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Review Article

Policy, systems, and environmental interventions addressing physical activity in early childhood education settings: A systematic review

Cody Neshteruk [a,*], Sarah Burkart [b], Emily W. Flanagan [c], Emily Melnick [d], Courtney Luecking [e], Chelsea L. Kracht [c]

[a] Department of Population Health Sciences, Duke University School of Medicine, Durham, NC, United States of America
[b] Department of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, SC, United States of America
[c] Pennington Biomedical Research Center, 6400 Perkins Road, Baton Rouge, LA 70808, United States of America
[d] College of Health Solutions, Arizona State University, Phoenix, AZ, United States of America
[e] Department of Dietetics and Human Nutrition, College of Agriculture, Food and Environment, University of Kentucky, Lexington, KY, United States of America

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ABSTRACT

Policy, systems, and environmental (PSE) approaches can facilitate physical activity in priority populations (e.g., racial and ethnic minority, low wealth groups) within early childhood education (ECE) settings. The purpose of this review was to 1) characterize the inclusion of priority populations within ECE physical activity interventions containing PSE approaches and 2) identify and describe interventions within these populations. Seven databases were systematically searched (January 2000-Febrary 2022) for ECE-based interventions focusing on children (0–6 years) that utilized at least one PSE approach. Eligible studies included a child physical activity or physical activity environment outcome and child or center-level population characteristics. Forty-four studies, representing 42 interventions were identified. For Aim 1, half of interventions included one PSE approach (21/42), with only 11/42 including three or more approaches. Physical environment changes [e.g., adding play equipment, modifying space (25/42)] were the most used PSE approaches followed by system [e.g., integrating activity into routines, (21/42)] and policy [e.g., outdoor time (20/42)] approaches. Nearly half of interventions were conducted in predominantly priority populations (18/42). Studies were primarily rated as good (51%) or fair (38%) methodological quality using the Downs and Black checklist. In Aim 2, of the 12 interventions assessing child physical activity in priority populations, 9/12 reported at least one physical activity outcome in the expected direction. Of the 11 interventions assessing the physical activity environment, 9/11 reported an effect in the expected direction. Findings indicate clear opportunities exist to target priority populations by incorporating PSE approaches in ECE physical activity interventions.

1. Background

Physical activity (PA) habits are established early in life (Jones et al., 2013). Sufficient PA positively influences children's physical, cognitive, and social/emotional development, reducing risk for future chronic disease (Carson et al., 2017; Poitras et al., 2016; Janssen and Leblanc, 2010; Donnelly et al., 2016). Current 24-h movement guidelines recommend that preschoolers (ages 3–4 years) spend 180 min/day in PA, including ≥60 min/day in moderate to vigorous physical activity (MVPA) (Tremblay et al., 2017). Global estimates suggest that only half of preschoolers meet these recommendations (Tucker, 2008; O'Brien et al., 2018; Ellis et al., 2017). Clear disparities exist as preschoolers from racial and ethnic minority groups, low wealth populations, and less resourced areas are less likely to meet these guidelines due to social and environmental constraints; hence, these are priority populations for intervention and support (Whitt-Glover et al., 2009; Katzmarzyk et al., 2018; Armstrong et al., 2018; Musić Milanović et al., 2021).

Early childhood education (ECE) settings are a critical space for the promotion of preschoolers' PA (Larson et al., 2011). The majority (~87%) of children ages 3–5 years in high-income countries are enrolled in some form of ECE (Enrollment in Childcare and Pre-School, n.d.), including during the majority of their waking hours when PA may occur

* Corresponding author at: Department of Population Health Sciences, Duke University School of Medicine, 215 Morris Street, Suite 210, Durham, NC 27701, United States of America.
E-mail address: cody.neshteruk@duke.edu (C. Neshteruk).

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(Corcoran and Steinley, 2017; Cui and Natzke, 2020). ECE settings support child PA through various policies (e.g., time for PA), practices (e.g., teachers promoting PA), and provisions (e.g., availability of play equipment) that work to create a supportive environment for PA. Many interventions have occurred within ECE settings with several reviews showing that these interventions are generally effective at improving child PA (Finch et al., 2016; Lum et al., 2022; Hnatiuk et al., 2019; Van Capelle et al., 2017; Gordon et al., 2013). For instance, in a review and meta-analysis of 17 interventions, findings showed an overall improvement in device-based measures of PA (Finch et al., 2016). However, many of the interventions in the ECE setting are predominately curriculum-based (e.g., structured activities as a part of a curriculum), which may lack sustainability as they rely on delivery by teachers trained in the curriculum (Matwiejczyk et al., 2018).

Incorporating policy, system, and environmental (PSE) intervention approaches can improve curriculum-based interventions by promoting sustainability, reducing teacher burden, and supporting children's PA at the population level (Story et al., 2008; Brownson et al., 2008; Farewell et al., 2020). PSE approaches can achieve this through changing the conduct, processes, and/or environments in these settings (Fig. 1). Within the PSE structure, policies refer to documented guidelines at the organizational (i.e., ECE facility), local, state, or federal level, systems are classified as organizational or operational changes (e.g., changes to ECE schedules), and environmental approaches can include both social (e.g., teacher-child interactions) and physical environment changes (e.g., modifications to the physical space). Studies have documented that PSE approaches are effective tools for promoting preschool children's PA, particularly through instituting change in the PA environment (i.e., policies, practices and provisions) (Stacey et al., 2017; Trost et al., 2010; Mehtälä et al., 2014; Wolfenden et al., 2020).

While PSE approaches hold potential for scalability and widespread dissemination, the extent to which PSE approaches have been enacted within priority populations and the effect on child PA and ECE PA environment among these populations is unclear. Therefore, the aims of this systematic review included: 1) characterize the inclusion of priority populations in ECE PA interventions using PSE approaches, and 2) identify and describe interventions using PSE approaches within priority populations and their effectiveness in improving child PA or the PA environment. With the wealth of research on PA in ECE settings, findings from this review will guide the field by identifying gaps in the literature, priorities for future research, and effective interventions in priority populations for future adoption.

2. Methods

2.1. Search strategy

This review was prepared in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Checklist (Supplementary Table 1) (Page et al., 2021). Review methodology was established prior to commencing the review and registered using PROSPERO (PROSPERO# CRD42022306670). This review sought peer-reviewed literature published from January 1, 2000 to February 2, 2022 due to the proliferation of obesity research in ECE settings in the last two decades (Larson et al., 2011). Seven databases were searched: MEDLINE OVID, PubMed, Web of Science, EMBASE, Education Resources Information Center, PsycInfo, and CINAHL. The full search strategy can be found in Supplementary Table 2. The supplemental search strategy included reviewing reference lists and citations of included articles and contacting experts in this field ($n = 15$). This review was conducted in tandem with a review focusing on obesity and diet-related outcomes of PSE interventions in ECE settings (Kracht et al., 2023).

2.2. Eligibility criteria

The full inclusion and exclusion criteria are shown in Table 1. In brief, to be eligible for Aim 1, which examined the inclusion of priority populations in PSE interventions, interventions must have included children ages 0–6 years (or mean age < 6.0 years), a primary or secondary focus on improving PA, related outcomes (e.g., sedentary time or motor skills), or the PA environment in the ECE setting, and included at least one PSE approach. Interventions could have included the PSE approach as the intervention itself, or in combination with other intervention components (e.g., educational or parent curriculum). Policy approaches were defined as written or formalized regulations whereas system approaches were a methodical change in processes, such as organizational or operational changes. An explicit statement that the intervention was changing a social setting component was categorize as a social environment approach. Physical environment approaches included observable or demonstrable changes to children's play spaces. Child-level characteristics or an explicit recruitment strategy for ECE settings based on priority status (e.g., recruiting only indigenous populations or federally subsidized childcare [e.g., Head Start, Sure Start]) were required for inclusion. Studies with baseline child or center level characteristics consisting of $\geq$50% priority populations, defined as children from racial/ethnic minority backgrounds, low-income/socioeconomic status, rural, or indigenous groups, were included in

