mathematics lessons and training was provided to most teachers before the intervention.

# Combination of flexible learning spaces, active breaks, and active lessons

Eight studies included a combination of two strategies, either active breaks and active lessons [109–112], or flexible learning spaces and active breaks [113–116] (Additional file 5). The active break and active lesson interventions used were 2 min [113, 115, 116], 5 min [111, 114], or vaguely described as 0 to 20 min [109] or 5 to 15 min [112]. All interventions started with training towards the activities [109-116], except for Contardo Ayala et al. 2016, which also addressed pedagogical approaches [115], and Christiansen et al. 2021, which did not incorporate any training [114]. The intensity of physical activity during breaks or lessons was low [113–116], vigorous [111], or both [112]. Among the four interventions focusing on flexible learning spaces, two replaced all furniture with height-adjustable sit-stand desks and stools [115] or standing tables and desk bikes [114]. Parrish et al. 2018 opted to enhance the traditional furniture by incorporating five "stand-based" student desks, two "free-standing" whiteboards (with wheels), and two standing outdoor tables [116]. The three interventions utilized additional educational approaches such as creating stations and rotation plans [114, 116] or promoting reducing sitting and increasing physical activity [115, 116]. The fourth intervention does not mention a change in classroom supplies, but they included standing time during classes [113]. In addition to in-class interventions, six of the eight interventions also incorporated out-ofclass components [110–114, 116]. More precisely, five interventions were implemented during physical education (e.g., reflection on the intervention and the effects of increasing moderate-to-vigorous physical activity on physical and mental health) [110-112, 114, 116], four interventions promoted physical activity during recess (e.g., providing access to sports equipment during recess and lunchtime) [110, 112, 113, 116], and two interventions engaged parents to promote physical activity at home [111, 113]. Globally, studies combined active breaks and active lessons, or flexible learning spaces and active breaks and most interventions included training. None of the studies combined all three strategies. Most interventions involving active breaks and active lessons lasted less than 20 min and most interventions used flexible learning spaces and modified furniture while incorporating various teaching approaches. Combined interventions frequently extended to environments beyond the classroom, including physical education classes, recess, or activities at home, aiming to reduce sedentary behaviors and increase physical activity.

#### What are the effects?

The following section summarizes the effects of flexible learning spaces, active breaks, and active lessons on sedentary behaviors as well as on physical activity, learning, and musculoskeletal health outcomes in children. A comprehensive overview of these effects is presented in Fig. 2.

#### Sedentary behaviors

#### Flexible learning spaces

In eighteen studies modifying the classroom environment with flexible furniture, sedentary behaviors were measured through variables such as sitting time, standing time, and fragmentation of sedentary periods (e.g., number of sit-stand transitions and sitting bouts) [25, 27-30, 32, 35-38, 41-46, 48, 49]. Seven of ten studies that evaluated sedentary behaviors throughout the entire day reported positive outcomes for either sitting time alone [28, 29, 48], standing time alone [30], sitting time, standing time, and sit-to-stand transitions [42], or sedentary time [38, 46]. Although most of these studies reported positive outcomes, compensation in out-ofschool behaviors was observed in six of the eight studies that separately measured behaviors over an entire day including at home, in class, or at school [28–30, 32, 44, 48]. The only intervention that positively influenced sitting time, standing time, and sit-to-stand transitions both in class and throughout the entire day (i.e., showing positive effects in the classroom without compensatory changes in other periods of the day) is the one detailed in the study of Sherry et al. 2020 [42]. This intervention included posture training, posters to promote good posture, adjustable sit-stand desks for all students, and instruction for teachers to stand during the first 20 min of each lesson to encourage a standing work norm. Most interventions incorporating flexible learning spaces resulted in positive changes in sitting time, standing time, and sit-to-stand transitions. However, compensatory behaviors were observed in some studies outside of school during the intervention period.

