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Review

# Characteristics of physical activity interventions and effects on cardiorespiratory fitness in children aged 6–12 years—A systematic review

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*Abbreviations:*
CRF, cardiorespiratory fitness
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ABSTRACT

*Objectives:* To examine the characteristics of physical activity (PA) interventions and the effects on cardiorespiratory fitness (CRF) in healthy children based on treatment theory.
*Design:* Systematic review.
*Methods:* PubMed and Embase were searched for studies published between 2003 and 2016.
Inclusion criteria were:
Participants: healthy children aged 6–12.
Interventions: interventions with activities to increase PA behaviour or physical fitness (PF) regardless of setting.
Control: no or alternative intervention.
Outcome: exercise-based CRF measure with appropriate analysis of CRF effects.
Study design: randomized controlled trial.
Effect size was calculated using $d_{ppc2}$ and the methodological quality of the studies was assessed using the PEDro scale.
*Results:* Of 1002 studies screened, 23 met the inclusion criteria. Thirteen of the 23 studies found statistically significant improvements in CRF and eight studies showed medium to high effect sizes. Interventions with medium to high effect sizes focused more often on PF than PA behaviour, had slightly higher frequencies of activities and had a shorter duration than the less effective interventions.
*Conclusions:* The fact that thirteen studies demonstrated statistically significant improvements in CRF is promising but also emphasizes the need to keep improving research methods and the development and execution of interventions. Interventions with larger effect sizes appear to be more controlled, as they usually relied on smaller sample sizes and the components of these interventions encompassed protocolled training sessions which defined and monitored the relative training intensity intended. A duration of at least six weeks and a frequency of three to four times a week is recommended.


## 1. Introduction

Over recent years, children's cardiorespiratory fitness (CRF) has decreased markedly.[1–4] Children's performance on the 20 m Shuttle Run Test (20 mSRT), indicative of CRF, has decreased by 0.43% annually since 1998.[4] CRF is an important health-related component of physical fitness (PF) which is mainly determined by physical activity (PA).[5] CRF or cardiorespiratory endurance "relates to the ability of the circulatory and respiratory systems to supply fuel during sustained PA and to eliminate fatigue products after supplying fuel" (p. 129).[6] PA is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure".[6]

Low levels of CRF in childhood are associated with higher risks of cardiovascular disease in adulthood,[7,8] and it also negatively affects psychological functioning (e.g. recovery from depression, anxiety, mood status) and cognitive functioning, which may become evident in lower academic performance.[7] Acknowledging these

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concerns associated with low levels of CRF, a wide range of PA interventions have been developed over the years.

Thus far, a number of reviews evaluating the effects of PA interventions have focused on changes in PA.[9–12] These reviews confirmed that PA interventions can improve PA levels. However, it cannot be ascertained from these reviews whether the increases in PA actually result in an improvement of CRF. A number of reviews have incorporated measures of CRF; however, they limited their focus to school-based PA interventions, indicating moderate to strong optimism on their effectiveness.[13–15] In addition, many reviews included both younger children and adolescents,[9,10,12–16] despite potential differences in training responses linked to maturational levels. Two previous reviews have evaluated the effects of aerobic training specifically on CRF in children and adolescents, reporting improvements in $VO_{2peak}$ of approximately 6%. However, these review only included studies published before 2003 and 2011.[17,18] To obtain greater insight into the effectiveness of PA interventions on CRF in children, it is important to analyse the effectiveness of more recently developed PA interventions on CRF, specifically for children and across different settings.

Complex interventions such as PA interventions, require a systematic method of development to ensure adequate design and evaluation and to enable systematic comparison among interventions. Treatment theory can be used to systematically unravel the underlying components of the interventions included in the review. Focusing on treatment theory enables one to carefully distinguish different treatment targets and enablement aims, their interrelationship, the mechanism of action specific to each target and ingredients.[19] The target is defined as: "the aspect of the treatment recipient's functioning, or the personal factor, that is predicted to be *directly* changed by treatment" (p. S25). Change in a target is attained through a specific mechanism of action which is a "process by which treatments' *essential ingredients* induce change in the target of treatment" (p. S32.e1). These essential ingredients are attributes of a treatment "selected or delivered by the clinician, that play a role in the treatment's effects on the target of treatment" (p. S32.e1). Essential ingredients have specific dosing parameters which describe "quantitative variations in the strength, intensity, frequency, and/or quantity of treatment ingredients" (p. S32.e1). Other active ingredients, such as motivational aspects, may "moderate the treatment's effect(s) but may be common to multiple treatments" (p. S32.e1).

