Preventive Medicine 95 (2017) S37–S52

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Strength of obesity prevention interventions in early care and education settings: A systematic review

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ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form 20 September 2016
Accepted 23 September 2016
Available online 28 September 2016

Keywords:
Pediatric obesity
Child care
Child, preschool
Physical activity
Motor activity
Diet, food, and nutrition

ABSTRACT

Time and place of study: 2010–2015; international. Given the high levels of obesity in young children, numbers of children in out-of-home care, and data suggesting a link between early care and education (ECE) participation and overweight/obesity, obesity prevention in ECE settings is critical. As the field has progressed, a number of interventions have been reviewed yet there is a need to summarize the data using more sophisticated analyses to answer questions on the effectiveness of interventions. We conducted a systematic review of obesity prevention interventions in center-based ECE settings published between 2010 and 2015. Our goal was to identify promising intervention characteristics associated with successful behavioral and anthropometric outcomes. A rigorous search strategy resulted in 43 interventions that met inclusion criteria. We developed a coding strategy to assess intervention strength, used a validated study quality assessment tool, and presented detailed descriptive information about interventions (e.g., target behaviors, intervention strategies, and mode of delivery). Intervention strength was positively correlated with reporting of positive anthropometric outcomes for physical activity, diet, and combined interventions, and parent engagement components increased the strength of these relationships. Study quality was modestly related to percent successful healthy eating outcomes. Relationships between intervention strength and behavioral outcomes demonstrated negative relationships for all behavioral outcomes. Specific components of intervention strength (number of intervention strategies, potential impact of strategies, frequency of use, and duration of intervention) were correlated with some of the anthropometric and parent engagement outcomes. The review provided tentative evidence that multi-component, multi-level ECE interventions with parental engagement are most likely to be effective with anthropometric outcomes.

1. Introduction

Childhood obesity continues to be a global public health problem whereby the number of overweight or obese infants and young children (0 to 5 years) increased from 32 million globally in 1990 to 42 million in 2013 (Facts and Figures on Childhood Obesity, 2014). In the US, 22.8% of preschool aged children (2–5 years) were classified as overweight or obese (Ogden et al., 2014). Although obesity rates have recently decreased among this age group, racial/ethnic and socio-economic disparities continue (Ogden et al., 2014). The high rates and disparities are of concern, given that children who are overweight by age 5 are more likely to be obese later in life (Cunningham et al., 2014). To reduce lifetime risk of obesity, the Institute of Medicine recommends that obesity prevention interventions begin before the age of 5 (Early Childhood Obesity Prevention Policies, 2011).

Obesity-related diet and physical activity patterns of preschoolers do not meet national guidelines (Cortes et al., 2013; Hinkley et al., 2012; Kranz et al., 2006; Wilson et al., 2009). Children, especially those from racial/ethnic minorities and low-income communities in the U.S., eat too few fruits, vegetables, and whole grains, and consume too many energy dense snacks and beverages (Piernas and Popkin, 2011; Reedy and Krebs-Smith, 2010). Similarly, only half of preschool-aged children engage in the recommended 60 min of physical activity per day, and many exceed recommended limits for screen time, averaging 4 h per day (Beets et al., 2011; Tandon et al., 2011). Thus, interventions to improve eating and activity behaviors of preschool children are needed.

Although home environments are important for shaping eating and activity behaviors, >63% of U.S. mothers with preschool-aged children work outside the home (The State of America's Children, 2013) and 70

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http://dx.doi.org/10.1016/j.ypmed.2016.09.033
0091-7435/

to 80% of children with working mothers spend on average 35 h per week in formal early care and education settings (ECE) (America's Children: Key National Indicators of Well-Being, 2009; Larson et al., 2011a, 2011b; Ogden et al., 2012; Ward et al., 2008), mostly in center-based care (Child Care Costs on the Upswing, Census Bureau Reports, 2013). For children in fulltime center-based care, approximately 50% of their daily dietary intake comes from meals and snacks served on site, and this location may be the main source of their physical activity (Bollella et al., 1999; Gubbels et al., 2014; Padget and Briley, 2005). Given the numbers of children enrolled and the amount of time spent in this setting, promoting healthy eating and physical activity in ECE settings are integral to obesity prevention (Obesity in the Early Childhood Years, 2016). Because U.S. children who attend child care are at increased risk for obesity (Gubbels et al., 2010; Neelon et al., 2015; Woo Baidal et al., 2016), identifying successful interventions in these settings is critical, so they can be recommended for wide implementation.

Many reviews of obesity prevention efforts in ECE settings have been published (Blake-Lamb et al., 2016; Ciampa et al., 2010; D'Onise et al., 2010; Hesketh and Campbell, 2010; Kreichauf et al., 2012; Larson et al., 2011a; Laws et al., 2014; Ling et al., 2016; Mikkelsen et al., 2014; Nelson et al., 2003; Nixon et al., 2012; Skouteris et al., 2011; Summerbell et al., 2012; Wolfenden et al., 2012), including a paper by Sisson and colleagues published in this journal (Sisson et al., 2016). Using broad inclusion criteria, Sisson et al. identified 71 ECE interventions, with more than two-thirds published since 2010. With this recent growth in ECE intervention studies, it is important for review papers to move beyond the single question of whether an intervention is generally effective and explore which specific characteristics and strategies contribute to intervention effectiveness.

In addition to adding a more comprehensive analysis, this review was also designed as a follow-up to the Larson et al. (2011a) review paper, which summarized child care-based intervention studies that covered the 10-year period between 2000 and 2010. The goal of the current study was to systematically review obesity prevention interventions in center-based ECE settings published 2010–2015 in order to identify the most promising intervention characteristics associated with successful behavioral and/or anthropometric outcomes. We hypothesized that more comprehensive and intensive interventions would be more effective. To accomplish this goal, we developed a coding strategy to assess intervention strength and allow for examination of several study questions:

1. Is intervention strength related to successful behavioral and/or anthropometric outcomes?
2. Are interventions that incorporate parent engagement more effective than those that do not?
3. Can specific intervention elements be identified that relate to desired outcomes, including number of intervention strategies used, potential impact of the strategies, and frequency and duration of these strategies?
4. Is overall study quality related to successful behavioral and/or anthropometric outcomes?

2. Methods

2.1. Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used (Moher et al., 2009). Separate searches (healthy eating, physical activity, and screen time) were conducted in three databases (PubMed, ERIC, and Web of Science) in December 2015, and search terms and methods are available in an online appendix (Appendix 2). Each search string contained four tailored components and corresponding terms: ECE setting; healthy eating, physical activity, or screen time; behavioral and anthropometric outcomes; and intervention-related. These searches returned 7494 results. After duplicates were removed, 6824 results were imported into EndNote for title and abstract review. Twenty-two additional papers were identified, nine of which were included, after cross-referencing included papers and recent reviews. Fig. 1 describes this process in more detail.

2.2. Inclusion and exclusion criteria

Papers were included if they were: peer-reviewed, published between 2010 and 2015, took place primarily in a center-based ECE setting, targeted children ages 0–6 years, included an intervention targeting healthy eating, physical activity and/or screen time, used an objective or validated measure of dietary intake, physical activity, screen-time, or anthropometric outcomes, provided a statistical measure of intervention success, and were published in English. All study designs, except case studies, were included if a pre- and post-evaluation was conducted.

2.3. Selection and data extraction

Two authors (EW & AC) each reviewed titles and abstracts, identifying 86 papers for full text review. EW and AC independently reviewed each article and extracted information using a template that included information on study design, location, sample characteristics, intervention components, and outcomes; meetings were held to discuss scoring and identify discrepancies. Any disagreements remaining following this discussion were resolved by consensus with a third reviewer who also read the full text (blinded to the other reviewers' decisions). One author from a pool of five (ML, DW, KH, AW, and AT) reviewed summary entries to validate the extracted data and affirm inclusion of the paper. The goal of this review was to reach consensus; thus, statistics evaluating level of agreement were not computed.

2.4. Evaluation of intervention strength

For the purpose of this review we defined intervention *strength* as a composite of the number of intervention strategies used, their potential impact, and the frequency and duration of their use. This coding method is similar to ones used to characterize community health efforts for obesity prevention (Fawcett et al., 2015; Schwartz et al., 2015b). Individual intervention strategies were identified as described in the outcome paper and treated individually unless presented as part of a package (e.g., tool kit). Each intervention strategy was identified, evaluated for potential impact (scores 4 vs 1), and weighted by intensity (scores 1–4) and frequency (scores 1–4). Based on previous literature and ecological models (Sallis and Owen, 2015), high impact intervention strategies included changes in food, physical activity, and screen time environments or policies that provided ongoing support or structure for behavior change (e.g., revising menus or nutrition policies; providing more physical activity in the ECE setting; and in-person staff training). Low impact strategies included educational activities that encouraged individuals to make changes (e.g., field trips, information, posters, and games). High impact parent engagement included in-person strategies such as parent trainings or family days, while low impact strategies were more passive (e.g., sending materials home). Frequency of use was based on how often each strategy was employed. For example, if the intervention included the use of a weekly DVD, it was scored as a 3 on frequency (i.e., not daily but ≥1/week). A policy change such as increasing daily outdoor time by 30 min was scored as a 4 since it was in place during the entire intervention period. Duration of an intervention strategy was coded based on the length of the intervention period; thus there was one code per study. Two authors assessed intervention strength scores for each component (healthy eating, physical activity and screen time combined, and/or parent engagement). Disagreements were resolved by consensus. A cumulative strength score was then tallied. See Table 1 for a description of the coding scheme.