#### Active breaks

Six studies integrating active breaks measured sedentary behaviors assessing various variables such as inactive/ sedentary time, the number of sedentary breaks, and the duration of prolonged sedentary periods lasting more than 10 min [56, 64, 71–73, 75]. Among the five studies that focused on total sedentary time, three reported significant positive changes at school resulting from



**Fig. 2** The effects of flexible learning, active breaks, and active lessons on main outcomes (i.e., sedentary behaviors, light intensity physical activity (LPA), moderate-to-vigorous intensity physical activity (MVPA), academic performance, and physical discomfort). In brackets, first number indicates the number of studies which found these results and second number indicates the total number of studies which measured this outcome. (†) indicates that the variable increases, while ( $\downarrow$ ) signifies that the variable decreases, and (Ø) means that the variable did not change

active break interventions [56, 64, 71]. These interventions were short in duration (5–10 min), occurring once or twice a day, several times a week, and used locomotor skill games. Thus, over half of the active break interventions effectively reduced sedentary time by implementing short on-site exercise breaks.

#### Active lessons

Sedentary behaviors were assessed in ten studies implementing active lessons [77, 82, 90, 94, 95, 100–103, 107], two studies measured sitting time, standing time, or the number of sit-to-stand transitions [82, 103], while the remaining eight studies measured solely sedentary time [77, 90, 94, 95, 100-102, 107]. Seven of those studies observed significant positive changes within the classroom [77, 82, 94, 95, 100-102]. Despite several studies implementing 10-to-15-minute active lessons, only Bartholomew et al. 2018, Norris et al. 2018, and Seljebotn et al. 2019 reported significant reductions in sedentary behaviors [77, 95, 102]. This suggests that the duration of the active lessons did not solely influence the effects on sedentary behaviors. Riley et al. 2015 and Riley et al. 2016 are the only ones to report reductions in sedentary behaviors within the classroom and throughout the entire school day [100, 101]. They integrated movementbased learning experiences into mathematics lessons, conducted three times a week for 60 min each session to teach and reinforce mathematical concepts. Riley et al. 2015 were implemented by the research team, whereas Riley et al. 2016 involved training teachers on the activities and emphasizing the importance of physical activity [100, 101]. Globally, most interventions incorporating active lessons through whole-class games and on-site exercises positively impacted sedentary time in the classroom. However, the duration of the lessons or teacher training alone does not seem to exert enough influence to decrease sedentary behavior throughout the day.

## Combination of flexible learning spaces, active breaks, and active lessons

Sedentary behaviors were measured with outcomes such as sedentary time, sedentary bouts, sitting, and standing time in seven studies implementing a combination of two interventions including flexible learning spaces, active breaks, and active lessons [109-116]. Among these, four studies reported positive effects of interventions on sedentary behaviors. One intervention observed reductions in sitting bouts both in class and at school [115] and three interventions observed reductions in sedentary time, either throughout the entire day [113], at school [110], or within classroom settings [109]. Of these interventions, two integrated, flexible learning spaces and active breaks [113, 115] and two combined active breaks and active lessons [109, 110]. Contardo Ayala et al. 2016 trained the teachers to used flexibles learning spaces with material such as sit-stand desks and to incorporated

2-minute active breaks and standing periods [115]. Parrish et al. 2018 similarly added flexible seating and 2-minute breaks, but focused less on teacher skill development [116]. Unlike Contardo Ayala et al. 2016, Parrish et al. 2018 found no significant changes in sedentary behaviors, suggesting skill development may be crucial. Carson et al. 2013 also observed reductions in sedentary time using 2-minute active breaks and standing periods without adding equipment to the classrooms. However, they promoted key messages in class with teachers and engaged parents [113]. Combining active breaks and standing periods effectively reduces sedentary behaviors, whether done with or without flexible furniture. Moreover, components such as skill development, the adaptation of teaching methods, and interventions beyond the classroom (e.g., involvement of parents) show promise in influencing behaviors throughout the day.