Treatment aims are not part of treatment theory but belong to enablement theory, which explains how a change in functioning at one level of the International Classification of Functioning, Disability and Health (ICF) translates into changes at other levels. Aims are more distal to the targets (e.g. high-intensity cycling training with the target of increasing CRF and the more distal aim of improving the recipient's social participation). Using a treatment theory compels one to explain the underlying rationale of the treatment, which leads to critical and possibly more comprehensive choices in the development and evaluation of treatment. In turn, this allows for more detailed insight into the mechanisms and effective components of treatments.

By using treatment theory, we aim to gain insight into the characteristics of effective PA interventions implemented across different settings and developed for healthy children aged 6–12. This potentially provides important information relevant to the development and improvement of future PA interventions. Moreover, we aim to examine the effects of this broad range of interventions on CRF. Specificity of fitness testing, targets, ingredients and the dosing parameters of the interventions will be examined in relation to the effects on CRF.

## 2. Methods

This systematic review was undertaken using the PRISMA checklist as a guideline.[20]

The following inclusion criteria were defined:

(1) Participants: healthy children aged 6–12 years at baseline assessment.

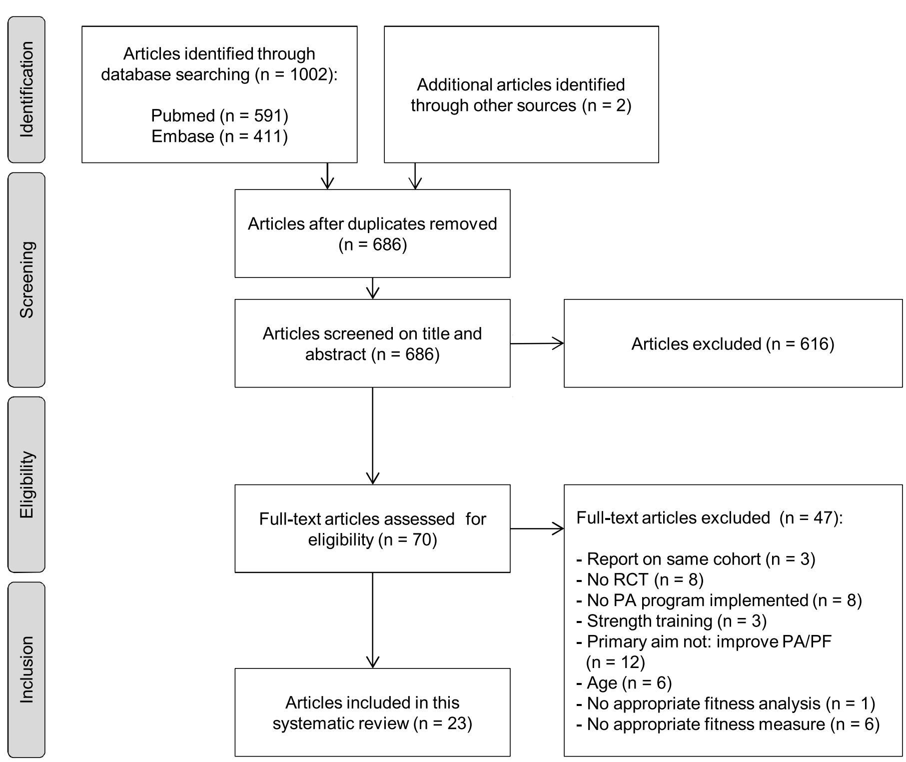


**Fig. 1.** Flow diagram showing number of articles retrieved and selected for systematic review.

(2) Intervention: intervention with activities, education or promotion of PA to increase PA behaviour or PF regardless of setting.
(3) Control: no or alternative intervention.
(4) Outcome: exercise-based CRF measure with appropriate analysis of effects on CRF (i.e. effects from pre- to post-test were analysed in comparison to a control group).
(5) Study design: randomized controlled trial.
(6) Written in English.
(7) Published between 1 January, 2003 and 1 January, 2016.