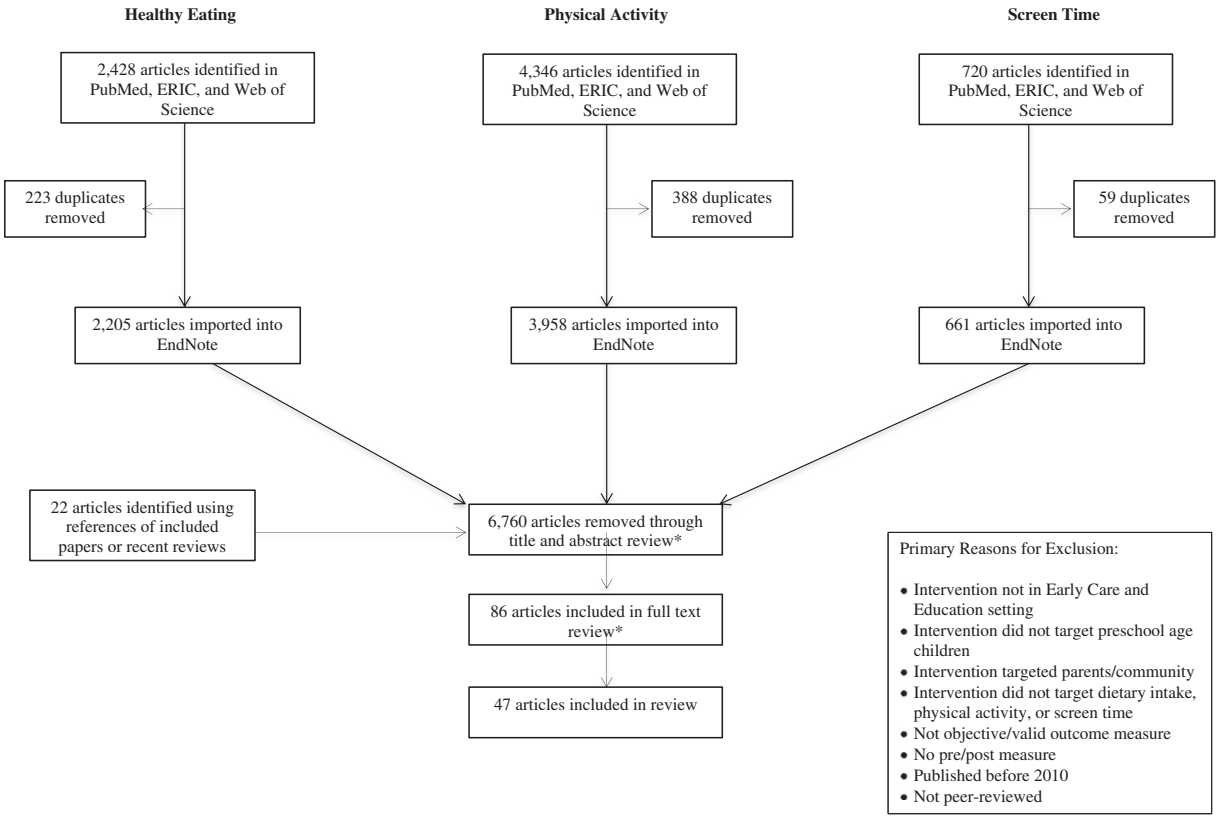

Fig. 1. Study selection flow diagram. Time and Place of Study: 2010–2015; International. *Some of the papers included in the full text review were returned by two or all three of the search strings.

2.5. Assessment of intervention success

For each study, reported outcomes were coded in a systematic manner to determine intervention success. Dietary outcomes were not included if insufficient detail was provided on variety or quality of the food or food groups measured to determine desired direction (e.g., only grains consumed reported, but focus was increasing whole grains; only total milk consumption was reported, but without differentiation between full-fat and low/non-fat varieties). For physical activity outcomes, light physical activity was not coded. For anthropometric outcomes, only relative measures (e.g., BMI z-scores) were coded when both relative and absolute measures were reported. Both in-school and at-home behavioral outcomes were included. If studies included overlapping outcomes (e.g., MPA, VPA, and MVPA), all were coded. Sub-group analyses (e.g., boys, girls) were included when provided. When multiple analysis models were used, only outcomes from the adjusted models were included. To enhance comparability among studies, only immediate post-intervention outcomes (not mid-point or maintenance outcomes) were included. Finally, only outcomes that were favorably and statistically significant ($p < 0.05$) were coded. To translate coded outcomes into intervention success, we calculated two measures: 1) overall intervention success (calculated as a percentage of successful outcomes to total number of outcomes (Σ successful outcomes / Σ all outcomes $*$ 100)); and 2) any intervention success, where individual study success was a dichotomous outcome (any successful outcome vs. no successful outcome). These measures were calculated for healthy eating, physical activity/screen time, and anthropometric target areas if provided. The overall intervention success and dichotomous success scores (any) were used as the dependent variables in the hypothesis testing.

2.6. Quality assessment

Methodological quality of each study was assessed by two authors using the Quality Assessment Tool for Quantitative Studies from the Effective Public Health Practice Project (Quality Assessment Tool for Quantitative Studies, 2009). Ratings were compared and consensus reached on the final global rating. Given the nature of ECE studies where child care staff often provide intervention delivery, the question, "were study participants aware of research question?" was not coded.

Table 1
Intervention strength coding and scoring.

Number of strategies	Potential impact rating	Frequency rating	Duration rating	Strength score
Tally of specific intervention strategies	4 = High (policy or environmental) 1 = Low (information, education)	4 = Daily 3 = Not daily but ≥1×/week 2 = < 1×/week but >1×/month 1 = 1×/month or less	4 = > 9 months 3 = > 6 months but ≤ 9 months 2 = ≥ 3 months but ≤ 6 months 1 = < 3 months	Σ of all intervention strategy score ratings Intervention strategy score rating = potential impact + frequency + duration

2.7. Analytic approach to hypothesis testing

All analyses were carried out in IBM SPSS Statistics for Windows, Version 23.0. Statistical tests included partial correlations between intervention strength scores and intervention success, adjusting for Quality Assessment score. Percent intervention success and intervention components (number of strategies, potential impact, frequency, and intervention duration) also were correlated. Study Quality Assessment scores and intervention success scores (continuous and dichotomous variables) were correlated as well. Finally, independent samples *t*-tests were conducted to compare studies with and without some key characteristics: RCTs vs non-RCTs and mode of intervention delivery (child care staff vs externally-delivered). All statistical tests were two-tailed with alpha set to 0.05. However, these analyses are considered exploratory given the novelty of the review approach. Due to low sample sizes, correlations were interpreted when $r \geq 0.30$, regardless of *p*-value. Throughout the results, we note both statistical significance and this exploratory standard.

3. Results

3.1. Study characteristics

Papers ($n = 47$) included in this review described 43 unique interventions (see Table 2). Six additional papers describing intervention protocols were used to code intervention strength and quality. Of these interventions, over half took place in the US (53%), followed by Australia (14%), Germany (9%), and Switzerland (6%). The remaining studies took place in Switzerland, Chile, and Belgium (2 studies each), and England, Colombia, Spain, and Turkey (1 study each). Although some interventions were designed for any child enrolled in the center, measured child age in the studies ranged from 2+ to 6 years and were considered preschool interventions. Sample sizes ranged from 23 to 2062 children. The majority of papers included were RCTs (32), but other study designs included non-experimental pre-post (9), within subject cross-over (4), and longitudinal follow-ups to RCTs (2). Generally, the studies took place in child care settings where many participants were low to middle socio-economic status (SES).

3.2. Intervention characteristics

3.2.1. Intervention duration

Duration of the interventions ranged from 8 days to 3 years, with most lasting 4–6 months.

3.2.2. Mode of delivery

Approximately half of the interventions were delivered primarily by child care staff (56%). Other modes of delivery included: primarily by external experts (14%), primarily by the research team (12%), combination of child care staff and external experts (12%), or combinations of research staff, center staff, external experts, and parents (7%).

3.2.3. Target behaviors

Seven of the 43 interventions targeted healthy eating only, 17 targeted only physical activity, 9 targeted healthy eating and physical activity, 1 targeted physical activity and screen time, and 9 targeted healthy eating, physical activity, and screen time.