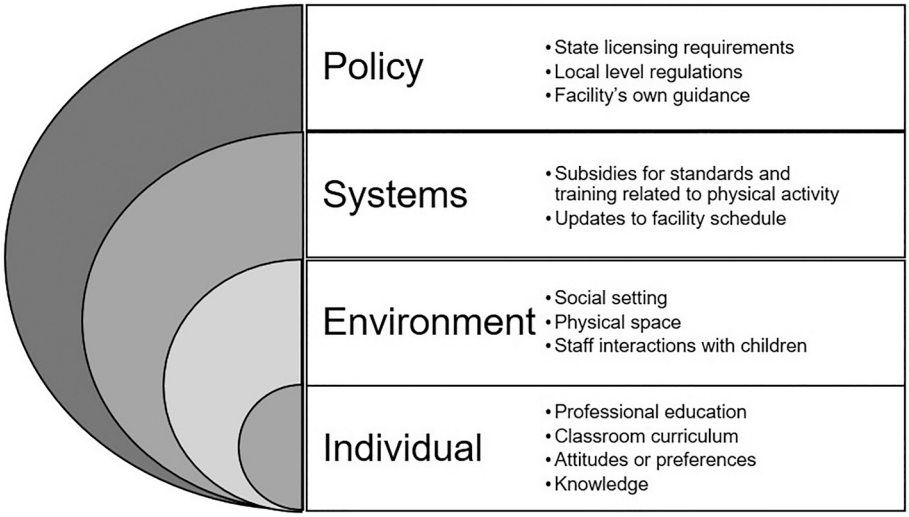

Fig. 1. Policy, systems, and environment approaches within early childhood education settings.

Table 1
Inclusion and exclusion criteria.

Component	Inclusion	Exclusion
Publication date	• After and including 2000	• Prior to 2000
Article type	• Peer reviewed journal article • Published in English	• Conference abstracts • Dissertations • Clinical trials registrations • Gray literature • Non-English publications
Population	• Children between ages 0–6 years or with a mean age < 6 years • Children without conditions that would affect physical activity	• Children above age of 6 years or mean age > 6 years or mainly conducted in children 7+ years • Children with acute or chronic conditions (e.g., asthma)
Setting	• Early childhood education setting – Settings that serve young children, have formal education component and are open during the weekdays (e.g., preschool, nursey, daycare, family child care home, child care, kindergarten)	• Home setting (i.e., with parents or other caregivers)
Design	• Pre-post • Natural experiment • Pilot/feasibility study • Randomized controlled trial • Cluster randomized controlled trial	• Case study • Qualitative study • Cross sectional study • Commentary • Systematic review or meta-analysis • Protocol
Intervention	• Policy component and/or • System component and/or • Environmental component	• Only individual level intervention component • Curriculum only intervention
Outcome	• Physical activity • Motor skills • Sedentary behavior • ECE physical activity environment	• Non-physical activity focused health outcomes (e.g., diet, dental caries, infectious diseases) • Provider level outcomes (e.g., teacher physical activity) • Parent-reported outcomes (e.g., physical activity at home)
Population description	• Child-level priority population description (e.g., race/ethnicity, family income, SES, parent education, rurality OR • Center-level characteristics that would include all members of a priority population (e.g., Head Start)	• No reporting of child level OR center level characteristics that could be used to classify sample as priority population

Aim 2.

2.3. Study selection

The senior author (CLK) completed title screening, and the remaining abstracts and full-texts of identified papers were screened in duplicate by the author team. Title screening allows abstracts with titles that meet inclusion criteria to move forward, streamlining the initial screening phase and has comparable return rates as abstract screening (Mateen et al., 2013). The senior author resolved conflicts at the abstract phase, and full-text conflicts were resolved by discussion. The abstraction document was established a priori and pilot tested, and all reviewers were trained prior to beginning the review. Abstract screening was completed using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Supplemental search strategy techniques were employed with the final list of full-text articles.

2.4. Data extraction and risk of bias

One reviewer independently extracted data using a pilot tested form, which was checked by a second reviewer. Extracted data included information related to the population included (e.g., priority population, recruitment strategy, type of ECE setting), intervention (e.g., study design, PSE approaches), comparison group (e.g., no comparator, or delayed intervention), outcome (PA, sedentary time, motor skills, or environment), and results.

The Downs and Black checklist, a tool for assessing risk of bias for randomized and non-randomized trials, was used for a critical appraisal of all included articles (Downs and Black, 1998). The checklist includes 27 items on reporting (10-items), external validity (3-items), internal validity (13-items), and power (1-item). Similar to others, the power item was modified to whether a power analysis was described (0 = not reported, 1 = reported) (Korakakis et al., 2018). The maximum possible score is 28 for randomized studies and 25 for non-randomized studies. Downs and Black scores were categorized by the following ranges: excellent (26–28), good (20–25), fair (15–19), and poor (≤14) (Hooper et al., 2008). The Downs and Black checklist was completed independently by one reviewer, and examined by a second reviewer. Disagreement was resolved by discussion. A certainty assessment of the evidence was not conducted due to the heterogeneity of comparators and outcomes.

2.5. Synthesis of results

To characterize the inclusion of priority populations in PSE interventions (Aim 1), central tendencies were calculated for extraction categories including: PSE approaches, population inclusion criteria and recruitment methods, intervention/comparator design, outcomes assessed, assessment methods, overall results, and methodological quality. Results were summarized based on direction of the effect as well as statistical significance based on limitations of presenting only significant results alone (Higgins et al., 2019). Then, a qualitative investigation was conducted to compare studies that included ≥50% of priority populations (Aim 2). Studies were compared based on intervention characteristics, PSE approaches, topics addressed in PSE approaches, and any prior testing or preliminary data discussion. A meta-analysis was not conducted due to the heterogeneity of interventions and outcomes (e.g., MVPA min/day, % MVPA time, time in LPA, motor skills, etc.) reported.

3. Results

After removal of 21,639 abstracts during title screening, 3590 abstracts were screened in duplicate, 480 full-text articles were reviewed in duplicate (468 identified in the search and 12 from supplemental search strategies), and 44 articles were included in the current review. (Fig. 2). During full-text screening, 436 articles were excluded based on the exclusion criteria shown in Fig. 2 and detailed in Supplementary Table 3. Articles were included if PA or an associated outcome was included as either the primary or a secondary outcome. Outcomes related to diet and obesity have been reported elsewhere (Kracht et al., 2023).Three articles reported on the same intervention (De Craemer et al., 2016; De Craemer et al., 2014; Birnbaum et al., 2017), thus there were 44 studies representing 42 unique interventions.