#### **Physical activity**

#### Flexible learning classes

The effects of physical activity were measured in twentytwo studies out of twenty-five [25-30, 32, 33, 35-39, 41–49] utilizing variables such as step count or duration of stepping or walking [25, 26, 28-30, 33, 36-38, 42-44, 48, 49], time in light physical activity [28, 29, 32, 35, 38, 41, 43, 45, 46], and time in moderate-to-vigorous physical activity [28, 29, 32, 35, 38, 41, 43, 46, 49]. Of these studies, twelve measured physical activity throughout the entire day [25, 28-30, 32, 38, 41-44, 46, 48] and ten observed behaviors within the classroom or at school [26, 27, 33, 35–37, 39, 45, 47, 49]. Nine interventions incorporating flexible learning spaces out of twenty-two led to significant positive changes in students' physical activity levels; six impacted the number of steps, stepping, or walking time [25–28, 37, 39], while four influenced the duration of moderate-to-vigorous physical activity [28, 35, 38, 43]. Flexible learning classes that positively affected physical activity varied in their setups, with some maintaining traditional furniture like desks and chairs [28, 38] or even replacing all furniture with standing desks and stools [25, 26, 39, 43], while others introduced inclined tables [27], mobile furniture [35], grouped tables, ottomans, couches, and writeable tables and walls [37]. When traditional materials were retained in the classrooms, the interventions included pedagogical strategies such as educating on the importance of a healthy lifestyle [38] or implementing rotation plans [28]. Globally, more than half of studies implementing flexible learning spaces did not yield significant changes in physical activity, but those that did primarily observed changes in low-intensity activity.

#### Active breaks

Physical activity was assessed in twenty studies through variables such as number of steps [51, 53-55, 59, 61, 63, 64, 69, 70] or physical activity of light [56, 64] or moderate-to-vigorous intensity [50, 52-54, 56, 58, 64, 67, 71, 72, 74, 75]. Eight of ten studies that measured school steps reported significant positive changes [51, 53-55, 59, 61, 64, 69]. Only Naylor et al. 2008 assessed the total daily step count, but they did not observe any significant changes following the intervention [70]. Studies that measured moderate-to-vigorous physical activity during classes or at school reported significant positive changes resulting from the intervention [52–54, 56, 71, 72, 75], except for Watson et al. 2019 [74]. The three interventions that measured physical activity throughout the day also observed positive changes following active breaks [50, 58, 67]. Bailey et al. 2015 conducted a study involving the same intervention (two active breaks of 10-20 min each) with different durations (five, seven, or nine weeks). They noted positive changes in step counts in each situation, showing that a 5-week intervention can influence the number of steps during a school day [51]. Beemer et al. 2019 compared two similar protocols (five bouts of 4 min of moderate-to-vigorous physical activity) with one group including competition, and they observed a favorable increase in physical activity in the competitive group [52]. Thus, active breaks generally positively affected light and moderate-to-vigorous physical activity.

#### Active lessons

Physical activity was assessed in twenty-eight studies [39, 61, 76-84, 86, 87, 89, 90, 94-104, 107, 108]. Among these, nineteen studies measured step counts or duration of light physical activity [61, 76, 77, 80, 81, 83, 84, 89, 90, 94-96, 99-104, 107] and fifteen studies measured the duration of moderate-to-vigorous physical activity [77, 79-81, 83, 87, 90, 94, 95, 100-103, 107, 108]. An increase either within the classroom, during school hours, or both following active lessons typically lasting between 10 and 15 min was reported in fourteen studies that assessed step counts or light physical activity [61, 76, 77, 80, 81, 84, 89, 94, 95, 99-103] and thirteen studies that measured moderate-to-vigorous physical activity [77, 79, 80, 83, 87, 90, 94, 95, 100-102, 107, 108]. The intensity of interventions is not always detailed, but interventions implementing moderate-to-vigorous physical activity during active lessons have consistently shown positive outcomes for step counts [76, 77, 83, 84, 94, 95, 102]. Donnelly et al. 2009 incorporated 10-minute active lessons (i.e., Take 10! Activities) aiming to achieve 90 min of moderate-to-vigorous physical activity per week, along with training on skill development and promoting physical activity [79]. Ultimately, this intervention increased physical activity at school, throughout the day, and even on weekends. Seljebotn et al. 2019 instead conducted 15-minute moderate-to-vigorous active lessons multiple times during the day (i.e., each lesson, 2–3 days per week), completed by training, active homework (10 min per day) and recommendations for active recess (10 min per day) [102]. These comprehensive strategies increased step counts and moderate-to-vigorous physical activity throughout the day. Active lessons represent thus an interesting strategy to positively influence step counts and light and moderate-to-vigorous physical activity.