3.2.4. Type of strategies

Strategies to improve healthy eating included menu changes, nutrition education, changing meal service approaches, and food tastings. Strategies to improve physical activity included structured physical activity lessons, staff training, and take-home activity cards or resources. Twenty-five of the 43 interventions included a parental engagement component with strategies ranging from newsletters, CDs, or other handouts to more active strategies such as parent workshops or cooking classes. The median potential impact score sum for all strategies was 14 (range 4–39).

3.2.5. Number, frequency and duration of strategies used

The total number of strategies used within healthy eating, physical activity/screen time, and parental engagement ranged from 1 to 15, with 5 strategies as the median. The median strategies for healthy eating, physical activity, and parental engagement were 2 (range 0–6), 3 (range 0–9), and 1 (range 0–4) respectively. The average frequency of intervention strategies ranged from once a month or less to daily, with the median average frequency being less than once per week, but more than once per month.

3.2.6. Intervention strength score

The median intervention strength score was 40 (range 8–122). Strength scores for healthy eating and physical activity/screen time components were similar (median 23, range 5–51; and median 23.5, range 9–64, respectively). The median strength score for parent engagement was much lower at 15 (range 4–28).

3.3. Outcomes measured

Of the 43 interventions, 18 included one or more valid or objective measure for dietary intake, 31 for physical activity, 5 for screen time, and 24 for anthropometric outcomes. Measures of dietary intake included observation or plate waste (11), validated parent survey (5), food frequency questionnaires reported by parents (3), 24-h recalls (2), and food records (2). Measures of physical activity included accelerometers (16), motor development (10), direct observation (5), pedometers (3), shuttle run (2), standing jump measure (2), obstacle course (1), and a questionnaire from the National Health and Nutrition Examination Survey (1). For anthropometric measures, the bulk of the studies used BMI (23), followed by body fat (7), waist circumference (4), waist-to-height ratio (1), weight (1), and mid-upper arm circumference (1). All five screen time measures were validated proxy reports from parents and caregivers. Physical activity and screen-time outcomes were combined in the analyses.

3.4. Study quality

Using the Quality Assessment Tool for Quantitative Studies (2009), 9 studies received a strong global rating, 14 received a moderate rating, and 20 received a weak rating.

3.5. Effect of interventions

3.5.1. Healthy eating

Of the 18 studies that included a dietary intake measure, the majority (72%) demonstrated at least one significant impact. Only five studies showed no effect on dietary intake. Percent successful outcomes ranged from 0 to 100%. Some studies demonstrated positive impacts on dietary intake, but only within specific food groups or nutrients such as fruits, vegetables, or sugar.

3.5.2. Physical activity/screen time

The majority (77%) of the 31 studies that measured changes in physical activity, fitness, or motor skills demonstrated at least one significant intervention effect. The remaining 7 studies showed no effect. Percent successful outcomes ranged from 0 to 100%, with a median of 50%. Only one of the 5 studies that measured screen time demonstrated a positive intervention effect.

3.5.3. Anthropometrics

Ten of the 24 studies with an anthropometric measure demonstrated at least one successful intervention effect. Percent successful outcomes ranged from 0 to 100%, with a median of 0%.

Table 2
Characteristics of included interventions, summary of results, quality assessment, and total intervention strength scores.

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
Alhassan et al. (2012)	*Design*: RCT *Location*: United States, MA *Duration*: 6 months	*Sample*: 2 centers, 8 classrooms, $N = 78$ *Age*: 2.9–5 yrs *SES*: Low *R/E*: 61% Latino/Hispanic, 39% AA	LMS-based PA program including structured PA activities vs. unstructured free play time. Teacher trainings and lesson plans/resources provided.	*Type*: PA *Measures*: PA via accelerometer, and LMS via TGMD-2.	*PA*: Decrease in sedentary time and increase in leaping skills.	*QA*: Strong *ISS*: 26
Alhassan et al. (2013)	*Design*: RCT *Location*: United States, MA *Duration*: 4 weeks	*Sample*: 2 centers, 8 classrooms, $N = 75$ *Age*: 2.9–5 yrs *SES*:NP *R/E*: NP	Based on SPARK. Normal outdoor play time + additional 30 min of structured outdoor play 3 days/week. Teacher trainings.	*Type*: PA *Measures*: PA via accelerometer.	*PA*: Decrease in sedentary time and increase in vigorous PA.	*QA*: Moderate *ISS*: 23
Alkon et al. (2014)	*Design*: RCT *Location*: United States, CA, CT, NC *Duration*: 7 months	*Sample*: 17 centers, $N = 552$ *Age*: 3–5 yrs *SES*: Low *R/E*: 46% White, 17% Latino, 16% AA, 14% Asian, 7% other	Child Care Health Consultant worked with provider to write/update nutrition and PA policies. Provided NAP SACC workshops for center staff. On-site consultations, phone calls, emails, posters, info sheets.	*Type*: PA & Anthro *Measures*: PA measured via OSRAP. BMI.	*PA*: NS. *Anthro*: Decrease in zBMI	*QA*: Weak *ISS*: 89
Annesi et al. (2013a)	*Design*: RCT *Location*: Southeast United States *Duration*: 8 weeks	*Sample*: 32 classrooms, $N = 275$ *Age*: 3.5–5.6 yrs *SES*: Low-mid *R/E*: 100% AA	Start for Life Program. 30 min structured PA, 4 h of teacher training. Daily gross motor skills and behavior skill training, goal setting and self-monitoring with achievement charts, logs, and certificates. Activity binder.	*Type*: PA *Measures*: PA measured via accelerometer.	*PA*: Improved MVPA and VPA in individuals and classrooms.	*QA*: Strong *ISS*: 30
Annesi et al., 2013b	*Design*: RCT *Location*: Southeast United States *Duration*: 9 months	*Sample*: 26 classrooms, $N = 1154$ *Age*: 4–5 yrs *SES*: Low - mid *R/E*: 86% AA, 9% Latino, 3% White, 2% other	Start for Life Program	*Type*: PA & Anthro *Measures*: PA measured via accelerometer. BMI.	*PA*: Increased time in MVPA and VPA. *Anthro*: Decrease in BMI.	*QA*: Strong *ISS*: 40
Annesi et al. (2013c)	*Design*: RCT *Location*: Southeast United States *Duration*: 9 months	*Sample*: 17 classrooms, $N = 273$ *Age*: 4–5 yrs *SES*: All at/below 130% of federal poverty line *R/E*: 100% AA	Start for Life Program	*Type*: PA & Anthro *Measures*: PA measured via accelerometer. BMI.	*PA*: Greater % participating in MVPA and VPA. *Anthro*: Decrease in BMI.	*QA*: Strong *ISS*: 43
Baskale and Bahar (2011)	*Design*: Pre/post experimental with control *Location*: Turkey *Duration*: 1 yr	*Sample*: 6 schools, 2 from each income bracket, $N = 238$ *Age*: 5 yrs *SES*: Low, middle, high *R/E*: NP	Nutrition education intervention based on Piaget's theory. Included play and visual materials, followed by observations of food selection and consumption.	*Type*: DI & Anthro *Measures*: Food consumption frequency. MUAC. BMI.	*DI*: Improved white meat and fish, leafy and root vegetables, citrus fruits and other fruits, lower intake of sugar and processed fruit juice. *Anthro*: NS.	*QA*: Moderate *ISS*: 14
Bell et al. (2015)	*Design*: Pre/post cohort *Location*: Australia *Duration*: 1 month	*Sample*: 20 centers, $N = 236$ *Age*: 2–4 yrs *SES*: NP *R/E*: NP	The Start Right, Eat Right program. Teacher training and improved school healthy eating policies and menu.	*Type*: DI *Measures*: Plate waste	*DI*: Increased consumption of fruit, vegetables, protein, carbohydrates, minerals (Ca, Na, K, Mg, P, Zn), riboflavin, niacin, and folate. Decreased consumption of discretionary foods, fats and oils, % saturated fat.	*QA*: Weak *ISS*: 30
Bellows et al. (2013)	*Design*: RCT *Location*: United States, CO *Duration*: 18 weeks	*Sample*: 8 centers, $N = 274$ *Age*: 3–5 yrs *SES*: Low *R/E*: 59% Hispanic, 32% White	Mighty Moves. Teacher-led activities on stability, locomotor, or manipulation. Food Friends nutrition program with binder, CD, activity mats, flashcards, balls, beanbags, scarves, puppets, ropes, and parent	*Type*: PA & Anthro *Measures*: PA and gross motor skills via pedometers and PDMS respectively. BMI.	*PA*: Improved gross motor skills, stability, and manipulation. *Anthro*: NS	*QA*: Weak *ISS*: 45

(continued on next page)

Table 2 (*continued*)