Exclusion criteria encompassed:

(1) Participants: the intervention was exclusively evaluated in children with a medical condition.
(2) Intervention: the intervention predominantly consisted of strength training or an injury prevention programme.

Records were retrieved via PubMed and Embase on 18 January 2016. The full search commands are included in Appendix A in Supplementary material and the selection process is presented in Fig. 1. The first phase of identification of records and removal of duplicates was performed by one author (PB). Screening of titles and abstracts and, subsequently, full-text assessment of eligibility was performed independently by two reviewers (CW, RG). PB solved disagreements. CW and RG reviewed the references of the 23 articles included for any additional relevant articles.

Three reviewers independently extracted data from the articles included (RG, CW, PB). The data extraction included: general information (country, sample size, setting), participant characteristics (age, weight status, maturation), ingredients (type of activity (e.g. mode of locomotion, type of sports, endurance/interval)), dosing parameters (duration, frequency, monitoring of intensity, attendance), CRF results and testing (test, unit of measurement). In this review, studies that exclusively examined children with overweight or overweight and obesity are referred to as studies of children with overweight. However, studies that did not select participants based on weight status could also encompass children with overweight or obesity. The term overweight depended on the criteria used in the specific article and the specific reference values used. When age limits or data required for calculating effect sizes were not available, additional information was requested from the author concerned.

The methodological quality was assessed using the Physiotherapy Evidence Database (PEDro) scale.[21] The PEDro scale includes criteria on selection bias (randomization, concealment of allocation), performance bias (blinding of participants and personnel) and detection bias (blinding of outcome assessment). The remaining criteria concern: eligibility criteria, baseline comparability, >85% retention, intention-to-treat, between-group statistical comparisons for at least one key outcome, point measures and measures of variability. When a criterion is met a score of one is awarded. Two reviewers independently assessed the articles, with differences in assessment resolved by consensus. If available, the scores published in the PEDro database were used. Blinding of participants and personnel was unlikely for the interventions, therefore the maximal PEDro score was potentially nine points. The criterion of random allocation of participants to treatment groups would always be met, as this was part of the inclusion criteria of the review.

The articles included were analysed based on the terminology of treatment theory.[19] This theory was developed to ensure adequate design and evaluation of interventions in rehabilitation and to enable systematic comparison of interventions. Although public health interventions technically cannot be classified as rehabilitation treatments, the distinctions proposed in this theory may be just as helpful to this field. An intervention may consist of several potentially interlinked targets and aims. As the studies included were not written using treatment and enablement terminology, and to avoid differences in interpretation between authors of the original study and this review, we did not distinguish targets from aims. For some studies, targets and aims were not specified; in these cases, the targets or aims were derived from the outcome measures or hypotheses.

Effect size was calculated using the formula for $d_{ppc2}$,[22,23] with the following intervals applied: 0.2–0.5, small effect; 0.5–0.8, medium effect; 0.8 and higher, large effect.[24] A meta-analysis was not planned as it was not compatible with examining a wide range of PA interventions (e.g. different outcome measures, different methodological study quality, studies differed in their main aim) and would not answer the aim of this review. The results were synthesized narratively.

## 3. Results

Of the 1002 studies identified, 23 studies were eligible for inclusion (Fig. 1). Table 1 provides an overview of study and participant characteristics, fitness measures and effectiveness. The PEDro scores ranged from 4 to 8 out of 9 points (mean ± SD, 5.3 ± 1.4), indicating fair to high quality.[25] The PEDro criteria reported least often were: concealed allocation, assessor blinding, intention-to-treat and retention rate >85% (reported in 6/23, 7/23, 9/23, 11/23 studies, respectively).