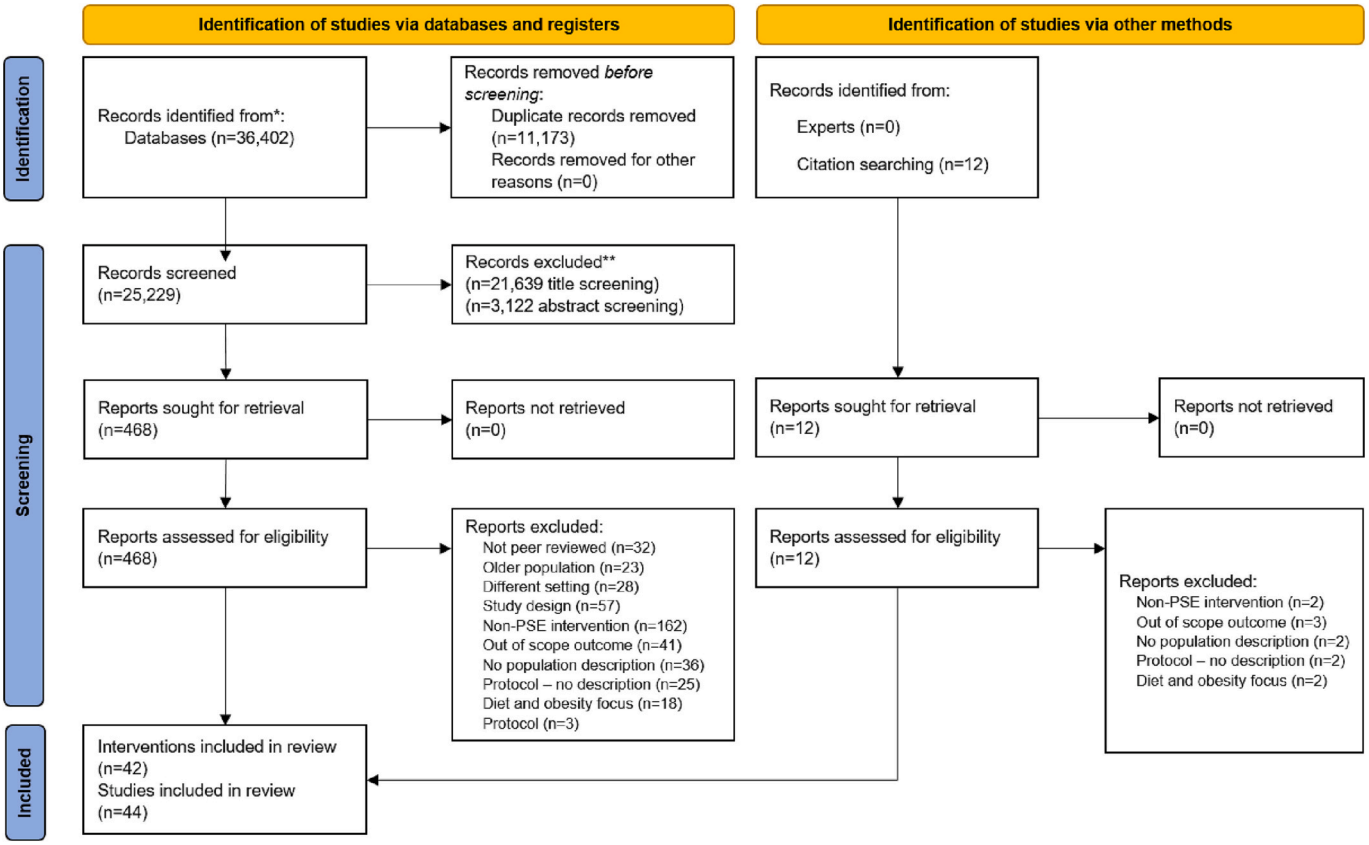

Fig. 2. PRISMA 2020 flow diagram for new systematic reviews that included searches of databases, registers, and other sources.
No automation tools were used in this review.
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: https://doi.org/10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/.

Summary characteristics of the included interventions (n = 42) including intervention type, study design, and priority population description are shown in Table 2. Characteristics of studies reporting child PA outcomes (n = 35) are shown in Table 3 and those reporting PA environment outcomes (n = 17) in Table 4. Seven studies reported child PA and PA environment outcomes and are subsequently included in both tables (Alkon et al., 2014; Carson et al., 2022; Razak et al., 2018; Tomayko et al., 2017; Finch et al., 2014; Kracht et al., 2020; LaRowe et al., 2016).

Most interventions were conducted exclusively within the ECE setting (24/42, 57%), while about a third were an ECE-based intervention with a parent component (11/42, 26%). Half of all interventions included only one PSE approach (21/42, 50%). Most interventions assessing child PA only had one PSE approach (19/33, 58%) compared to those measuring PA environment (5/17, 29%). Only 11 studies included three or more PSE approaches (26%).

Physical environment changes (25/42, 60%) were the most common PSE approaches. Physical environment changes included adding portable play equipment (e.g., balls, hula hoops) (Finch et al., 2014; Zhou et al., 2014; Pate et al., 2016; Tucker et al., 2017; Bonvin et al., 2013; Lee et al., 2020; Robinson et al., 2019; Yin et al., 2012; Puder et al., 2011), rearranging space to provide more room for play (De Craemer et al., 2016; De Craemer et al., 2014; Birnbaum et al., 2017; Brandes et al., 2020; Kobel et al., 2020; Steenbock et al., 2019), modifications to the outdoor play environment (e.g., adding natural materials, creating bike paths) (Zhou et al., 2014; Bonvin et al., 2013; Nicaise et al., 2012; Brussoni et al., 2017; Palmer et al., 2020), or adding fixed play equipment (Tomayko et al., 2017; Bonvin et al., 2013; Puder et al., 2011). System approaches were the next most common PSE approach (21/42, 50%) and included changes to the daily schedule or integration of PA into specific periods of time (e.g., transitions) (De Craemer et al., 2016; Razak et al., 2018; Tomayko et al., 2017; LaRowe et al., 2016; Tucker et al., 2017; Okely et al., 2020; Driediger et al., 2019; Wolfenden et al., 2019; Alhassan et al., 2007). For instance, one study examined the impact of multiple, shorter periods of outdoor time compared to a single extended period of outdoor time (Razak et al., 2018). Another study included daily music-based activities with high intensity PA as a strategy to break up long bouts of sedentary time (Okely et al., 2020). Nearly, half of interventions included policy approaches (20/42, 48%), namely the amount or duration of PA while in care including state level guidance (Kracht et al., 2020; O'Neill et al., 2017; Benjamin Neelon et al., 2017; Carson et al., 2015), or creating individual setting standards (Tomayko et al., 2017; LaRowe et al., 2016; Zhou et al., 2014; Kao et al., 2018; Natale et al., 2022; Ward et al., 2020; Ward et al., 2008a; Drummond et al., 2009; Garvin et al., 2019; Benjamin Neelon et al., 2014). Social environment changes were the least used PSE intervention approach (16/42, 38%), those most focused on having ECE teachers encourage PA and act as role models (Alkon et al., 2014; Tomayko et al., 2017; Pate et al., 2016; Okely et al., 2020; Benjamin Neelon et al., 2014; van de Kolk et al., 2019; Toussaint et al., 2021).

Four interventions included infants and/or toddlers (0–24 months) (Carson et al., 2022; Carson et al., 2015; Ward et al., 2020; Benjamin Neelon et al., 2014), while the remaining studies focused exclusively on preschoolers (2–6 years). All but two of the interventions were conducted in full day, center-based care (40/42, 95%), as opposed to family child care homes (Kao et al., 2018; Ward et al., 2020). Most interventions were evaluated using a randomized (17/42, 40%) or quasi-experimental design (16/42, 38%). Most interventions were compared to no intervention/usual care (14/42, 33%) or a delayed control (14/42, 33%). PA (i.e., total, light, MVPA, or counts per minute) was an outcome

Table 2
Summary characteristics of included interventions ($n = 42$) by physical activity outcome and for all interventions.[a]

	Child PA outcome ($n = 33$)[b,c]		PA environment outcome ($n = 17$)[b]		Total ($n = 42$)	
	n	%	*n*	%	*n*	%
Interventions						
ECE intervention with parent component	9	27.3	3	17.6	11	26.2
ECE intervention only	18	54.5	11	64.7	24	57.1
Multi-sector (ECE, parent, community)	2	6.1	0	0.0	2	4.8
Government regulation or policy	4	12.1	3	17.6	5	11.9
PSE components included[b]						
Policy	11	33.3	16	94.1	20	47.6
System	13	39.4	12	70.6	21	50.0
Social environment	11	33.3	11	64.7	16	38.1
Physical environment	21	63.6	9	52.9	25	59.5
Number of PSE components						
1	19	57.6	5	29.4	21	50.0
2	9	27.3	1	5.9	10	23.8
3	1	3.0	3	17.6	3	7.1
4	4	12.1	8	47.1	8	19.0
Study designs						
Randomized controlled trial	15	45.5	5	29.4	17	40.1
Pre-post study	5	15.2	6	35.3	8	19.0
Quasi-experimental	12	36.4	6	35.3	16	38.1
Other	1	3.0	0	0.0	1	2.4
Comparator						
No intervention	13	39.4	3	17.6	14	33.3
Delayed intervention	11	33.3	5	29.4	14	33.3
No comparator	7	21.2	6	35.3	10	23.8
Attention control	1	3.0	2	11.8	2	3.8
Not described	1	3.0	1	5.9	2	3.8
Outcomes assessed						
Physical activity	30	90.1	8	47.1	30	71.4
Sedentary time	19	57.6	4	23.5	19	45.2
Physical activity environment	7	21.2	17	100.0	16	38.1
Fundamental motor skills	9	27.3	0	0.0	9	21.4
Physical activity measurement						
Accelerometer	24	72.7	6	35.3	24	57.1
Observed	13	39.4	2	11.8	13	31.0
Pedometer	3	9.1	1	5.9	3	7.1
Priority population recruitment						
Served priority population (e.g., head start)	6	18.2	5	29.4	9	21.4
Convenience sample	6	18.2	3	17.6	7	16.7
Specific low-income region	3	9.1	0	0.0	3	7.1
Random sample	10	30.3	4	23.5	12	28.6
Not reported	2	6.1	1	5.9	3	7.1
Other	6	18.2	4	23.5	8	19.0
Priority population metrics[b]						
Race	17	51.5	12	70.6	23	54.8
Ethnicity	12	36.4	9	52.9	17	40.5
Parent education	14	42.4	9	52.9	20	47.6
Household income/socioeconomic status	20	60.6	5	29.4	21	50.0
Tribal, indigenous or aboriginal	3	9.1	4	23.5	5	11.9
Rural	4	12.1	1	5.9	4	9.5