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
			materials. Teacher training.			
Bonis et al. (2014)	*Design*: RCT *Location*: United States, LA *Duration*: 6 months	*Sample*: 26 centers, $N = 251$ *Age*: 3–5 yrs *SES*: NP *R/E*: NP	4 workshops delivered by dietitians (certified NAP SACC consultants) to center staff, TA for center staff, nutrition and PA information distributed to parents/guardians. Used NAP SACC to choose 3–4 areas for improvement and created a facility improvement plan.	*Type*: PA *Measures*: PA via accelerometer	*PA*: Increase in MVPA, VPA and total PA in intervention group.	*QA*: Moderate *ISS*: 52
Bonvin et al. (2013)	*Design*: Single-blinded RCT with 1:1 random assignment. *Location*: Switzerland *Duration*: 9 months	*Sample*: 58 centers, $N = 1467$ *Age*: 3.3 avg yrs *SES*: 17.5% low parental EL *R/E*: 57.9% migrant	Youp'là Bouge. Teacher training, rearrangement of the built environment, parental involvement, daily activity recommendation. Center received flyers, $1500, and advice. Centers encouraged to hold a parent information and discussion session. Parent flyers.	*Type*: PA & Anthro *Measures*: PA measured using the Zurich Neuromotor Assessment. PA measured using accelerometer in a subset of participants. BMI.	*PA*: NS *Anthro*: NS	*QA*: Moderate *ISS*: 41
Cespedes et al. (2013a, 2013b)	*Design*: RCT *Location*: Colombia *Duration*: 5 months	*Sample*: 14 preschools, $N = 1216$ *Age*: 3–5 yrs *SES*: NP *R/E*: NP	Sesame Workshop Healthy Habits. Daily (1 h) classroom and play activities including storybooks, posters, videos, games, and songs. "Healthy family day" parent workshop, weekly newsletters. Teacher trainings, guide.	*Type*: Anthro *Measures*: BMI.	*Anthro*: NS *36 mo f/u*: Decrease in underweight and increase in normal weight	*QA*: Moderate *ISS*: 66
Cosco et al. (2014)	*Design*: Pre/post *Location*: United States, NC *Duration*: 1 month	*Sample*: 27 centers, $N = 804$ *Age*: 3–5 yrs *SES*: NP *R/E*: NP	Preventing Obesity by Design. Assistance to change the outdoor environment. POEMS site assessment. Seed grants. Teacher training workshops, webinars. TA. Website, renovation evaluation.	*Type*: PA *Measures*: PA measured via CARS	*PA*: Children were more likely to be engaged in non-sedentary activity. Connected single and double loops associated with higher activity than linear/straight pathways.	*QA*: Weak *ISS*: 15
De Bock et al. (2012)	*Design*: Cluster RCT *Location*: Germany *Duration*: 6 months	*Sample*: 18 schools, $N = 377$ *Age*: 3–6 yrs *SES*: 16.3% low maternal EL *R/E*: 32.4% migrant	Come Aboard the Health Boat. State-sponsored health promotion program. External nutrition experts delivered 15 nutrition sessions, 5 sessions with parents. Activities included familiarizing children with different food types, preparation methods, cooking, eating meals together, and healthy drinks.	*Type*: DI & Anthro *Measures*: Parental questionnaire asking fruit, vegetable, water, and sugary drink consumption. Measured BMI, waist-circumference, WTHR, and total body fat.	*DI*: Increase in fruit and vegetable consumption. *Anthro*: NS.	*QA*: Moderate *ISS*: 32
De Bock et al. (2013)	*Design*: Cluster RCT *Location*: Germany *Duration*: 6 months	*Sample*: 37 centers, $N = 809$ *Age*: 4–6 yrs *SES*: 25% low maternal EL, 55% middle, 20% high *R/E*: 37% migrant	Parents and preschools received a website, video, and printed book. Trained gym teachers coordinated parent activities, encouraged participation, and documented implementation. Most project ideas designed de novo by the child care community.	*Type*: PA & Anthro *Measures*: PA via accelerometer. BMI, and body fat measured.	*PA*: Less sedentary and more physically active. *Anthro*: NS.	*QA*: Strong *ISS*: 31
De Coen et al. (2012)	*Design*: Cluster RCT *Location*: Belgium *Duration*: 2 yrs	*Sample*: 31 schools, $N = 1102$ *Age*: 3–6 yrs *SES*: High and low *R/E*: NP	Prevention of Overweight among Pre-school and School Children (POP). Community meetings. Teacher manual, improved playground & snack policy. Parent handouts. Teacher meetings, financial incentive. External support from regional health boards.	*Type*: DI, ST & Anthro *Measures*: DI data via parental semi-quantitative FFQ. ST via parent survey. BMI.	*DI*: NS. *ST*: NS. *Anthro*: Improved BMI in low-SES children.	*QA*: Weak *ISS*: 96
De Craemer et al. (2014)	*Design*: Cluster RCT *Location*: Belgium	*Sample*: 27 schools, $N = 1150$	Toy Box. Teachers' guide, activities, newsletters, tip	*Type*: PA *Measures*: PA via	*PA*: Increase in VPA and MVPA.	*QA*: Moderate *ISS*: 38

Table 2 (*continued*)

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
	Duration: 24 weeks	*Age*: 4–6 yrs *SES*: Low, middle, high *R/E*: NP	cards, hand puppet, and posters. Teacher training. Environmental changes to increase PA. Parent newsletters, tip cards, and posters.	accelerometer.		
Finch et al. (2010, 2014)	*Design*: Cluster RCT *Location*: Australia *Duration*: 4 months	*Sample*: 20 centers, $N = 459$ *Age*: 3–5 yrs *SES*: NP *R/E*: NP	FMS sessions; structured activities; staff role modeling; limiting small screen recreation and sedentary time; and any activity promoting physical environment.	*Type*: PA *Measures*: PA via pedometers.	*PA*: N.	*QA*: Moderate *ISS*: 64
Fitzgibbon et al. (2011), Kong et al. (2015)	*Design*: RCT *Location*: United States, IL *Duration*: 14 weeks	*Sample*: 18 centers, $N = 669$ *Age*: 3–5 yrs *SES*: Low *R/E*: 94% AA, 3% Latino, 3% multiracial/other	Hip-Hop to Health Jr. Teacher training. Education lessons targeting reductions in dietary fat and television viewing, and increases in fruits, vegetables, and physical activity. 20 min PA. Parent workshops, CD, and newsletters.	*Type*: PA, DI, ST & Anthro *Measures*: PA via accelerometer, ST via parent survey, DI via 24 h recall, food records, and in school observation. BMI measured. Kong: 1 yr f/u.	*PA* (2011): Increase in MVPA min/day, MVPA min/h, & vigorous activity min/day. *DI*: NS. *ST*: NS. *Anthro*: NS.	*QA*: Weak *ISS*: 53
Fitzgibbon et al. (2013)	*Design*: RCT *Location*: United States, IL *Duration*: 14 weeks	*Sample*: 4 centers, $N = 147$ *Age*: 3–5 yrs *SES*: Low *R/E*: 94% Latino, 2% AA, 4% multiracial/other	Family-Based Hip-Hop to Health. Education lessons targeting reductions in dietary fat and television viewing, and increases in fruits, vegetables, and physical activity. Emphasis on family environment and parenting. 20 min nutrition lesson and 20 min PA. 6, 90-min classes for parents.	*Type*: PA, DI, ST & Anthro *Measures*: PA via accelerometer, ST via parent survey, DI via 24 h recall, food records, and in school observation. BMI measured.	*PA*: NS. *DI*: NS. *ST*: NS. *Anthro*: NS.	*QA*: Weak *ISS*: 48
Hardy et al. (2010)	*Design*: Cluster RCT *Location*: Australia *Duration*: 20 weeks	*Sample*: $N = 29$ centers, $N = 430$ *Age*: 4.4 avg yrs *SES*: 47.7% low *R/E*: 63% non-English spk	Munch and Move. Teacher training, resources, grant, and expert advice. Program included games, learning experiences, examples of policy statements, fact sheets etc.	*Type*: PA *Measures*: PA via the TGMD-2 checklist.	*PA*: Improved locomotor, object control and total FMS.	*QA*: Weak *ISS*: 38
Harnack et al. (2012)	*Design*: Randomized crossover trial *Location*: United States, MN *Duration*: 6 weeks	*Sample*: 1 center, $N = 57$ *Age*: 2–5 yrs *SES*: 41.5% high school, 49.1% some college or assoc. degree *R/E*: 75.5% AA, 5.7% Hispanic/Latino, 13.2% multiracial, 3.8% American Indian, 1.9% White	Two serving styles: (1) Fruits and vegetables first: fruits and non-starchy vegetables served family style 5 min in advance of meal; and (2) Provider portioned meals: plate prepared for each child according to CACFP guidelines.	*Type*: DI *Measures*: Meal observation. Lunch observation data entered into NDSR.	*DI*: Fruit, vitamin A, and folate intakes were higher when fruits and vegetables served first. Fruit, vegetable, and total calorie intake higher in provider portioned meals.	*QA*: Weak *ISS*: 18
Herman et al. (2012)	*Design*: Pre/post *Location*: United States, PA, TX, AZ, RI, NY *Duration*: 6 months	*Sample*: 75 centers, $N = 112$ *Age*: 3–5 yrs *SES*: Low parental EL *R/E*: Parents were 33.3% White, 32.4% Hispanic/Latino, 14.8% AA	Eat Healthy, Stay Active! Teacher training and TA provided. Parent training and incentives. Nutrition and PA lessons, and field trips to farmer's market and grocery store for children.	*Type*: Anthro *Measures*: BMI	*Anthro*: Decrease in BMI and % obese.	*QA*: Moderate *ISS*: 67
Huss et al. (2013)	*Design*: Repeated exposure, randomized, cross-over quasi-experimental study *Location*: United States, IN *Duration*: 12 weeks	*Sample*: 4 classrooms, $N = 23$ *Age*: 2–5 yrs *SES*: NP *R/E*: 56.5% Caucasian, 30.4% Asian, 13.1% other	Four combinations of portion size of main course and dessert: (1) reference portion, dessert with lunch; (2) reference portion, dessert after lunch; (3) large portion (50% larger), dessert with lunch: (4) large portion, dessert after lunch.	*Type*: DI *Measures*: Researchers measured plate waste and entered data into the NDSR. Parent survey.	*DI*: Serving dessert after meal increased energy intake from main course and dessert. Serving dessert with meal decreases total energy intake.	*QA*: Weak *ISS*: 16
Jones et al. (2011)	*Design*: Parallel Cluster 2-arm RCT *Location*: Australia	*Sample*: 2 centers, $N = 97$ *Age*: 3–5 yrs	Jump Start. Teacher training; structured lessons and unstructured activities	*Type*: PA & Anthro *Measures*: PA via the TGMD-2 and	*PA*: Improved jump and overall movement skill. *Anthro*: NS.	*QA*: Moderate *ISS*: 22