The studies were performed in ten different countries, the mean age was 9.5 and the total sample size was 7071. The studies were implemented at school (during or after school time, 13/23), at home (1/23), at a research facility (2/23), or a combination of settings including a fitness school and the community (7/23). Most studies set limits for the chronological age of the participants. Two studies included broad age ranges, one ranging from 6 to 12 years[26] and the other ranging from 7 to 12 years.[27] The other studies covered smaller age ranges. One study did not set an age range but required participants to be classified in Tanner stage 1, 2 or 3 (limits were verified with the authors: 7–11 years).[28,29] Eleven of the 23 studies assessed the maturational stage of participants at baseline, usually by means of self-assessed, parent or clinician-assessed Tanner stages.[28]

Five of the 23 studies only included overweight and obese children.[27,30–33] These studies reported various cut-off points for weight classification, usually using national reference values. Study sample sizes exclusively consisting of children with overweight ranged from 20 to 205 (68 ± 77), while those study samples that were not limited to weight status ranged from 36 to 1221 (374 ± 359).

Seventeen of the 23 studies used field tests to evaluate CRF. All field tests were based on running or stepping, and the 20 mSRT was the most frequently used test (n = 6).[42,44,46–49] Six of the 23 studies incorporated laboratory tests based on treadmill running or ergometer cycling.[27,30,32,34–36] With the exception of one study,[34] all CRF tests required exercising to a maximal level. In 3/23 studies, testing of CRF was not specific to the mode of activity in the intervention (e.g. a cycling test was used, while the activities in the intervention were based on running).[27,34,37]

Table 2 provides an overview of the treatment theory components and enablement aims of the interventions covered. Only the essential ingredients, such as training or actual activities, are included in the table, with the parameters for these ingredients. Multiple targets/aims were identified for most studies. Essential ingredients ranged from regulated training protocols, PE classes to play activities. Most activities were based on running. When interventions targeted PF, ingredients usually involved pre-set training activities that were performed under supervision (at least 12/23 studies). Eight of the 23 interventions also included targets con-

**Table 1**
Study and participant characteristics, fitness measures and effectiveness.

| Study | PEDro score | Participants (number, characteristics) | Outcome | | ES |
|---|---|---|---|---|---|
| | | | CRF measure (unit) | p-Value[c] | |
| Lau et al.[31] | 4[a] | n = 48<br>10.4 (0.9) y<br>Overweight: boys BMI >20.20 kg/m$^2$; girls BMI >20.29 kg/m$^2$<br>Maturation NM | YYIET:<br>-Distance (m)<br>-Velocity (km/h) | HIIE*,[e]<br>LIIE*<br>HIIE*,[e]<br>LIIE n.s. | HIIE 1.05 large<br>LIIE 0.79 medium<br>HIIE 0.41 small<br>LIIE 0.97 large |
| Bendiksen et al.[43] | 8 | n = 59<br>8–9 y<br>Maturation NM | YYIRL1:<br>-Distance (m)<br>-%HR$_{max}$ after 2 min | *<br>* | 0.69 medium<br>0.88 large |
| Baquet et al.[36] | 4 | n = 63<br>8–11 y<br>Maturation: Tanner stage, all participants ≤3 (40 boys Tanner stage 1, 3 boys stage 3, 29 girls at stage 1, 4 girls stage ≤ 3) | MGTT:<br>-VO$_{2peak}$ (ml/kg/min)<br>-Velocity (km/h) | ***,[d]<br>***,[d] | CTG 0.71 medium<br>ITG 0.72 medium<br>CTG 0.63 medium<br>ITG 0.64 medium |
| Murphy et al.[27] | 4[a] | n = 35<br>7–12 y<br>Overweight: ≥85th percentile BMI (US reference values)<br>88.6% metabolic syndrome<br>Maturation: Tanner stage, girls mean 2.39 (0.61), boys mean 1.78 (0.65) | MGCET (VO$_{2peak}$ (ml/kg/min)) | ** | 0.67 medium |
| Kelly et al.[32] | 6[a] | n = 20<br>10.9 (0.4) y (range NM)<br>Overweight: >85$^{th}$ percentile BMI (reference values NM)<br>44% metabolic syndrome<br>Maturation: Tanner stage, mean 2.0 (0.2) | MGCET (VO$_{2peak}$ (ml/kg/min)) | * | 0.63 medium |
| Eather et al.[44] | 8[b] | n = 188<br>10–12 y<br>Maturation NM | 20 mSRT (levels) | *** | 0.59 medium |
| Reed et al.[47] | 4[a] | n = 224<br>9–11 y<br>Maturation: Tanner stage, all participants <4 | 20 mSRT (laps) | * | 0.54 medium |
| Davis et al.[30] | 7[a] | n = 205<br>7–11 y<br>Overweight: ≥85th percentile BMI (US reference values) (85% obese)<br>Sedentary children: no regular PA program of more than 60 min/week<br>Maturation: Tanner stage, 74% 1, 13% 2, 11% 3, 2% 4, <1% 5 | MGTT (VO$_{2peak}$) | * | HD 0.49 small<br>LD 0.50 medium |
| Baquet et al.[42] | 4 | n = 52<br>8–11 y<br>Maturation; Tanner stage, all participants ≤3 (all boys Tanner stage 1, 25 girls Tanner stage 1) | 20 mSRT (velocity (m/s)) | *** | 0.49 small |
| Nogueira et al.[48] | 5[a] | n = 138<br>10–12 y<br>Girls only<br>Maturation: YAPHV ≥1.2 years before peak height velocity | 20 mSRT (VO$_{2peak}$ (ml/kg/min)) | *** | 0.43 small |
| Harder-Lauridsen et al.[33] | 6[a] | n = 33<br>7–10 y<br>Overweight/obese: BMI > 90$^{th}$ percentile (Danish reference values)<br>Maturation: Tanner stage, IG Tanner stage 3, CG Tanner stage 4 | Modified Andersen fitness test (distance (m)) | n.s. | 0.41 small |
| Thivel et al.[46] | 5[a] | n = 456 (of which 101 obese)<br>6–10 y<br>Maturation NM | 20 mSRT (levels) | n.s. | Normal 0.41 small<br>Obese 0.14 < small |
| Magnusson et al.[34] | 4[a] | n = 142<br>7 y<br>Maturation NM | MGCET (CRF (Watt/kg)) | n.s. | 0.32 small |