Abbreviations: early care and education (ECE); physical activity (PA).
[a] Table reports on 42 studies as three studies reported on the same intervention.
[b] Article could be included in multiple categories.
[c] Total of 35 articles representing 33 unique interventions in this category.

for most interventions (30/42, 71%) and nearly half of these interventions assessed sedentary behavior (19/42, 45%). Motor skills were assessed in some interventions (9/42, 21%). The PA environment was assessed in over one third of interventions (17/42, 40%), namely through the Environment and Policy Assessment and Observation (EPAO) tool (13/17, 76%) (Ward et al., 2008b). Interventions that assessed children's PA behavior (e.g., MVPA) primarily used accelerometry (24/33, 73%). Motor skills were assessed via direct observation in slightly more than a third of interventions (13/33, 39%).

3.1. Aim 1: inclusion of priority populations

Recruitment strategies for the included interventions are detailed in Table 2. Most interventions used random sampling (12/42, 29%) or recruited samples that served priority populations (9/42, 21%). Most interventions reported multiple priority population metrics with the most frequent being child race (23/42, 55%), parent education (20/42, 48%), household income or socioeconomic status (21/42, 50%) and child ethnicity (17/42, 41%).

Nearly half of interventions (18/42, 43%) included ≥50% of priority populations in their study samples (Tables 3 and 4). The majority of interventions with predominantly priority populations were conducted in the United States (15/18, 83%) and were ECE interventions only (11/18, 61%). Seven (39%) of intervention only assessed child PA, six (34%) only assessed PA environment, and five (28%) included both child PA and PA environment outcomes. A third of studies (6/18, 33%) included all four PSE, while another third (6/18, 33%) only included one PSE approach. As for recruitment strategies, most (10/18, 56%) enrolled ECE settings serving priority populations or located in low socioeconomic status regions. Study samples ranged from 32 to 508 children.

Table 3
Characteristics of studies with child physical activity outcomes by inclusion of priority population ($n = 35$).

Author, year	Country	PSE approach	PSE included				Recruitment strategy	Final sample	PA/ST outcome(s) (assessment method)	Main results[a]	
			P	S	SE	PE				Direction of effect	Significant effects
Included ≥ 50% priority population ($n = 12$)											
Alhassan et al. (2007)	USA	ECE only		X			Head Start	32	CPM, LPA, MVPA, ST (accelerometers)	(−) ST (+) CPM, LPA, MVPA	No difference
Alkon et al. (2014)	USA	ECE + parent	X	X	X	X	Served priority population	209	PA intensity (observed)	Not reported	No difference
Benjamin Neelon et al. (2017)	USA	Policy	X				Random sample	324	Total PA, MVPA, VPA, MPA, LPA, ST (observed)	(−) LPA (+) ST, MPA, VPA, MVPA, Total PA	No difference
Carson et al. (2022)	Canada	Policy	X				Random sample	252	ST, LPA, MVPA (accelerometers)	(−) ST (+) LPA, MVPA	No difference
Okely et al. (2020)	Australia	ECE + parent		X	X		Low SES region	508	Total PA, MVPA, MPA, VPA, ST (accelerometers)	(−) Total PA, MPA, MVPA (+) ST, VPA	No difference
Palmer et al. (2020)	USA	ECE only				X	Head Start	46	FMS: 20 total (observed)	(+) Total FMS, locomotor FMS, ball FMS	(+) locomotor FMS
Pate et al. (2016)	USA	ECE only			X	X	Random sample	327	Total PA, LPA, MVPA, ST (accelerometers)	(−) ST, LPA (+) MVPA, Total PA	(+) MVPA
Razak et al. (2018)	Australia	ECE only		X			Convenience sample	357	MVPA, CPM, Total PA, LPA, MPA, VPA (accelerometers)	(+) MVPA, MPA, CPM, Total PA, LPA, VPA	(+) MVPA, MPA
Robinson et al. (2019)	USA	ECE only				X	Head Start	96	Total PA, MVPA, VPA, MPA, LPA (accelerometers)	(−)Total PA, MVPA, VPA, MPA, LPA	(−)Total PA, MVPA, VPA, MPA, LPA
Tomayko et al. (2017)	USA	ECE only	X	X	X	X	Served priority population	66	ST, LPA, MVPA (accelerometers)	Not reported	No difference
Ward et al. (2020)	USA	ECE only	X	X	X	X	Convenience sample	291	MVPA, active play minutes, ST (accelerometer)	(−) ST, (+) MVPA, active play	No difference
Yin et al. (2012)	USA	ECE + parent			X	X	Head Start	338	Steps (pedometer); gross motor skills (observation)	(+) steps, gross motor skills	(+) steps, gross motor skills
Did not included ≥ 50% priority population ($n = 23$)											
Birnbaum et al. (2017)	Germany	ECE + parent		X		X	Included low SES regions	1293	Motor skills: Jumping side to side; standing long jump (observed)	(+) jumping side to side, standing long jump	(+) jumping side to side
Bonvin et al. (2013)	Switzerland	ECE + parent				X	Other	554	Motor skills: 5 tasks (observed); CPM, MVPA, VPA in subsample (accelerometers)	(−) motor skills (+) CPM, MVPA, VPA	No difference
Brandes et al. (2020)	Germany	ECE + parent				X	Random sample	144	Total PA, MVPA, LPA, ST (accelerometers)	(−) ST (+) Total PA, MVPA, LPA	No difference
Brussoni et al. (2017)	Canada	ECE only				X	Convenience sample	45	MPVA (accelerometers)	(−) MVPA	(−) MVPA
Byun et al. (2018)	USA	ECE only		X	X		Other	93	Total PA, MVPA, ST (accelerometers)	(−) ST (+) Total PA, MVPA	(−) ST (+) Total PA
Carson et al. (2015)	Canada	Policy	X				Random sample	86	MVPA, LPA, ST (accelerometers)	(−) ST (toddlers), LPA (preschoolers) (+) ST (preschoolers), MVPA, LPA (toddlers) (Ø) MVPA (preschoolers)	(−) ST (toddlers), LPA (preschoolers) (+) ST (preschoolers), MVPA (toddlers)
De Craemer et al. (2016)	Belgium	ECE + parent		X		X	Included low SES regions	859	ST (accelerometers)	(−) ST	No difference
De Craemer et al. (2014)	Belgium	ECE + parent		X		X	Included low SES regions	472	Total PA, MVPA, LPA, MPA, and VPA (accelerometers)	(+) LPA, MPA, VPA, Total PA, MVPA	No difference
Driediger et al. (2019)	Canada	ECE only		X			Other	127	Total PA, LPA, MVPA, ST (accelerometers)	(−) MVPA, Total PA (+) ST, LPA	No difference
Finch et al. (2014)	Australia	ECE only	X		X	X	Random – Stratified by SES	294	Step counts/min (pedometers)	(+) step counts/min	No difference
Kobel et al. (2020)	Germany	ECE + parent		X		X	Random sample	419	Motor skills: Sit and reach, one-legged stand, standing long	(−) one-legged stand, sit and reach	(+) 3-min run

(*continued on next page*)

Table 3 (*continued*)