(*continued on next page*)

Table 2 (*continued*)

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
	Duration: 20 weeks	*SES*: NP *R/E*: NP	for children. Lesson focuses on one FMS and unstructured activities let the children practice the new skill. Equipment provided for unstructured activities.	accelerometer. BMI.		
Krombholz (2012)	*Design*: RCT *Location*: Germany *Duration*: 20 months	*Sample*: 22 centers, $N = 559$ *Age*: 4.59 avg yrs (intervention); 4.53 avg yrs (control) *SES*: NP *R/E*: NP	Physical education lessons and additional physical activity time in school. Teacher Training.	*Type*: PA & Anthro *Measures*: Motor skills via MoTB 3–7 and standing broad jump. BMI and skin fold measured.	*PA*: NS. *Anthro*: NS.	*QA*: Moderate *ISS*: 39
Monsalves Alvarez et al. (2015)	*Design*: Cohort *Location*: Chile *Duration*: 6 months	*Sample*: 1 school $N = 70$ *Age*: 3.2 avg yrs (boys); 3.3 avg yrs (girls) *SES*: NP *R/E*: NP	Physical activity classes including circuits with jumps, sprints, carrying medicinal balls, gallops, and crawling.	*Type*: PA & Anthro *Measures*: Motor skill tests performed SLJ and 12 m run. BMI.	*PA*: Decrease in 12 m run time and increase in SLJ. *Anthro*: NS.	*QA*: Weak *ISS*: 17
Natale et al., 2013, 2014	*Design*: RCT *Location*: United States, FL *Duration*: 6 months	*Sample*: 8 centers, $N = 307$ *Age*: 2–5 yrs *SES*: Low *R/E*: 36% AA, 34% White, 18% other, 14% unknown	Healthy Inside-Healthy Outside (HI-HO) program. Teacher training, weekly TA visits. Parent monthly dinner, monthly newsletters, and at-home activities. Schools developed new policies and menus to increase PA and healthy eating.	*Type*: PA, DI, ST & Anthro *Measures*: PA and ST questions were extracted from NHANES and modified (parent report); FFQ used for parents and teachers. BMI.	*DI*: Decrease in junk food consumption, increase in mean fresh fruit and vegetable consumption. *ST*: Decrease in time spent at computer and TV. *PA*: NS. *Anthro*: NS.	*QA*: Strong *ISS*: 91
Nicaise et al. (2012)	*Design*: Cross sectional at two time points *Location*: United States, CA *Duration*: 1 yr	*Sample*: $N = 50$ pre, $N = 57$ post *Age*: 4–5 yrs *SES*: NP *R/E*: White (70.2% & 63.2%), Hispanic (7.0% & 13.2%), Asian (12.3% & 13.2%), AA (10.4% & 10.3%)	Renovation of outdoor space. L-shaped path transformed into a looping path, grassy hill was created, and climbing/sliding structures removed to create more open space.	*Type*: PA *Measures*: PA measured via OSRAC-P and accelerometer.	*PA*: Increase in observed MVPA and decrease in observed sedentary time.	*QA*: Weak *ISS*: 12
O'Dwyer et al. (2013)	*Design*: Cluster RCT *Location*: England *Duration*: 6 weeks	*Sample*: 12 schools, $N = 240$ *Age*: 4.5 avg yrs *SES*: NP *R/E*: 84.3% White	Teacher resource pack with 20 activity cards, user manual, lesson plans, sign posting information, and a poster promoting active play.	*Type*: PA *Measures*: PA via accelerometer.	*PA*: Increase in activity, % MVPA & % Total PA.	*QA*: Weak *ISS*: 20
Penalvo et al. (2013a, 2013b, 2015)	*Design*: Cluster RCT *Location*: Spain *Duration*: 1–3 yrs	*Sample*: 24 schools, $N = 2062$ *Age*: 3–5 yrs *SES*: NP *R/E*: NP	Program Si! Teacher training, classroom materials, online resources, and access to a blog to share best practices between schools. PA/DI lessons and take home activities. Annual health fair for families.	*Type*: DI & Anthro *Measures*: DI via questionnaire. BMI, skin fold, and waist circumference.	*DI*: NS. *Anthro*: NS.	*QA*: Moderate *ISS*: 89
Puder et al. (2011), Burgi et al. (2012)	*Design*: Cluster RCT *Location*: Switzerland *Duration*: 1 school yr	*Sample*: 40 preschool classes, $N = 652$ *Age*: 5.2 avg yrs *SES*: 38% of low parental EL *R/E*: 72% migrant	Ballabeina intervention. Children participated in weekly PA sessions, and received education on healthy eating, media use, and sleep. Teacher training. Parent information leaflets, activity cards with CD, and discussion sessions promoting PA, healthy food, limitation of TV use, and sufficient sleep. Improved environment.	*Type*: PA, DI, ST & Anthro *Measures*: PA via 20 m shuttle run test. Secondary outcomes: agility, balance, PA via accelerometer, DI via FFQ. ST via parent survey. BMI, % body fat, and waist circumference.	*Puder*: *PA*: Increase in aerobic fitness and agility. *DI*: Increase in healthy eating habits *Anthro*: Decrease in percent body fat, waist circumference, and sum. *Burgi*: *PA*: Decrease in shuttle run NM & HEL, obstacle course M & LEL. *Anthro*: Decrease in % body fat NM & M, waist NM & M, body fat HEL, waist HEL & LEL.	*QA*: Strong *ISS*: 96
Roe et al. (2013)	*Design*: Cross-over design	*Sample*: $N = 61$ *Age*: 3–5 yrs	Teachers offered children a healthy snack, either a	*Type*: DI *Measures*: Meal	*DI*: Serving a variety of vegetable and fruit vs. no	*QA*: Weak *ISS*: 8

Table 2 (*continued*)