Table 1 (*Continued*)

| Study | PEDro score | Participants (number, characteristics) | Outcome | | ES |
|---|---|---|---|---|---|
| | | | CRF measure (unit) | p-Value[c] | |
| Barbeau et al.[35] | 5[a] | n = 201<br>8–12<br>Girls (presumed to be at risk for overweight)<br>Maturation: Tanner stage, IG mean 2.4, CG mean 2.6 | MGTT<br>($VO_{2\text{-}170}$ (ml/kg/min)) | * | 0.2 small |
| Trevino et al.[37] | 6[a] | n = 1221<br>9–10 y<br>Maturation NM | Modified Harvard step test (PF score) | * | 0.19 <small |
| Kriemler et al.[49] | 8[a] | n = 448<br>6–7 and 10–11 y<br>Maturation: Tanner stage, 6–7 year olds <1, 10–11 year olds 49% >1 | 20 mSRT (levels) | * | 0.13 <small |
| De Heer et al.[50] | 5 | n = 804<br>8–11 y<br>72% low SES, 47% limited proficiency in English, 50% overweight<br>Maturation NM | PACER (laps) | n.s. | 0.03 <small<br>Spillover −0.00 < small |
| Serbescu et al.[29] | 5 | n = 370<br>Not previously engaged in sport participation<br>Mean 9.6 y (range NM)<br>Maturation: Tanner stage, criterium for inclusion was stage 1, 2 or 3 | Eurofit ESRT (velocity (km/h)) | n.s. | 0 <small |
| Finkelstein et al.[26] | 8[a] | n = 285<br>6–12 y<br>Maturation NM | 6 MWT (distance (m)) | n.s. | −0.15 negative < small |
| Crouter et al.[38] | 4[a] | n = 36<br>8–12 y<br>70% from minority racial/ethnic backgrounds, 80% received free and reduced price school lunch, 60% from single parent households<br>Maturation NM | PACER 15 m ($VO_{2peak}$ (ml/kg/min)) | n.s. | −0.39 negative medium |
| Katz et al.[40] | 5 | n = 1106<br>7–10 y<br>62% Eligible for free/reduced price lunch<br>Maturation NM | PACER 20 m/15 m ($VO_{2peak}$ (ml/kg/min)) | n.s. | |
| Hopper et al.[41] | 4 | n = 238<br>8–9 y<br>Maturation NM | Mile run (duration (s)) | n.s. | |
| Aburto et al.[39] | 5[a] | n = 699<br>9–11 y<br>Maturation NM | 9 min run (distance (m)) | n.s.[d] | |