Author, year	Country	PSE approach	PSE included				Recruitment strategy	Final sample	PA/ST outcome(s) (assessment method)	Main results[a]	
			P	S	SE	PE				Direction of effect	Significant effects
									jump, 3-min run (observed)	(+) 3-min run, standing long jump	
Kracht et al. (2020)	USA	Policy	X				Random sample – Stratified by SES	49	Total PA, MVPA, ST (accelerometers); active play, TV viewing (observed)	(−) Total PA, MVPA, TV viewing (+) ST, active play	(−) Total PA (+) ST
LaRowe et al. (2016)	USA	ECE only	X	X	X	X	Other	66	ST, LPA, MVPA (accelerometers)	(−) ST (+) MVPA, LPA	(−) ST (+) MVPA
Lee et al. (2020)	China	ECE only				X	Convenience sample	42	Step count (pedometers)	(+) step count	No difference
Nicaise et al. (2012)	USA	ECE only				X	Not described	57	ST, LPA, MPVA (observed; accelerometers)	(−) observed ST; accelerometer LPA, MVPA (+) observed LPA, MVPA; accelerometer ST	(−) observed ST (+) observed LPA, MVPA
Puder et al. (2011)	Switzerland	ECE + parent				X	Other	632	Aerobic fitness, motor agility and balance (observed); CPM (accelerometer)	(−) CPM (+) aerobic fitness, agility, balance	(+) aerobic fitness, agility
Steenbock et al. (2019)	Germany	ECE + parent				X	Random sample	641	Gross motor skills: 5 tests (observed)	(−) lateral jumping, sit and reach (+) standing long jump, shuttle run, one leg stand	(+) standing long jump
Szpunar et al. (2021)	Canada	ECE only	X				Random sample	148	Total PA, LPA, MVPA, ST (accelerometers)	(−) ST (+) LPA, Total PA, MVPA	(+) LPA
Toussaint et al. (2020)	Netherlands	ECE only			X		Not described	36	PA intensity (observed), FMS (observed)	(+) FMS, PA intensity	(+) FMS, PA intensity
Tucker et al. (2017)	Canada	ECE only		X		X	Random sample	195	Total PA, LPA, MVPA, ST (accelerometers)	(−) ST (+) LPA, MVPA, total PA	(−) ST (+) MVPA, total PA
van de Kolk et al. (2019)	Netherlands	Multi-sector			X	X	Other	136	ST, LPA, MVPA, CPM (accelerometer)	(−) ST (+) MVPA, LPA, CPM	(−) ST (+) MVPA, CPM
Wolfenden et al. (2019)	Australia	ECE only		X			Convenience sample	218	MVPA, Total PA, CPM, VPA, MPA, LPA, ST (accelerometers)	(−) ST (+) MVPA, Total PA, CPM, VPA, MPA, LPA	No difference
Zhou et al. (2014)	China	Multi-sector	X			X	Convenience sample	357	Fitness; 7 tests (observed); heart rate during outdoor play (heart rate monitor), MVPA (accelerometer)	(+) 20-m agility run, broad jump, tennis ball throwing, sit and reach, balance beam walk, 30-m spring, and 20-m crawl; heart rate during outside play; MVPA	(+) 20-m agility run, broad jump, ball throwing, sit and reach, balance beam walk, 30-m spring, 20-m crawl, heart rate, MVPA

Abbreviations: policy, systems, environment (PSE), early care and education (ECE), policy (P), system (S), social environment (SE), physical environment (PE), United States of America (USA), physical activity (PA), light physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA), moderate to vigorous physical activity (MVPA), counts per minute (CPM), sedentary time (ST), fundamental motor skills (FMS).

[a] Only main results are presented. Secondary or sensitivity analyses are not presented (e.g., subgroups, completers only, etc.). When results are presented from multiple time points, the time point most proximal to the end of the intervention is used.

The remaining interventions that did not include ≥50% of priority populations represented a variety of countries, including the United States (7/24, 29%) and Canada (5/24, 21%). Random sampling was the most often used recruitment strategy (10/24, 42%). The majority utilized only one PSE approach (15/24, 63%). Of studies assessing child PA in non-predominantly priority populations ($n = 23$), nearly all (22/23, 96%) demonstrated at least one effect in the expected direction (i.e., increased PA, reduced sedentary time, or improved motor skills); however, only slightly more than half reached statistical significance (13/23, 57%). Of studies assessing the PA environment in non-predominantly priority populations ($n = 6$), all (6/6, 100%) demonstrated positive effects on the PA, however the effect was statistically significant in four studies (67%).

3.2. Quality of included studies

The quality of included articles ($n = 44$) as assessed by the Downs and Black checklist is shown in Table 5 and additional information is available in Supplementary Table 4. Most articles were classified as good (24/44, 55%) or fair (18/44, 41%). Only one article was classified as excellent (Benjamin Neelon et al., 2014), and one as poor (O'Neill et al., 2017). On average, many articles met reporting requirements (9.1/11 points), but met only two thirds of external validity (1.8/3 points), bias (4.9/6 points), confounding (4.1/6 points) criteria, About half (20/44, 45%) reported a power analysis. Comparing randomized and non-randomized studies, there were few differences in reporting (9.2 randomized vs. 9.1 non-randomized) and external validity (1.8 randomized vs. 1.7 non-randomized). However, randomized studies reported higher scores for bias (5.3 randomized vs. 4.5 non-randomized) and confounding (5.0 randomized vs. 3.1 non-randomized). More randomized studies reported a power analysis compared to non-randomized studies (72% vs. 11%). All articles reported funding for the project and investigators (Supplementary Table 5).

3.3. Aim 2: PSE approaches in priority populations

Interventions ranged from 2 days to 2 years and the majority had PA as the primary outcome (9/12, 75%) and did not report any formative

Table 4
Characteristics of studies with physical environment outcomes by inclusion of priority population ($n = 17$).

Author, year	Country	PSE approach	PSE included				Recruitment strategy	Final sample	PA/ST outcome(s) (assessment method)[a]	Main results[b]	
			P	S	SE	PE				Direction of effect	Significant effects
Included ≥ 50% priority population ($n = 11$)											
Alkon et al. (2014)	USA	ECE + parent	X	X	X	X	Served priority children	209 children	PA policies (observed); PA practices (observed – Items from EPAO)	(NR) PA practices (+)PA policy score	(+) PA policy score
Benjamin Neelon et al. (2014)	USA	ECE only	X	X	X	X	Served priority children	26 centers	Environment (observed – EPAO)	(+) Total PA score	(+) Total PA score
Carson et al. (2022)	Canada	Policy	X				Other	252 children	Environment (observed – EPAO)	(+) Total PA score	No difference
Drummond et al. (2009)	USA	ECE only	X	X	X	X	Not described	17 centers	Environment (self-report)	(+) number of centers meeting PA best practices	(+) number of centers meeting PA best practices
Esquivel et al. (2016)	USA	ECE + parent	X	X			Head Start	233 children	Environment (observed – EPAO)	(+) Total PA score	(+) Total PA score
Natale et al., 2022	USA	ECE + parent	X	X	X		Served priority children	24 centers	Environment (observed - EPAO)	(+) Total PA score	(+) Total PA score
Razak et al. (2018)	Australia	ECE only		X			Convenience sample	357 children	Environment (observed – EPAO)	(+) Total PA score	No difference
Schuler et al. (2019)	USA	ECE only	X	X	X		Other	354 children	Environment (observed – EPAO)	(−) Total PA score	No difference
Tomayko et al. (2017)	USA	ECE only	X	X	X	X	Served priority populations	66 children	Environment (observed - EPAO); teacher-led PA (observed)	(−) Total PA score (+) teacher-led PA	(+) teacher-led PA
Ward et al. (2008a)	USA	ECE only	X	X	X	X	Convenience sample	82 centers	Environment (observed - EPAO)	(+) Total PA score	No difference
Ward et al. (2020)	USA	ECE only	X	X	X	X	Convenience sample	291	Environment (observed – EPAO)	(+) Total PA score	No difference
Did not included ≥ 50% priority population ($n = 6$)											
Finch et al. (2014)	Australia	ECE only	X		X	X	Random – Stratified by SES	294 children	Environment (observed – Items from EPAO)[c]	(+) Total minutes staff delivered structured activities	
Garvin et al. (2019)	USA	ECE only	X	X	X	X	Other	1173 centers	Environment (self-report)	(+) % of PA and outdoor play and learning best practices met	(+) % of PA and outdoor play and learning best practices
Kao et al. (2018)	USA	ECE only	X				Random sample	17 centers	Environment – Policies, practices, amount of PA offered (observed)[c]	(+) written PA policy, media time use for education only, provider PA training; number/min of adult-led activities	
Kracht et al. (2020)	USA	Policy	X				Random sample	49 children	Environment (observed - EPAO)	(+) Total PA score	No difference
LaRowe et al. (2016)	USA	ECE only	X	X	X	X	Other	66 children	Environment (observed - EPAO); teacher-led PA	(+) Total PA score, teacher led PA	(+) Total PA score, teacher led PA
O'Neill et al. (2017)	USA	Policy	X				Random sample	59 centers	Environment (observed - EPAO)	(+) Total PA score	No difference