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
	Location: United States, PA *Duration*: 8 days over the course of 4 weeks	*SES*: NP *R/E*: 56% White, 29% Asian, 11% AA, 4% Pacific Islander	single type vegetable/fruit vs. a variety of 3 types. Uniform-sized pieces were served family style, and children ate as much as they wanted.	observation. Uneaten pieces counted and plate weight recorded.	variety increased selection and consumption of these foods.	
Roth et al. (2010, 2015)	*Design*: Cluster RCT *Location*: Germany *Duration*: 1 yr	*Sample*: 41 schools, $N = 709$ *Age*: 4–5 yrs *SES*: Intervention group = 23.3% low, 50% mid, 26.7% high *R/E*: NP	Prevention through Activity in Kindergarten Trial (PAKT). Daily physical activity lessons, classroom materials, teacher training, and homework cards. Parents received interactive lectures and newsletters with health tips and activities.	*Type*: PA & Anthro *Measures*: PA via accelerometer and obstacle course. BMI and skin fold measured.	*PA*: Increase in MVPA, motor skills performance, explosive leg strength, and jumping coordination. *Anthro*: Decrease in sum of four skin folds.	*QA*: Strong *ISS*: 56
Salazar et al. (2014)	*Design*: RCT *Location*: Chile *Duration*: 5 months	*Sample*: 4 centers,[b] $N = 265$ *Age*: 4–5 yrs *SES*: Low *R/E*: NP	Teacher education materials and training. Parent workshops, leaflets, and family event. Nutrition and PA education for children.	*Type*: PA, DI, & Anthro *Measures*: PA via accelerometer. DI via plate weight and food intake questionnaire for foods consumed at home. Total body fat and skin fold sum.	*PA*: Increase in VPA and decrease in minimal activity. *DI*: Decrease in energy intake and fat intake. *Anthro*: Decrease in sum of skin fold and % body fat.	*QA*: Weak *ISS*: 44
Schwartz et al. (2015a)	*Design*: Within subjects crossover design *Location*: United States, CT *Duration*: 3 weeks	*Sample*: 1 center, $N = 85$ *Age*: 3–5 yrs *SES*: NP *R/E*: 81% Hispanic	Two variations of family-style feeding were compared to usual practice: (1) fruits, vegetables, and milk were served before the main meal (first course); and (2) fruits, vegetables, and milk were served before the main meal and meats and grains were removed from the table after the first serving (combination).	*Type*: DI *Measures*: DI via standard weighing methods.	*DI*: Offering fruits and vegetables before a meal did not consistently lead to larger serving or consumption of these foods. Milk consumption was significantly higher in combined intervention for both meals.	*QA*: Weak *ISS*: 16
Sharma et al. (2011)	*Design*: Convenience sample — pre/post pilot intervention. *Location*: United States, TX *Duration*: 6 weeks	*Sample*: 2 centers, $N = 75$ *Age*: 3–5 yrs *SES*: Low *R/E*: Hispanic & AA	Coordinated Approach to Child Health for Early Childhood (CATCH Early Childhood). There were four major components of the intervention: (1) Teacher-led, nutrition-based classroom curriculum "It's Fun to Be Healthy!;" (2) Teacher-led PA Box; (3) Parent education and tip-sheets; (4) Teacher training.	*Type*: PA & DI *Measures*: PA via SOFIT-P. DI via meal observation.	*PA*: NS. *DI*: NS.	*QA*: Weak *ISS*: 31
Veldman et al. (2015)	*Design*: Pilot RCT *Location*: Australia *Duration*: 8 weeks	*Sample*: 4 preschools, $N = 60$ *Age*: 2.5 avg yrs *SES*: NP *R/E*: NP	Active Beginnings Program. Focused on three skills (balance, kick (stationary ball), and broad jump). Teacher training and daily lessons/activities sought to improve these three gross motor skills.	*Type*: PA *Measures*: TGMD-2 and Get Skilled, Get Active checklist	*PA*: Improved overall gross motor score and stationary ball kick.	*QA*: Weak *ISS*: 15
Williams et al. (2014)	*Design*: Pre/Post RCT *Location*: United States, NY *Duration*: 6–10 weeks	*Sample*: 24 centers, $N = 1143$ *Age*: 3–5 yrs *SES*: NP *R/E*: 40% Latino, 24% White, 27% AA, 9% other	Eat Well Play Hard in Child Care. Part of NY SNAP-Ed. Multilevel messaging to preschool children, their parents, and center staff. RDNs selected 6 of 10 modules to use in classrooms and with parents separately.	*Type*: DI *Measures*: Parent survey of low-fat and fat-free milk, cups of fruits and vegetables consumed, requesting vegetable or fruit as snack, offering of vegetables as snack.	*DI*: More likely to drink low-fat or fat-free milk; increase in vegetable intake. Increase in child-initiated vegetable snacking.	*QA*: Strong *ISS*: 40
Winter and Sass (2011)	*Design*: Pre/Post quasi-exp matched sites *Location*: United States, TX *Duration*: 24 weeks	*Sample*: 4 centers, $N = 405$ *Age*: 3–5 yrs *SES*: Low *R/E*: 95% Latino	Healthy & Ready to Learn. Child activities: set of children's books and corresponding activities for parents/teachers to do with children. Increased daily MVPA. Teacher and parent training.	*Type*: PA & Anthro *Measures*: PA via the Brigance Diagnostic Inventory of Child Development-II, and SOFIT tool. BMI.	*PA*: Improved gross motor skills on the Brigance non-locomotor and locomotor scores. *Anthro*: NS.	*QA*: Weak *ISS*: 47
Witt and Dunn (2012)	*Design*: Randomized Pre/Post *Location*: United	*Sample*: 17 centers, $N = 263$ *Age*: 4–5 yrs *SES*: NP	Color Me Healthy. Uses color, music, and exploration of the senses to teach children about healthful eating and PA. Circle	*Type*: DI *Measures*: DI measured via plate weight to calculate % of snack consumed.	*DI*: Increase in consumption of overall fruit, strawberry, cantaloupe, grape, pineapple, overall	*QA*: Weak *ISS*: 41

(*continued on next page*)

Table 2 (*continued*)

First author and year	Study design Location Duration	Characteristics of sample[a]	Exposure or intervention	Valid outcome type(s) and measures	Key/significant findings	Quality assessment/intervention strength score
	States, ID *Duration*: 6 weeks	*R/E*: NP	time lessons and 1 imaginary trip each week. Take home activities for parents. Teacher training prior to program implementation on circle time lessons and imaginary trips.		vegetable, celery, cherry tomato, and broccoli. Fruit and veg snacks increased.	
Yin et al. (2012)	*Design*: Pre/Post quasi-experimental *Location*: United States, TX *Duration*: 18 weeks	*Sample*: 4 centers, $N = 384$ *Age*: 3–5 yrs *SES*: NP *R/E*: 90% Mexican-American	Míranos! Motor skill development, structured outdoor play, nutrition education and activities, integration of health literacy into classroom activities, staff development and wellness, and engagement of parents for support at home.	*Type*: PA, DI, ST & Anthro *Measures*: PA via LAP-3 and pedometer on three consecutive days. DI via NDSR and aggregated plate waste measure. ST via parent survey. BMI.	*PA*: Improved gross motor development center and outdoor play intensity. *DI*: Improved consumption of fruits, vegetables, and low-fat milk. *ST*: NS. *Anthro*: Weight gain was less for combined center and home intervention.	*QA*: Moderate *ISS*: 88
Zask et al. (2012a, 2012b), Adams et al. (2009)	*Design*: Cluster RCT & longitudinal f/u *Location*: Australia *Duration*: 10 months, and 3 yr f/u	*Sample*: 31 centers, $N = 560$ children. *Age*: 4, 5, and 8 yrs *SES*: NP *R/E*: NP	Tooty Fruity Veggie. Increased PA through games, playground alterations, small grants for sports equipment, parent workshop, monthly newsletter. School menu improvement and policy changes, posters, DVD for parents, workshops for parents, education for the students, staff acting as role models, water access.	*Type*: PA & Anthro *Measures*: PA via TGMD-2. BMI and waist circumference measured.	*PA*: Improved movement skills, raw locomotor, and object control scores. *F/U*: Girls maintained their object control skill advantage. *Anthro*: Decrease in BMI z-score and waist circumference.	*QA*: Moderate *ISS*: 122

AA: African American.
BMI: body mass index.
CACFP: Child and Adult Care Food Program.
CARS: Children's Activity Rating Scale.
CMH: Color Me Healthy.
DI: dietary intake.
EL: education level.
FFQ: Food Frequency Questionnaire.
FMS: fundamental movement skills.
F/U: follow up.
HEL: high education level.
LAP-3: Learning Achievement Profile Version 3.
LEL: low education level.
LMS: locomotor skill.
M: migrant.
MoTB: Motor Test Battery.
MUAC: mid-upper arm circumference.
MVPA: moderate to vigorous physical activity.
N: sample size at baseline.
NAP SACC: Nutrition and Physical Activity Self-Assessment for Child Care.
NDSR: Nutrition Data System for Research.
NM: non-migrant.
NP: not provided.
NS: not significant.
OSRAC-P: Observational System for Recording Activity in Children-Preschool Version.
OSRAP: Observation System for Recording Activity in Preschools.
PA: physical activity.
POEMS: Preschool Outdoor Environment Measurement Scale.
PDMS: Peabody Developmental Motor Scales.
QA: quality assessment.
RDNs: registered dietitian nutritionists.
R/E: race/ethnicity.
SLJ: standing long jump.
SNAP: Supplemental Nutrition Assistance Program.
SOFIT-P: System for Observing Fitness Instruction Time for Preschoolers.
SPARK: Sports, Play, and Active Reaction for Kids.
ISS: Intervention Strength Score.
ST: screen time.
TA: teaching assistant.
TGMD: Test of Gross Motor Development.
VPA: vigorous physical activity.
WTHR: weight to height ratio.

[a] Sample size noted is based on the reported sample size at baseline; the final sample on which data analysis was performed may be smaller.
[b] Center no. based on Methods section; differed from abstract.

4. Hypotheses tested

4.1. Is intervention strength related to successful behavioral and/or anthropometric outcomes?

When correlating strength scores to percent successful outcomes/total outcomes, no significant positive correlation was observed for either a healthy eating or physical activity behavior outcome, with or without the inclusion of parent engagement (see Table 3). In fact, all of these correlations were unexpectedly in the negative direction. The strength of physical activity plus parent engagement and healthy eating plus parent engagement scores were both correlated greater than +0.30 with percent successful anthropometric outcomes, although this was not the case for the combined interventions.