Abbreviations: BMI = body mass index; CG = control group; CTG = continuous-running training group; CRF = cardiorespiratory fitness; ES = effect size,[22] a positive ES indicates an improvement of CRF; Eurofit ESRT = eurofit endurance shuttle run test; 20 mSRT = 20 m shuttle run test; HIIE = higher intensity interval exercise group; IG = intervention group; ITG = intermittent-running training group LIIE = lower intensity interval group; MGCET = maximal graded cycle ergometer test; MGTT = maximal graded treadmill test; 6 MWT = 6 minute walk test; NM = not mentioned or not assessed; n.s. = not significant; PACER = progressive aerobic cardiovascular endurance run; spillover = classmates of children in the IG; X = no data received for calculating ES; YAPHV = years of age to peak height velocity (skeletal maturity); $VO_{2peak}$ = maximal oxygen uptake; YYIRL1 = yo-yo intermittent recovery level 1; YYIET = yo–yo intermittent endurance test.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

[a] Assessed by both PEDro database and reviewers (scores without [a] were assessed by the reviewers only).

[b] Reviewers awarded 8 points because concealed allocation was mentioned in the article (in the PEDro database 7 points were awarded).

[c] p-Value of improvement of intervention group compared to improvement of control group (or variations like less intensive intervention).

[d] p-Value for both IG compared to CG (no statistically significant differences between improvement of both IG).

[e] No statistically significant differences between improvement of both IG.

cerning improvement of PA behaviour. In interventions targeting PA behaviour, the intervention encompassed ingredients in which the actual activity was less regulated (e.g. PA homework, promotion of PA, use of pedometers).

Considering the statistical significance of improvements in the intervention group over the control group, 13/23 studies were effective. In 20/23 studies, data was available to calculate effect sizes. The effect sizes ranged from 1.05[31] to −0.39,[38] with 2/20 studies showing a large effect, 6/20 a medium, 6/20 a small and 6/20 a very small or negative effect. All studies with non-significant intervention effects had small, very small or negative effect sizes. In the 3/23 studies that provided no data to calculate the effect size, the results were not statistically significant.[39–41]

Overall, studies with medium to high effect sizes had smaller samples sizes and were more often conducted in children with overweight. The 5/23 studies that only included overweight and obese children had effect sizes of at least 0.41.[27,30–33] The 3/23 studies using CRF tests that were not specific to the mode of activity in the intervention had medium,[27] small[34] and very small[37] effect sizes, respectively.