Abbreviations: policy, systems, environment (PSE), early care and education (ECE), policy (P), system (S), social environment (SE), physical environment (PE), United States of America (USA), physical activity (PA, environment and policy assessment and observation (EPAO).

[a] The Environment and Policy Assessment and Observation (EPAO) tool is frequently used in child care settings to assess the physical activity environment. The EPAO yields a total PA environment score as well as subscales including: active opportunities, sedentary opportunities, sedentary environment, portable play environment, fixed play environment, staff behavior physical activity, physical activity training and education, and physical activity policy.

[b] Only total PA score outcomes are presented unless otherwise noted. Only main results are presented. Secondary or sensitivity analyses are not presented (e.g., subgroups, completers only, etc.)

[c] Outcomes were presented at the item/construct level, hence only significant findings are presented.

works (8/12, 67%) (Table 6). Based on PSE approach, 3/5 interventions which included policy approaches, 3/6 with system approaches, 3/6 with social environment approaches, and 4/7 with physical environment approaches reported improvements in child PA outcomes. Half of interventions only used one PSE approach (6/12, 50%), two evaluating new policies (Carson et al., 2022; Benjamin Neelon et al., 2017), two making changes to the number of recess or outdoor periods (Razak et al., 2018; Alhassan et al., 2007), and two adding additional portable play equipment (Robinson et al., 2019; Palmer et al., 2020). Three studies (3/12, 25%) utilized two PSE approaches, with one making a system change by adding in activity breaks while also prompting providers to engage in and promote PA (Okely et al., 2020). The two other interventions both made changes to the social and physical environment by promoting teacher encouragement and modeling of PA and providing play equipment (Pate et al., 2016; Yin et al., 2012). The remaining three interventions (3/12, 25%) included all four PSE approaches, making policy changes, providing technical assistance and training, and making changes to the social and physical environment (Tomayko et al., 2017; Ward et al., 2020; Alkon et al., 2014). Of the 12 interventions assessing child PA that included ≥50% priority populations in their sample, most (9/12, 75%) reported at least one outcome in the expected direction; however, effects were only statistically significant in one third of interventions (4/12, 34%).

Interventions from the PA environment ($n = 11$), ranged from 3 months to two years, and for the majority, PA was not the primary outcome (8/11, 73%), while most were based off formative work (8/11, 73%) (Table 7). Based on PSE approach, 8/10 interventions which included policy approaches, 7/9 with system approaches, 7/9 with social environment approaches, and 5/6 with physical environment approaches reported improvements in PA environment outcomes. Half of

Table 5
Quality of included articles ($n = 44$).[a]

Maximum points available	Reporting	External validity	Internal validity - bias	Internal validity - confounding	Power	Total	Quality rating[b]
	11 points	3 points	7 points	6 points	1 points		
Randomized studies (maximum score = 28)							
Benjamin Neelon et al. (2014)	11	3	6	6	0	26	Excellent
Bonvin et al. (2013)	9	3	6	5	1	24	Good
Finch et al. (2014)	11	1	6	5	1	24	Good
Lee et al. (2020)	9	1	7	6	1	24	Good
Okely et al. (2020)	11	2	5	5	1	24	Good
Puder et al. (2011)	9	3	6	5	1	24	Good
Szpunar et al. (2021)	9	3	6	5	1	24	Good
De Craemer et al. (2016)	9	3	4	6	1	23	Good
Pate et al. (2016)	10	2	4	6	1	23	Good
Tucker et al. (2017)	8	3	6	5	1	23	Good
Ward et al. (2020)	10	1	6	5	1	23	Good
De Craemer et al. (2014)	9	3	4	5	1	22	Good
Driediger et al. (2019)	8	3	6	4	1	22	Good
Razak et al. (2018)	11	0	4	6	1	22	Good
Ward et al. (2008a)	10	1	5	6	0	22	Good
Wolfenden et al. (2019)	10	1	5	6	0	22	Good
Alhassan et al. (2007)	7	3	5	5	1	21	Good
Birnbaum et al. (2017)	9	3	4	4	1	21	Good
Kobel et al. (2020)	9	0	5	5	1	20	Good
Toussaint et al. (2020)	8	1	5	5	1	20	Good
Alkon et al. (2014)	10	0	6	3	0	19	Fair
Byun et al. (2018)	8	1	5	5	0	19	Fair
Natale et al., 2022	8	1	6	4	0	19	Fair
Robinson et al. (2019)	8	1	5	4	1	19	Fair
Schuler et al. (2019)	8	2	5	3	0	18	Fair
Non-randomized studies (maximum score = 25)							
van de Kolk et al. (2019)	10	3	5	4	1	23	Good
Benjamin Neelon et al. (2017)	10	0	7	4	0	21	Good
Kracht et al. (2020)	10	2	5	4	0	21	Good
Palmer et al. (2020)	10	3	5	3	0	21	Good
Carson et al. (2015)	9	3	4	4	0	20	Good
Brandes et al. (2020)	9	1	4	4	1	19	Fair
Brussoni et al. (2017)	10	2	4	3	0	19	Fair
Carson et al. (2022)	10	1	4	4	0	19	Fair
Kao et al. (2018)	9	3	5	2	0	19	Fair
Yin et al. (2012)	10	1	4	4	0	19	Fair
Esquivel et al. (2016)	9	2	5	2	0	18	Fair
Garvin et al. (2019)	10	1	4	3	0	18	Fair
Steenbock et al. (2019)	9	2	4	3	0	18	Fair
Zhou et al. (2014)	9	0	5	4	0	18	Fair
Nicaise et al. (2012)	10	1	4	2	0	17	Fair
Tomayko et al. (2017)	7	3	5	2	0	17	Fair
Drummond et al. (2009)	9	1	4	2	0	16	Fair
LaRowe et al. (2016)	7	2	5	2	0	16	Fair
O'Neill et al. (2017)	5	2	2	2	0	11	Poor

[a] Assessed by the Down's and Black Checklist (Downs and Black, 1998).
[b] Quality rating: Excellent (26–28), good (20–25), fair (15–19), and poor (≤14).

interventions used all four PSE approaches (6/11, 55%), four of which used variations of the Nutrition and Physical Activity Self-Assessment in Child Care (NAPSACC) intervention (Ward et al., 2008a; Drummond et al., 2009; Benjamin Neelon et al., 2014; Alkon et al., 2014). Two interventions (2/11, 18%) used one PSE approach, one of which was a policy change around accreditation standards (Carson et al., 2022), and the other a system change that involved multiple outdoor play periods (Razak et al., 2018). One interventions (1/11, 9%) used two PSE approaches, making a policy change and providing technical assistance to implement the policy change (Esquivel et al., 2016). Two interventions (2/11, 18%) utilized three PSE approaches, both instituting new policies, making system changes, and altering the social environment to improve the modeling and practices of providers (Natale et al., 2022; Schuler et al., 2019). In the 11 interventions assessing the PA environment, most (9/11, 82%) reported an outcome in the expected direction, which was statistically significant in half of interventions (6/11, 55%).