### Combination of flexible learning spaces, active breaks, and active lessons

Of the six studies that assessed physical activity, four measured stepping or light physical activity [111, 114-116] and four measured moderate-to-vigorous physical activity [110-112, 114]. Only two reported significant positive changes and both used a combination of active breaks and active lessons [110, 112]. Cradock et al. 2014 observed changes in moderate-to-vigorous physical activity after implementing an intervention that included training teachers on active breaks and lessons, coaching, booster sessions (i.e., short sessions to reinforce the intervention), and a lesson implementation plan. Additionally, it incorporated more moderate-to-vigorous physical activity in physical education, promoted physical activity during recess, and concluded with a celebration for wellness champions at the end of the year [110]. The intervention in the Sacheck et al. 2021 study did not increase physical activity; instead, it helped prevent a decline observed in the control group. In their discussion, the authors highlighted that these daily breaks and lessons lasting 5 to 15 min help prevent a decline in moderate-to-vigorous physical activity, but that these programs alone did not provide sufficient activity to help children meet daily recommendations [112]. Overall, most studies implementing a combination of flexible learning spaces, active breaks, or active lessons do not demonstrate a more significant effect on physical activity than separate interventions. However, a combination of active breaks and active lessons has shown the potential to increase physical activity and prevent the decline observed throughout the school year.

#### Learning

#### Flexible learning spaces

Three studies assessed learning outcomes using academic performance in different school subjects such as mathematics [34, 40, 47] and literature [34, 47]. Mead & Scibora, 2016 are the only ones to report an improvement in mathematics performance following the intervention [40]. Nevertheless, identifying the components responsible for this improvement is challenging given the nearly identical nature of the intervention to the one implemented in the study by Fedewa et al. 2015, which did not observe improvement [34, 40]. Reaching definitive conclusions with only three studies, one of which observed significant differences, is difficult. That said, it is, once again, noteworthy that none of these studies reported negative effects of flexible learning spaces on academic performance.

#### Active breaks

Eleven studies assessed academic performance [40, 50, 57, 60-62, 65, 66, 68, 72, 74]; ten focused on mathematics [40, 57, 60-62, 65, 66, 68, 72, 74] and four on English [60, 61, 72, 74]. Four studies reported positive changes in mathematics [40, 62, 66, 68] and one in English [61] following active breaks. Only one study measured an increase in both academic performance and physical activity [61], while the rest either did not measure physical activity [40, 62, 66, 68] or observed an increase in physical activity without an effect on learning outcomes [50, 65, 72]. Meanwhile, Fedewa et al. 2018 and Mavilidi et al. 2019 showed that active breaks could enhance academic achievement more effectively than active lessons [61, 68]. Incorporating activities like jumping, walking, or running in place, squats, and burpees for 5, 10, or 15 min once or multiple times daily can positively influence academic performance [40, 61, 62, 66, 68]. Most studies indicate that active breaks positively affected learning outcomes with no observed negative effects. This suggests that active breaks can enhance academic performance even if they reduce learning time.