**Table 2**
Treatment theory components and enablement theory aims (studies ordered according to effect size).

| Study | Targets/aims | Essential ingredients of target/aim CRF or PA | Dosing parameters of CRF or PA essential | | | Mechanism of action: |
|---|---|---|---|---|---|---|
| | | | Frequency (min/week) | Duration (week) | Intensity | Monitoring and attendance |
| Lau et al.[31] | 1. CRF<br>2. Body composition<br>3. Functional walking performance | Training:<br>HIIE: 12 intermittent running intervals<br>LIIE: 16 intermittent running intervals | <br>3 × 6<br>3 × 8 | <br>6<br>6 | <br>120% MAS<br>100% MAS | Mon NM (intervals were timed)<br>Att NM |
| Bendiksen et al.[43] | Fitness and cardiovascular health profile i.a. CRF | Training: High intensity soccer and unihockey | 2 × 30 | 6 | High aerobic intensity | Mon heart rate: unihockey 74% $HR_{max}$, soccer 76% $HR_{max}$<br>Att NM |
| Baquet et al.[36] | CRF | Training:<br>CTG: continuous running<br>ITG: intermittent running | <br>3 × (18–39)<br>3 × (18–39) | <br>7<br>7 | <br>80–100% MAS<br>90–130% MAS | Mon NM (intervals were timed)<br>Att: ≥20 attended sessions required for inclusion in the analysis |
| Murphy et al.[27] | 1. Endothelial function<br>2. Other risk factors i.a. CRF | Instruction and training on frequency and how to use DDR game | Start: 5 × 10<br>End: 5 × 30 | 12 | NM | Mon: overall step counts<br>Att daily log: 75% exercised on ≥5 day/week; 15% exercised 3 or 4 day/week |
| Kelly et al.[32] | 1. Inflammation<br>2. Fasting insulin<br>3. Endothelial function<br>4. PF i.a. CRF | Training: stationary cycling | Start: 4 × 30<br>End: 4 × 50 | 8 | 50–60% $VO_{2peak}$ to 70–80% $VO_{2peak}$ | Mon heart rate (corresponding to $VO_2$peak)<br>Att NM |
| Eather et al.[44]<br>Fit-4-fun | 1. Overall PA<br>2. PF i.a. CRF | A. Active break time<br>B. Instructions for PA at home | A. 5 day/week each break<br>B. 3 × 20 | 8 | Vigorous intensity | Mon NM<br>Attt: A. 47.1% ≥ 3 times per week (self-report)<br>B. NM |
| Reed et al.[47]<br>Action schools! BC model | CVD risk factors i.a. CRF | A. Activities (e.g. jumping, chair aerobics, hiphop dancing, playground circuits, resistance exercises) | A. 5 × 15 | 36 | Moderate to intensive PA | Mon NM<br>Att NM |
| Davis et al.[30] | 1. CRF<br>2. Insulin resistance<br>3. Overall and visceral adiposity | Training:<br>HD: aerobic training (e.g. running games, jump rope, modified basketball, soccer)<br>LD: aerobic training (e.g. running games, jump rope, modified basketball, soccer) | <br>5 × 40<br>5 × 20 | <br>10–15<br>10–15 | <br>Vigorous activities | Mon heart rate: daily means<br>Att: HD 84%, LD 85% |
| Baquet et al.[42] | PF i.a. CRF | Training: short-term interval running training | 2 × 30 | 7 | 100–130% MAS | Mon NM (intervals were timed)<br>Att ≥13 sessions attendance required for inclusion in analysis |
| Nogueira et al.[48]<br>CAPO kids | 1. Bone<br>2. Fat<br>3. Metabolic outcomes i.a. CRF | Training: high intensity impact loading exercises largely based on Capoeira | 3 × 10 | 36 | NM | Mon NM<br>Att NM |
| Harder-Lauridsen et al.[33] | 1. BMI<br>2. Body fat<br>3. Insulin insensitivity<br>4. Other components of metabolic syndrome i.a. CRF | Training:<br>A. Children: continual exercise, games, dancing<br>B. Children, parents, siblings: aerobic and strength exercises | A. 1 × 45<br>B. 1 × 30 | 40 | NM | Mon NM<br>Att NM |

Table 2 (*Continued*)