4. Discussion

The purpose of this review was to characterize the inclusion of priority populations within ECE interventions that utilized PSE approaches to promote child PA and describe these interventions and how effect they were in improving child PA or the PA environment among these groups. Overall, most interventions included minimal PSE approaches, less than half were conducted within priority populations, and even fewer demonstrated effectiveness in these populations. Many interventions demonstrated effects in the expected direction; however, few reached statistical significance, which may be explained by small sample sizes. Those that were effective in priority populations primarily improved the PA environment, and there were few that improved children's PA behavior. Yet, many interventions conducted in non-priority populations were effective at improving children's PA behavior. This highlights a clear discrepancy among PA interventions utilizing PSE approaches within priority populations compared to non-priority populations, as well as our understanding of how effective PSE intervention

Table 6
Description of PSE ECE interventions with child physical activity outcomes in priority populations ($n = 12$).

	Alhassan et al. (2007)	Alkon et al. (2014)	Benjamin Neelon et al. (2017)	Carson et al. (2022)	Okely et al. (2020)	Palmer et al. (2020)	Pate et al. (2016)	Razak et al. (2018)	Robinson et al. (2019)	Tomayko et al. (2017)	Ward et al. (2020)	Yin et al. (2012)
Intervention design												
Formative work	NR	NAPSACC	NR	NR	NR	NR	NR	NR	NR	Prior testing in high resource area	Survey; pilot study	Pilot study
Length	2 days	7 months	Policy – pre/post	Policy-pre/post	6 months	15 weeks	2 years (15–25 weeks in Y1; 31 weeks in Y2)	3 months	5 weeks, 4 days	2 years	9 months	7 months
Time period	Dec 2005 – Feb 2006	2009–2010	Fall 2008 – Fall 2012	2017–2019	Feb-Dec 2015	Jan-April 2018	2008–2010	May-Nov 2016	NR	Spring 2012-Spring 2014	2013–2016	Oct 2010-April 2011
PSE intervention approaches												
Policy	–	Selected NAPSACC changes in PA policies	New policy requiring ≥60 min of PA	New accreditation standards	–	–	–	–	–	Development of center policies to support PA	Changes in policies, related to PA	–
System	Two additional 30-min recess periods per day	Technical assistance on NAPSACC areas of improvement	–	–	Activities designed to break up ST with high-energy PA	–	–	Multiple periods of outdoor free-play vs single instance of outdoor free-play -	–	Training and ongoing technical assistance to develop daily routines and transitions to promote PA	Technical assistance on areas of improvement	–
Social environment	–	Selected NAPSACC changes in practices and environment	–	–	Providers engage in PA with children & encourage correct PA skills	–	Teacher PA encouragement, participation in PA, and inclusion of activities children enjoy that involve PA	–	–	Training on teacher-child PA interactions	Changes in practices and environment related to PA	Role modeling PA
Physical environment	–	Selected NAPSACC changes in practices and environment	–	–	–	FMS stations and equipment to outdoor free play area	Provided PA supplies (e.g., balls, music, scarves)	–	Adding indoor/outdoor portable play equipment	Training on modification of environment to support PA; microgrant given to provide resources for PA	Changes in practices and environment related to PA	PA equipment
Main results												
PA primary outcome (y/n)	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N
MVPA outcomes (direction)[a]	+	NR	+	+	–	NR	+	+	–	NR	+	NR
Other outcomes (direction)[a]		NR - PA intensity				+ FMS						+ steps + GMS

Abbreviations: policy, systems, environments (PSE), early care and education (ECE), moderate to vigorous physical activity (MVPA), physical activity (PA), not reported (NR), fundamental movement skills (FMS), gross motor skills (GMS), Nutrition and Physical Activity Self-Assessment for Child Care (NAPSACC).

[a] Positive (increase) or negative (decrease) is based on the direction of the effect; If not reported.

approaches are on these children's PA.

Half of studies in this review included interventions with only one PSE approach, especially among interventions that primarily assessed children's PA. Interventions assessing the PA environment, tended to include three or more PSE approaches and most often were obesity prevention interventions (vs. PA promotion). These studies tended to utilize multi-level approaches as they focused on the entirety of the ECE setting [i.e., organizational (directors, environment), interpersonal (provider-child), and individual (child)] whereas interventions focusing on child PA tended to focus on only one of these levels. One example of a multi-level intervention was NAPSACC, a comprehensive obesity prevention intervention that uses all four PSE approaches. NAPSACC has demonstrated positive changes in child body mass index (BMI), PA and eating behaviors, and the nutrition and PA environment in priority populations (Alkon et al., 2014; Ward et al., 2008a; Bonis et al., 2014). Given the success of having multiple PSE approaches on diet and obesity (Kracht et al., 2023), future studies should consider adopting more PSE approaches, as these comprehensive intervention approaches that are effective on the PA environment, may yield larger effects on child PA.

Physical environment changes were the most frequently reported PSE strategy, followed closely by systems, policy, and social environment approaches. In a review of ten reviews on ECE PA interventions, Lum et al. found evidence for positive intervention effects related to two intervention strategies: creating a physical environment that promotes PA and social environment of opportunities for adult-led, structured PA (Lum et al., 2022). Environmental approaches are likely most often utilized because they are relatively easy to implement (e.g., adding play equipment or encourage teachers to promote PA vs. making changes to the system within an ECE center). Further, most physical environments of ECE settings do not meet standards, so there are clear opportunities for improvement (Neshteruk et al., 2018; Zhang et al., 2021). As for policy and systems, several studies evaluating policy and system level approaches demonstrated positive intervention effects, particularly on the PA environment (Carson et al., 2022; Natale et al., 2022; Ward et al., 2008a; Benjamin Neelon et al., 2014; Esquivel et al., 2016). While child level PA was often not measured in ECE policy interventions, a systematic review examining ECE policies and children's PA found that PA policies were often linked to increases in the child PA (Stacey et al., 2017). Still, these changes may require additional administrative support and scheduling demands (e.g., coordinating between classes to spend additional time outdoors while meet capacity requirements), which may be a contrast to less burdensome changes of updating outdoor play areas and encouraging staff to be active with children.

This review highlights a clear gap related to the inclusion of priority populations in ECE PA interventions with PSE approaches. Although most studies in this review included participants from priority populations, less than half included predominantly priority populations. A greater proportion of studies focusing on the PA environment included priority populations compared to those focusing on child PA as a primary outcome. Many of the PA environment studies were conducted in the context of obesity prevention within federally funded ECE centers that have income requirements for enrollment. These programs also participate in a federal food assistance program, and this infrastructure can be leveraged to institute PSE changes in priority populations. Unfortunately, there is no PA assistance program for ECE settings, and many PA requirements are dictated by state level policies or licensing (Kenney et al., 2022; Jackson et al., 2021). Without this network of eligible program for priority populations, many included interventions used random sampling and convenience sampling which may not result in predominantly priority populations. Another consideration for not including priority populations may be that settings serving priority populations were not readily available to participate (i.e., recruitment barriers). We also acknowledge the arbitrary cutoff of $\geq$50% priority population. Many studies attempted to reach priority populations, but did not reach this threshold. For instance, the Toy Box studies conducted stratified recruitment (e.g., inclusion of low, medium, and high socioeconomic status municipalities) which precluded their inclusion (ToyBox-study et al., 2014). Still, given the dearth of interventions conducted within these populations, this is a clear future direction for future interventions, especially with a recognized need to focus on equity within PA interventions (Love et al., 2017).

When considering the full sample of included studies, our results align with prior reviews demonstrating ECE interventions in general, as well as those with PSE approaches, are effective at improving children's PA, motor skills, and the PA environment (Finch et al., 2016; Hnatiuk et al., 2019; Gordon et al., 2013; Stacey et al., 2017; Engel et al., 2018; Jones et al., 2019). This review contributes to the literature that this is not necessarily the case in priority populations. The heterogeneity of the various PSE approaches prevents clear conclusions about PSE intervention approaches being drawn to support PA among priority populations; however, these are promising approaches, particularly in terms of scalability. Improving lacking environments is needed, but efforts should be refocused to priority populations who may experience additional social and environmental constraints beyond the ECE setting such as limited resources (e.g., active play equipment), lack of access to parks and other recreation spaces, unsafe neighborhoods with poor walkability, discrimination and structural racism, thus making ECE an even more important setting to support PA (Ball et al., 2015; Trent et al., 2019; Shoesmith et al., 2021).