#### Active lessons

Fifteen studies implementing active lessons assessed academic performances [61, 68, 76, 79, 85, 88, 91-94, 97, 98, 101, 105, 106] in various subjects including mathematics [61, 68, 76, 79, 85, 92, 93, 98, 101, 105, 106] and literature [61, 79, 88, 91–93, 98]. Five of the eleven studies assessing performance in mathematics [68, 79, 92, 93, 106], six of the seven studies measuring literature performance [61, 79, 88, 91-93], and one of the two studies that evaluated general learning [97] observed positive changes after the active lessons interventions. Among the nine studies that observed positive changes in learning and assessed physical activity [61, 68, 79, 88, 91-93, 97, 106], only Donnelly et al. 2009, McCrady-Spitzer et al. 2015, and Pinto-Escalona & Martínez-de-Quel 2019 also reported changes in physical activity [79, 91, 97]. The remaining studies either did not assess or observed increased physical activity. Similarly to active breaks, active lessons have the potential to positively affect academic performance without negatively influencing them.

Resaland et al. 2016 is the only study to assess performance in mathematics and literature following an intervention combining active breaks and active lessons [111]. It did not affect academic performance in any way compared to controls. It is impossible to draw a conclusion based only on this study, especially considering that the intervention did not influence participants' sedentary behavior or physical activity levels. Nonetheless, further studies are needed to examine the effects of interventions combining flexible learning spaces, active breaks, or active lessons on learning outcomes.

#### Musculoskeletal health

#### Flexible learning spaces

Musculoskeletal health was measured in seven studies using different outcomes such as discomforts (e.g., neck, back, shoulder, knee) or ergonomic [25, 27, 31, 32, 36, 41, 42]. Two of these seven studies reported favorable outcomes associated with flexible learning space interventions such as reductions in neck discomfort [32, 41], shoulder and knee discomfort [41], while one study noted positive effects on ergonomics [27]. The three articles that noted favorable outcomes also reported positive changes in sedentary behaviors [27, 32, 41]. These interventions incorporated sit-stand desks, and Cardon et al. 2004 added inclined tables for all students and adjusted furniture to align with children's knee and elbow height [27]. Conversely, other studies that added sit-stand desks and observed changes in sedentary behaviors did not measure changes in musculoskeletal health [25, 36, 42]. However, these studies implemented interesting strategies such as directed training on postures and tips displayed in the classroom for students [42]. Ultimately, establishing a clear relationship between flexible learning spaces, sedentary behaviors, and musculoskeletal health is challenging. However, at the very least, adding flexible furniture appears to have no negative effects on discomfort and ergonomics.

#### Active breaks and active lessons

No study has assessed the effects of active breaks or active lessons as the sole intervention on musculoskeletal health.

### Combination of flexible learning spaces, active breaks, and active lessons

Contardo Ayala et al. 2016 were the only ones to assess the combined effects of flexible learning spaces and active breaks and they reported that these did not lead to significant changes in musculoskeletal health [115]. The implemented intervention included 2 min of light physical activity and one 30-minute standing lesson each day, conducted in a fully flexible environment where all furniture was replaced with height-adjustable sit-stand desks and stools. Teachers were also trained to reduce sitting time, promote reducing sitting and increasing physical activity, and adapt the curriculum. Beyond being the only intervention in this category, the lack of change in sedentary behaviors aside from prolonged sitting periods in the classroom limits conclusions regarding the effect of the combination of flexible learning spaces and active breaks on musculoskeletal health outcomes. Once again, it would be instructive to examine the impact of additional interventions combining flexible learning spaces, active breaks, or active lessons on musculoskeletal health through outcomes such as discomfort or ergonomics within the classroom settings.

# What are the best practices? *Flexible learning spaces*

Flexible learning spaces can positively influence sedentary behavior within the classroom. Here are the main recommendations to increase the likelihood of a positive effect of flexible learning spaces:

- Implement a complete overhaul of furniture.
- Utilize large spaces allowing stations and teamwork (important, but not mandatory).
- Incorporate standing desks to maximize the effects on physical activity, but acknowledge that prolonged standing can lead to poor posture (provide alternatives to standing work).
- Adapt furniture to children's ergonomics to optimize musculoskeletal health.
- Introduce training on flexible learning spaces (important, but not mandatory).
- Adopt different educational strategies such as rotation systems, stations, teamwork, and education on sedentary behaviors.