When strength scores were correlated with the dichotomized outcome measure (some success vs. no success), physical activity intervention scores were correlated with physical activity outcomes >0.30, but again, negatively. Correlations between healthy eating intervention strength scores and healthy eating outcomes were also unexpectedly negative, and the correlation between healthy eating plus parent engagement and any healthy eating outcome was greater than −0.30. By contrast, all six intervention strength scores were positively correlated with any successful anthropometric outcome, with correlations all >0.30 and two reaching statistical significance ($p < 0.05$).

4.2. Are interventions that incorporate parent engagement more effective than those that do not?

Correlations of intervention strength scores with anthropometric outcomes were consistently higher when parent engagement scores were included. This pattern was stronger with the dichotomous anthropometric outcomes.

4.3. Can specific intervention elements be identified that relate to desired outcomes?

Of the 28 correlations shown in Table 4 relating number of strategies, potential impact, frequency, and duration to outcomes, seven were >0.30. Four of the seven were observed in parental engagement components.

4.4. Is the overall quality of the study related to desired behavioral and anthropometric outcomes?

As shown in the last row of Table 3, QA global rating score was positively correlated to both continuous and dichotomous outcomes for healthy eating, physical activity, and anthropometric outcomes, but only the healthy eating continuous correlation was >0.30.

Independent samples *t*-tests were conducted to compare RCTs with studies that did not meet RCT criteria on the primary outcomes (HE, PA/ST, anthropometric) for percent desired outcomes. Given the small sample sizes, none of the comparisons reached significance. However, we observed a consistent trend, with non-RCT studies showing a greater percent of positive outcomes across all four measures, with mean differences ranging from 7 to 16%.

We also compared those interventions delivered solely by child care providers to those that were externally-delivered (i.e., external experts, research staff, or some combination). A trend was observed for externally-delivered interventions that showed a greater percent of positive outcomes across three of the four measures, with differences ranging from 9 to 26%. The anthropometric outcome, however, did not show this trend, with a difference of only 1.5% between the groups.

5. Discussion

Healthy eating, physical activity, and obesity prevention interventions in ECE settings have been an active area of study, with 43 interventions published between 2010 and 2015. Because of the extensive growth of interventions for obesity prevention (Larson et al., 2011b; Sisson et al., 2016), it is critical to understand which specific intervention characteristics and strategies contributed to intervention effectiveness. As such, we undertook a systematic review and created a coding scheme to examine the relation of intervention strength to healthy eating, physical activity/screen time, and anthropometric outcomes, based on the hypothesis that more intensive interventions should yield better outcomes.

In our review, we found that all of the intervention strength scores were correlated >0.30 with at least one significant anthropometric outcome. The strength scores included healthy eating interventions, physical activity/screen time interventions, and combined interventions. If this pattern is confirmed with further studies, the implication is that more comprehensive, multi-component, multi-level interventions with frequent and long-term implementation in ECE settings are more

Table 3
Partial correlations between intervention strength scores and intervention outcomes (% all or any) for healthy eating, physical activity/screen time and anthropometric targets[a], controlling for study quality.

Intervention strength score[b]	PA outcomes (% all)	HE outcomes (% all)	Anthropometric outcomes (% all)	PA outcomes (any)	HE outcomes (any)	Anthropometric outcomes (any)
PA strength	−0.262 (31) $p = 0.161$		0.265 (22) $p = 0.245$	−0.389 (31) $p = 0.034$		0.333 (22) $p = 0.140$
PA + PE strength	−0.159 (31) $p = 0.403$		0.333 (22) $p = 0.140$	−0.349 (31) $p = 0.059$		0.488 (22) $p = 0.025$
HE strength		−0.064 (18) $p = 0.807$	0.269 (15) $p = 0.352$		−0.245 (18) $p = 0.343$	0.433 (15) $p = 0.122$
HE + PE strength		−0.123 (18) $p = 0.639$	0.395 (15) $p = 0.162$		−0.458 (18) $p = 0.064$	0.584 (15) $p = 0.028$
PA + HE strength			0.226 (13) $p = 0.480$			0.396 (13) $p = 0.203$
PA + HE + PE strength			0.296 (13) $p = 0.350$			0.498 (13) $p = 0.100$
Study QA global rating: quantitative	($n = 31$) 0.052 $p = 0.781$	($n = 18$) 0.394 $p = 0.105$	($n = 24$) 0.199 $p = 0.350$	($n = 31$) 0.249 $p = 0.177$	($n = 18$) 0.289 $p = 0.244$	($n = 24$) 0.204 $p = 0.339$`

PA = physical activity &/or screen time; HE = healthy eating; PE = parent engagement; QA = quality assessment.
[a] Intervention strength: Σ intervention strategies coded for potential impact, frequency, & duration.
[b] Number of interventions with the specific targets appears in parentheses.

Table 4
Correlations between number of strategies used, potential impact of strategy used, frequency of strategy use, and duration of intervention and intervention outcomes (% successful).

Components of intervention strength	Physical activity/screen time outcomes	Healthy eating outcomes	Anthropometric outcomes
PA/ST Intervention Strength Score	$N = 31$		$N = 22$
Strategies (#)	−0.185		0.423
	$p = 0.320$		$p = 0.050$
Potential Impact Score	−0.249		0.092
	$p = 0.177$		$p = 0.684$
Frequency Score	−0.230		0.276
	$p = 0.212$		$p = 0.213$
Intervention Duration Score	−0.094		0.259
	$p = 0.617$		$p = 0.245$
HE Intervention Strength Score		$N = 18$	$N = 15$
Strategies (#)		0.196	0.353
		$p = 0.435$	$p = 0.197$
Potential Impact Score		0.232	0.149
		$p = 0.355$	$p = 0.595$
Frequency Score		0.024	0.140
		$p = 0.924$	$p = 0.618$
Intervention Duration Score		−0.161	0.303
		$p = 0.524$	$p = 0.273$
PE Strength Score[a]	$N = 18$	$N = 13$	$N = 20$
Strategies (#)	0.352	0.294	0.052
	$p = 0.152$	$p = 0.330$	$p = 0.826$
Potential Impact Score	0.467	0.534	0.171
	$p = 0.051$	$p = 0.060$	$p = 0.470$
Frequency Score	0.121	−0.065	−0.067
	$p = 0.633$	$p = 0.833$	$p = 0.778$
Intervention Duration Score	0.103	−0.154	0.348
	$p = 0.684$	$p = 0.616$	$p = 0.133$

PA/ST—physical activity/screen time; HE—healthy eating; PE—parent engagement.
[a] Includes *only* studies with parent intervention components.

likely to be effective at helping children maintain or achieve healthy weights. These findings are generally consistent with ecological models of behavior (Sallis and Owen, 2015) and recommendations from the Institute of Medicine (Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation, 2012) and other authoritative groups favoring multi-level comprehensive interventions (Huang et al., 2009).

We found that parent engagement components added to the effectiveness of ECE interventions. In all cases, correlations between intervention strength and at least one significant anthropometric outcome were higher when the strength of parent engagement was included in the overall score (+0.16 for physical activity interventions; +0.15 for health eating interventions; +0.10 for combined interventions, see Table 3). Consistent with prior literature (Golley et al., 2011, Skouteris et al., 2011; Sussner et al., 2006), our results support the critical role parents play in shaping a young child's behaviors early in life and that without actively engaging them, interventions may not be successful.

Surprisingly, we found that the correlation between intervention strength and percent of all significant anthropometric outcomes was lowest for the combined interventions; parent engagement components improved this relationship slightly. However, when any successful outcome was considered, the strength score for combined healthy eating and physical activity interventions including parent engagement, was one of the higher correlations ($r = 0.498$). Perhaps, combined interventions are not sufficiently powered on all outcomes that are included.

Confidence in the main findings with anthropometric outcomes should be tempered by inconsistencies across the two methods of quantifying outcomes. Prior reviews have categorized whether a study had any significant intervention effect on a given outcome (Blake-Lamb et al., 2016; Larson et al., 2011a; Laws et al., 2014; Ling et al., 2016; Mikkelsen et al., 2014; Nixon et al., 2012; Sisson et al., 2016). Due to concerns about overestimating success, we also computed the percent of significant findings in the desired direction as a continuous measure of outcomes. The latter approach was expected to roughly adjust for the number of measures taken and tests conducted. The two approaches produced mainly inconsistent results. Intervention intensity correlations with the continuous outcome indicators were consistently lower than correlations with the dichotomous anthropometric outcomes. One possible explanation is that studies with multiple anthropometric outcomes may have some measures with less sensitivity to change. Two patterns seen with the dichotomous outcomes were generally replicated with the continuous outcomes. Correlations with continuous anthropometric outcomes were higher when parent engagement was included in the intervention strength score. Correlations with continuous anthropometric outcomes tended to be higher for single-behavior interventions compared to combined interventions. Only the physical activity plus parent engagement and the healthy eating plus parent engagement intervention scores were correlated with continuous anthropometric outcomes >0.30.