Studies represented a wide range of study quality, ranging from poor to excellent but most were good or fair quality. Differences were found, particularly related to randomization, bias, confounding, and power analysis. This may reflect the community-based nature of interventions, rather than tightly controlled clinical trials. While over half of studies utilized randomization, many did not, often because the intervention being tested (i.e., state policy) precluded randomization (Carson et al., 2022; O'Neill et al., 2017; Benjamin Neelon et al., 2017; Kao et al., 2018), studies were pilot testing an intervention (Palmer et al., 2020; Byun et al., 2018), or randomization was not feasible (Nicaise et al., 2012; Brussoni et al., 2017). Additionally, power analyses may not have been conducted due to pilot/preliminary nature of the studies or eligible samples were limited to specific communities.

There are several opportunities for future PA research in the ECE setting. First, the limited number of studies that included predominantly priority populations must be addressed. To reduce disparities in PA, researchers and public health professionals must specifically focus on priority populations through their recruitment methods and purposive sampling. Second, there was a lack of interventions focusing on infants and toddlers. Even though our review focused on children 0–6 years, all but four studies included exclusively preschoolers (2–6 years) (Benjamin Neelon et al., 2014). The ECE environment is important for promoting PA in infants and toddlers, (Gubbels et al., 2018) though they may not have been included due to wide range in ambulation (i.e., crawling, walking, and running) and motor skills. It is likely that different intervention strategies are needed for this population to promote healthy PA habits prior to preschool age (Hewitt et al., 2018). Further, only two studies in this review were conducted in family child care homes (Kao et al., 2018; Ward et al., 2020). Family child care homes are the second largest provider of out of home care for young children and often are more affordable and accessible, providing an opportunity to reach priority populations (Cui and Natzke, 2020). Interventions occurring in family child care homes are effective in improving diet quality (Ward et al., 2020; Gans et al., 2022), thus may be suitable for PA promotion as well. Fourth, the limited effectiveness of PSE PA interventions in the ECE setting may be due in part to intervention implementation. For instance, in one study intervention implementation varied widely at both the center level (25–76%) and teacher level (0–94%), which may explain differences in effectiveness (Neshteruk et al., 2021). Greater attention to implementation outcomes such as adoption, acceptability, and fidelity can provide important insights into designing and disseminating PSE intervention approaches (Proctor et al., 2011). Finally, all included studies were conducted in high-income countries, highlighting a clear

Table 7
Description of PSE ECE interventions with physical activity environment outcomes in priority populations ($n = 11$).

	Alkon et al. (2014)	Benjamin Neelon et al. (2014)	Carson et al. (2022)	Drummond et al. (2009)	Esquivel et al. (2016)	Natale et al., 2022	Razak et al. (2018)	Schuler et al. (2019)	Tomayko et al. (2017)	Ward et al. (2008a)	Ward et al. (2020)
Intervention design											
Formative work	NAPSACC	NAPSACC	NR	NAP SACC	Focus groups	Lessons from prior study	NR	NR	Prior testing in high resource area	Pilot test, advisory group input	Survey; pilot study
Length	7 months	6 months	Policy – Pre/post	9 months	Policy – pre/post	2 school yrs., 9 mos. each	3 months	6 months	2 years	6 months	9 months
Time period	2009–2010	2009	2017–2019	2005–2008	April 2013–May2014	2015–2017	May-Nov 2016	2014–2015	Spring 2012-Spring 2014	2005–2006	2013–2016
PSE intervention approaches											
Policy	Selected NAPSACC changes in PA policies	Support for breastfeeding, feeding infants and toddlers PA for infants, and center environment	New accreditation standards	Selected NAPSACC changes in PA policies	New policy eliminating juice and establishing family-style meal service	PA and screen time policies	–	Wellness and nutrition policies	Development of center policies to support PA	Selected NAPSACC changes in PA policies	Changes in policies, related to PA
System	Technical assistance on NAPSACC areas of improvement	Technical assistance on baby NAPSACC areas of improvement	–	Technical assistance on NAPSACC areas of improvement	Technical assistance to implement meal service	Individual assistance for menu planning and cost spending	–	Menu planning and food purchasing	Training and ongoing technical assistance to develop daily routines and transitions to promote PA	Technical assistance on NAPSACC areas of improvement	Technical assistance on areas of improvement
Social environment	Selected NAPSACC changes in practices and environment	Teachers make positive comments about PA, engage in PA with children	–	Selected NAPSACC changes in practices and environment	–	Role modeling healthy eating	Multiple periods of outdoor free-play vs single instance of outdoor free-play	Meal environment modifications	Training on teacher-child PA interactions	Selected NAPSACC changes in practices and environment	Changes in practices and environment related to PA
Physical environment	Selected NAPSACC changes in practices and environment	Designated place for breastfeeding	–	Selected NAPSACC changes in practices and environment	–	–	–	–	Training on modification of environment to support PA; microgrant given to provide resources for PA	Selected NAPSACC changes in practices and environment	Changes in practices and environment related to PA
Main results											
PA primary outcome (y/n)	N	N	Y	N	N	N	Y	N	Y	N	Y
PA environment (direction)[a]	+ PA policy	+ Total PA	+ Total PA	+ Best practices	+ Total PA	+ Total PA	+ Total PA	- Total PA	- Total PA	+ Total PA	+ Total PA

Abbreviations: policy, systems, environments (PSE), early care and education (ECE), physical activity (PA), not reported (NR), Nutrition and Physical Activity Self-Assessment for Child Care (NAPSACC).
[a] Positive (increase) or negative (decrease) is based on the direction of the effect.

gap in our knowledge of ECE PA interventions with PSE approaches in low- and middle-income countries who may experience differences in ECE settings and PA.

This study had study had several strengths including a comprehensive and systematic search strategy, an exclusive focus on PSE approaches, and inclusion of a quality assessment. However, there were also several limitations. The exclusive focus on PSE approaches did not account for teacher education on children's PA, which can also support child PA (Copeland et al., 2012; Mak et al., 2021). The review focused on approaches beyond PA curriculum, but does not diminish the importance of these curriculums within the ECE setting to promote child PA. There was also a high degree of heterogeneity in reporting of sample characteristics and outcomes across articles and countries. To account for this heterogeneity, we included several categories to designate priority populations, but this precludes us from directly comparing specific PSE approaches and populations. This limited opportunity for quantitative analysis across studies to identify the amount and specific components that are effective at improving PA outcomes. Additionally, the inclusion criteria specific to this review precluded the inclusion of interventions utilizing PSE approaches that did not include child or center level characteristics from which we could determine priority population status. Obtaining child-level information may provide additional burden on interventions, and limit studies focusing on implementation or widespread dissemination. We recommend that future studies, include population metrics to report the reach of their intervention and the settings in which interventions are being adopted. The inclusion criteria also did not include any gray literature, which may influence the effect sizes reported. Even so, not all reported a statistically significant effect on their outcome. Finally, we did not conduct a meta-analysis due to the heterogeneity of PA outcomes,

5. Conclusion

PSE approaches hold great potential for affecting population-level change in children's PA through the ECE setting and reducing health disparities. However, findings from this review show that less than half of the identified ECE PA interventions utilizing PSE approaches were conducted among mainly priority populations. Findings were mixed in regards to particular PSE strategies that were effective in improving child PA; however, it appears that interventions utilizing three or more PSE approaches were effective in improving the PA environment in ECE settings serving priority populations. Further research is needed into specific PSE strategies that are effective in improving child level PA within priority populations, so that all children can have adequate opportunities for PA.

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Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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Author contributions

CN conceptualized and designed the study, screened articles, extracted data, analyzed and interpreted the data, and drafted the initial manuscript. EF, EM, and CLK conceptualized and designed the study, screened articles, extracted data, interpreted the results, and provided critical feedback on the manuscript. SB and CL extracted data, interpreted the results, and provided critical feedback on the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Data availability

Data extract from studies can be found in supplementary tables or is available upon request.

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