#### Active breaks

Short active breaks can positively influence sedentary behavior and physical activity in classrooms. Here are the main recommendations to enhance the effectiveness of active breaks:

- Limit active breaks to 5–10 min (on-site or wholeclass activities).
- Implement active breaks throughout the day (i.e., two to three times daily).
- Select activities that can be easily implemented based on the available space and resources.
- Choose activities that enhance health-related and skill-related fitness (important, but not mandatory).

- Incorporate competition as a motivating factor with objectives or challenges (important, but not mandatory).
- Utilize videos and video games, but it is important to avoid relying solely on traditional video games for physical activity (important, but not mandatory).

#### Active lessons

Moderate-to-vigorous active lessons can positively influence sedentary behavior and physical activity throughout the day. Here are the main recommendations for maximizing their effectiveness:

- Limit active lessons to 10 to 30 min with moderateto-vigorous intensity (10 to 15 min are most effective).
- Introduce training on active lessons.
- Provide activities that can be easily implemented based on the available resources.
- Incorporate competition as a motivating factor with objectives or challenges (important, but not mandatory).
- Integrate interventions like active homework or promoting active recess (important, but not mandatory).

### Combination of flexible learning spaces, active breaks, and active lessons

The combination of more than one type of intervention has the potential to influence sedentary behaviors as well as physical activity, but there are too few studies to provide clear recommendations. Nevertheless, existing studies indicate that future interventions should:

- Combine active breaks and active lessons using active breaks of 5 to 15 min and low-intensity active lessons such as standing during math classes.
- Utilize strategies such as training, booster sessions, lesson plan implementation, and additional materials.

#### Discussion

This review aimed to identify the characteristics of interventions incorporating flexible learning spaces, active breaks, and active lessons, either individually or in combination, that have been implemented in elementary and secondary school settings, their effects on sedentary behaviors as well as on physical activity, learning, and musculoskeletal health and the best practices for future interventions in classrooms aimed to decrease sedentary time. Most studies have shown beneficial effects on sedentary behavior and physical activity among children. Furthermore, when measured, these interventions demonstrated favorable effects on academic achievement and musculoskeletal health. Notably, no study reported negative effects of any intervention on these variables. Flexible learning spaces are the intervention with the greatest potential to influence sedentary behavior throughout the day. Active breaks and active lessons may increase physical activity, but there is a lack of studies that have measured their effects on sedentary behavior throughout the day to make conclusions. Flexible learning spaces can influence physical activity, but active breaks and active lessons have the most potential to increase all types of physical activity throughout the school day. Too few studies have measured the effects of these interventions on learning and musculoskeletal health outcomes, thus limiting conclusions. However, reducing sedentary behavior and ensuring proper adjustment of school furniture seem important for positively influencing musculoskeletal health. It is also particularly interesting to note that the combination of active breaks and active learning, precisely standing work, with or without flexible furniture, can reduce sedentary behavior and increase physical activity and positively affect academic results and musculoskeletal health.

The findings of this review are consistent with those of other reviews that have examined the effects of various interventions on similar outcomes [12, 13, 15-22]. Based on six studies, one review focused on flexible classrooms established that students in flexible learning spaces spent significantly less time sitting and more time standing and moving compared to traditional classrooms [12]. They also reported that the increased freedom and opportunities to break up sitting and move around in flexible learning spaces enhanced student well-being. In their analysis of 22 studies on active breaks, Masini and colleagues concluded in another review that most studies reported significant improvements in moderate-tovigorous physical activity and step count among children participating in active break interventions [13]. They also noted that active breaks are more likely to enhance attention during the school day, although the effects on cognitive outcomes are inconclusive. Similarly, a review on active lessons reported significant increases in lessontime physical activity and increases, although non-significant, in overall physical activity following the active lessons [21]. Overall, these reviews also concluded that flexible learning spaces, active breaks, and active lessons have positive effects on sedentary behaviors and physical activity; however, none describe the combined effects of all these interventions in schools. Based on the conclusions of these reviews and this one, future studies should closely examine interventions that implement short active breaks and active lessons including standing

and moderate-to-vigorous physical activity within a flexible classroom environment. Additionally, these studies should investigate the effects on sedentary behaviors and physical activity, as well as on learning, and musculoskeletal health.