Our behavioral outcome findings were anomalous. For healthy eating intervention strength and dietary intake outcomes, all four correlations were negative. Similarly, all four correlations between physical activity intervention strength and physical activity outcomes were negatively correlated. Thus, none of the findings supported the hypothesis that more comprehensive ECE interventions produce better behavioral outcomes. This pattern suggests a paradox whereby the strength of interventions was correlated with less favorable behavioral outcomes but more favorable anthropometric outcomes. The explanation that measuring dietary and physical activity behaviors in young children is imprecise is insufficient given that measurement error should bias correlations toward zero, not negative.

We offer two potential explanations for these unexpected findings related to behavioral outcomes. Visual inspection of the data indicated that outliers may play a role in the negative correlations, which is not surprising given the small number of studies. For example, the scatterplot of physical activity intervention strength with physical activity continuous outcomes (not shown) demonstrated that the intervention with the highest intervention strength had no significant intervention effects, which appeared to enhance a negative correlation. A more troublesome explanation may be that "stronger" interventions, with multiple components and complex environmental and policy changes over extended durations, may be particularly difficult to implement. The challenges of implementation may be amplified when child care staff are instructed to deliver the interventions. Thus, we

hypothesize that comprehensiveness may be negatively associated with feasibility and fidelity of implementation. Physical activity intervention strength was more negatively related to behavioral outcomes than healthy eating intervention strength. This could be due to many healthy eating intervention components being implemented by food service workers who are more likely to have relevant training and support than child care workers whose wages are low and are generally not trained in providing physical activity. The critical role of implementation of prevention interventions was demonstrated in a review of 500 studies (Durlak and DuPre, 2008). Effect sizes were two to three times higher in studies with good implementation of interventions. Thus, it will be important to document and analyze implementation in future studies.

There was limited evidence that specific intervention components were particularly important. The negative (though nonsignificant) correlations between physical activity intervention scores and physical activity outcomes were repeated. Seven of 28 correlations between intervention components and outcomes was >0.30, with four drawn from the parent engagement components. Further research is needed to identify whether some intervention components contribute more to outcomes than other components. Also, there were no significant differences by study design (RCT vs. non-RCT) or by method of implementation (externally-delivered vs. child care staff).

Demonstrating increased interest in early childhood as an important time for intervention, several reviews on obesity prevention interventions in this age group have been published in recent years (Blake-Lamb et al., 2016; Ciampa et al., 2010; D'Onise et al., 2010; Hesketh and Campbell, 2010; Kreichauf et al., 2012; Larson et al., 2011a; Laws et al., 2014; Ling et al., 2016; Mikkelsen et al., 2014; Nelson et al., 2003; Nixon et al., 2012; Sisson et al., 2016; Skouteris et al., 2011; Summerbell et al., 2012; Wolfenden et al., 2012). The present paper overlaps in some ways with these reviews; however, it makes several unique contributions. First, previous work generally focused either on infancy (birth-two years) or early childhood (two-six years); however, the present review theoretically included children from birth to age six. It is important to note that no studies included in this review reported measurements for children ages birth to two years. Second, though several previous studies focused exclusively on the ECE setting (Kreichauf et al., 2012; Larson et al., 2011a; Mikkelsen et al., 2014; Nixon et al., 2012; Sisson et al., 2016; Zhou et al., 2014), many other reviews have included multiple intervention sites such as home, primary care, and mixed-setting interventions (Blake-Lamb et al., 2016; Ciampa et al., 2010; D'Onise et al., 2010; Hesketh and Campbell, 2010; Laws et al., 2014; Ling et al., 2016, Skouteris et al., 2011; Wolfenden et al., 2012). Considering the significant time that millions of young children spend in child care in the U.S. and globally, it was justified to focus only on interventions in ECE settings for the present review. Third, the present paper only included studies with objective or validated outcome measures. Fourth, several prior studies also examined the potential effects of parental involvement in ECE settings (Golley et al., 2011; Ling et al., 2016; Sisson et al., 2016; Skouteris et al., 2011; Sussner et al.). To our knowledge, this review is the first to code and quantitatively assess the impact of parental engagement intervention components on dietary intake, physical activity/screen time, and anthropometric outcomes. Fifth, previous reviews estimated the impact of interventions on outcomes by *any* positive effect (Blake-Lamb et al., 2016; Larson et al., 2011a; Laws et al., 2014; Ling et al., 2016; Mikkelsen et al., 2014; Nixon et al., 2012; Sisson et al., 2016). The present review makes a contribution by also examining the overall intervention success (calculated as the percentage of successful outcomes to total number of outcomes). Finally, the present review contributed a novel intervention strength coding tool and methods for incorporating those coding results into quantitative analysis to answer key questions about intervention characteristics and effectiveness.

An important strength of this review was the focus on examining the role of intervention strength in study outcomes. A coding system was developed to help capture the comprehensive, multi-level, multi-component nature of interventions given that they are the most likely to be effective (Sallis and Owen, 2015; Accelerating Progress in Obesity Prevention: Solving the Weight of the Nation, 2012). The coding was designed to roughly quantify components of interventions expected to predict better outcomes. By summarizing intervention components on a common metric, we were able to conduct a quasi-quantitative analysis that we hoped would be more informative than a narrative review. Given the lack of details presented in the published papers, the intervention strength metric may not have captured all of the study information. For example, there was not enough information to code specific intervention strategies across studies, and implementation of strategies was rarely reported. The content validity of the intervention strength coding was supported by similar indices used to assess childhood obesity interventions in the Healthy Communities Study (Fawcett et al., 2015) and to quantify intervention dose in community interventions (Schwartz et al., 2015b).

Though the intervention intensity coding system generated a wide range of scores, there was limited evidence to support the main hypothesis that ECE intervention strength is related to outcomes of healthy eating, physical activity and obesity prevention. Though nonsignificant, the pattern of findings supported tentative conclusions that intervention strength was positively correlated ($r \geq 0.30$) with the dichotomous anthropometric outcomes, and stronger parent engagement interventions tended to improve outcomes as noted by two significant correlations. These positive findings are particularly notable because the outcome measures were objective or validated. Our findings provide encouragement that well-designed ECE interventions may be able to play an important role in obesity prevention. However, other analyses did not support the intervention intensity hypothesis, raising the possibility that the positive results are not replicable. The negative correlations of intervention intensity scores and behavioral outcomes raise many questions. It was also surprising that the strength of single behavior interventions in general had higher correlations with anthropometric outcomes than did the combined diet and physical activity interventions, which could be related to issues of study power. Although our assessment of intervention strength is innovative and could add to the research literature, questions remain about our scoring. We encourage other investigators to develop alternate coding systems for intervention strength and compare results to the present approach.

Additional strengths of the study were the careful methods of the systematic review, use of a rigorous quality assessment method, and coding of study characteristics, study quality, and intervention strength by two raters. Several aspects of the review limit conclusions that can be drawn. We were unable to include intervention results from unpublished studies, a problem which has been recently noted among pediatric obesity interventions registered in the Clinical Trials Registration Database (Cui et al., 2015). To decrease publication bias, future intervention studies should always register trials with powered primary outcomes prior to study implementation. Due to the small number of studies with long-term follow-up ($n = 10$) and the variation in the follow-up time period (3 months to 3 years), only outcomes at the end of the intervention were analyzed. Measuring dietary and physical activity behaviors in young children is very challenging, so measurement limitations could explain some of the inconsistent and unexpected findings. The small number of studies used in correlations resulted in low statistical power, and several moderate-strength correlations (e.g., $r > 0.40$) were nonsignificant. Meta-analytic methods were not used, though a meta-analysis could not have evaluated the strength of the overall intervention and its components as was done here.

6. Conclusion

Preventing obesity in young children could have lifelong benefits, and many recent studies have evaluated obesity prevention interventions in preschool children. The exploratory, but quantitative, approach

to the present review of ECE interventions revealed that stronger interventions, with parent engagement and environmental and policy components, tended to be positively related to anthropometric outcomes. Thus, the best evidence suggests that comprehensive, multi-level obesity prevention interventions in ECE can be recommended. The present review raised several questions that should be priorities for future research.

- Important unanswered questions about the extent and quality of intervention implementation should be addressed in future studies, including the role of intervention complexity.
- Anomalous findings regarding intervention strength and behavioral outcomes should be examined further.
- Feasibility and effectiveness of single-behavior versus combined physical activity and healthy eating interventions requires more focused study.
- The intervention strength scoring system developed is similar to other systems (Fawcett et al., 2015), and we welcome other investigators to use and improve it.
- Importantly, it may be more productive to evaluate improved implementation of already-effective interventions than to study novel combinations of intervention strategies.

Conflict of interest

The authors declare no conflict of interest.

Transparency document

The Transparency document associated with this article can be found in the online version.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2016.09.033.

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