The main strength of the review is its comprehensive examination of the literature and the inclusion of multiple articles through thorough and detailed research across several databases. Using various outcomes to describe interventions is also a strength of this study, whereas most other reviews focus on just one. Furthermore, when possible, an effort has been made to have conclusions by using the results of interventions on behaviors throughout a full day, providing a comprehensive overview of the interventions and their effects. The use of PRISMA-ScR in designing and writing the scoping review is also a strength of the review. Nevertheless, this review is subject to some limitations. Consistent with the objectives of a scoping review, which aims for a more descriptive analysis compared to systematic reviews, the quality assessment of the articles was not documented. As a result, the review compares the results of randomized controlled trials to other guasi-experimental studies without control groups. Finally, few studies have assessed the effects of interventions on learning and musculoskeletal health outcomes, limiting the conclusions and recommendations. Further, few studies have employed combinations of interventions, with none integrating all three.

#### Conclusion

This scoping review demonstrated that flexible learning spaces, active breaks, active lessons, and their combination effectively reduce children's sedentary behavior within school environments. Moreover, the literature underscores that flexible learning spaces may support increasing light physical activity, while active breaks and active lessons are worthwhile for positively influencing children's moderate-to-vigorous physical activities, especially when implemented with adapted educational approaches. These interventions are effective strategies to reach the guidelines as daily physical activity increased, while sedentary behavior decreased and was more fragmented. However, the lack of studies assessing the effects of these interventions on learning and musculoskeletal health limits the ability to formulate comprehensive conclusions and recommendations to impact these outcomes positively. Nevertheless, none of the studies measuring these variables suggest that interventions will have negative effects. Future studies should investigate the global impact of these interventions on children's academic achievement as well as on musculoskeletal health, particularly discomfort or pain, to gain a broader understanding of their outcomes. The results also emphasize the necessity of further studying the combined effects of these interventions, both within and outside of school, to gain a better understanding of their overall impact, especially considering the promising findings from initial studies.

#### Abbreviations

- NA Not available/specified
- SB Sedentary behaviors PA Physical activity
- PA Physical activity LPA Light physical activity
- LPA Light physical activity MPA Moderate physical activity
- VPA Vigorous physical activity
- MVPA Moderate-to-vigorous physical activity
- CBPA Classroom-based physical activity
- SBPA School-based physical activity
- FLS Flexible learning spaces
- AB Active breaks
- AL Active lessons
- PE Physical education classes
- STS Sit-to-stand transitions
- TFO Time effect only
- GEO Group effect only

**Supplementary Information** The online version contains supplementary material available at https://doi.or q/10.1186/s44167-024-00068-2.

Supplementary Material 1	
Supplementary Material 2	
Supplementary Material 3	
Supplementary Material 4	
Supplementary Material 5	

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#### Author contributions

The study was designed by DL, CLM, ASA, VBP and MDL and supervised by VD. Articles were read and sorted by DL, CLM, ASA, and VBP. Data interpretation and the first draft of the manuscript were done by DL. All authors have read, critically revised the manuscript, and approved the final version (DL: 50%, CLM: 15%, ASA: 5%, VBP: 5%, EB: 5%, JY: 5%, AT: 5%, VD: 10%).

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#### Data availability

No datasets were generated or analysed during the current study.

#### Declarations

**Ethics approval and consent to participate** Not applicable.

#### **Consent for publication**

Not applicable.

#### Competing interests

The authors declare no competing interests.

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