| Study | Targets/aims | Essential ingredients of target/aim CRF or PA | Dosing parameters of CRF or PA essential | | | Mechanism of action: |
|---|---|---|---|---|---|---|
| | | | Frequency (min/week) | Duration (week) | Intensity | Monitoring and attendance |
| Thivel et al.[46] | 1. CRF<br>2. Anaerobic fitness<br>3. Body composition | Training:<br>Psychometric activities and exercises focusing on coordination, flexibility, strength, speed and endurance | 2 × 60 | 24 | NM | Mon NM<br>Att NM |
| Magnusson et al.[34] | 1. PA at school<br>2. Fruit intake<br>3. Body composition<br>4. CRF | A. PE<br>B. Promotion of PA (e.g. active commute to school, materials for indoor/outdoor play at school)<br>C. Nutritional education | A. 1 × 40 | 104 | PE high intensity | Mon NM<br>Att NM |
| Barbeau et al.[35] | 1. CRF<br>2. Fat mass, % body fat<br>3. Bone mineral density | Training:<br>A. PA to improve sports skills, MVPA, strengthening/stretching | A. 5 × 80 | 40 | MVPA | Mon heart rate and children were taught how to keep HR > 150 bpm during PA<br>Att: mean 54% |
| Trevino et al.[37] Bienestar | 1. Overall PA<br>2. Dietary saturated fat and fiber intake<br>3. PF i.a. CRF<br>4. % Body fat | A. PE (32 different activities)<br>B. PA in Bienestar health club (voluntary attendance, parents also invited) | A. 4 × 45 | 28 | NM | Mon NM<br>Att: mean 32 Bienestar sessions (mean sessions delivered 50) |
| Kriemler et al.[49]<br>KISS | 1. CRF<br>2. Overall PA<br>3. Body fat<br>4. Quality of life<br>5. CVD risk | A. Extra PE<br>B. Activity breaks during class<br>C. PA homework | A. 2 × 45<br>B. 5 × (6 to 25)<br>C. 7 × 10 | 36 | NM | Mon NM<br>Att NM |
| De Heer et al.[50] | 1. CRF<br>2. Body composition<br>3. Dietary intentions<br>4. Dietary knowledge | Cardiovascular activity and aerobic recreational games | 2 × (45–60) | 12 | Aerobic activities | Mon NM<br>Att NM |
| Serbescu et al.[29] | 1.PF i.a. CRF<br>2.Motor ability | Training:<br>Impact-loading, weight-bearing exercises, strengthening exercises, running, jumping | 2 × 50 | 24 | Moderate to vigorous intensity | Mon NM<br>Att: mean 83%, ≥ 75% attendance required for inclusion in analysis |

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|---|---|---|---|---|---|---|
| Finkelstein et al.[26] | 1. Overall PA<br>2. PF i.a. CRF<br>3. Quality of life | A. Weekend structured park activities (e.g. hikes)<br>B. Pedometer<br>C. Prizes for meeting step goals | A.<br>1 × (120–180),<br>optional | 24–40 (mean 36) | NM | Mon NM<br>Att: first month 43%, last month 7% |
| Crouter et al.[38] | 1. Overall PA<br>2. CRF<br>3. BMI, waist circumference, % body fat<br>4. Blood pressure<br>5. Total cholesterol<br>6. Blood glucose | IG1:<br>PA (circuit with treadmill/cycle, strength training, exergaming) | 3 × 60 | 10 | NM | Mon NM<br>Att >80% |
| Katz et al.[40]<br>ABC | 1. PF<br>2. Academic performance<br>3. Classroom behavior<br>4. Health outcomes i.a. CRF | Training:<br>Activity bursts in the classroom, consisting of strength or aerobic exercises | 5 × 30 (ideally) | 28–32 | Aerobic | Mon NM<br>Att NM |
| Hopper et al.[41]<br><br>Family fitness | 1. Overall PA<br><br>2. Nutrition | A. Physical education classes focusing on increasing aerobic activity<br>B. Home based exercise partly with parents | A. 3 × 30<br><br>B. .×100 | Fall 10 and spring 10 | Aerobic | Mon NM<br>Att NM |
| Aburto et al.[39] | 1. CRF<br>2. Flexibility<br>3. Strength<br>4. PA at school | Plus:<br>A. Extra PE<br>B. Teacher promotion of activity during recess<br>C. PA before class<br>Basic:<br>A. Extra PE<br>B. Teacher promotion of activity during recess | <br>A. 2 × 50[a]<br>B. 5 × 15<br>C. 5 × 20<br><br>A. 1 × 50[a]<br>B. 5 × 15 | 24<br>24 | NM | Mon NM<br>Att NM |

Abbreviations: Att = attendance; BMI = body mass index; CRF = cardiorespiratory fitness; CTG = continuous-running training group; CVD = cardiovascular disease; DDR = Dance Dance Revolution video game; IG = intervention group; HD = high dose; HIIE = higher intensity interval exercise group; ITG = intermittent-running training group; LD = low dose; MAS = maximal aerobic speed attained on a maximal exercise test; LIIE = lower intensity interval exercise group Mon = monitoring; MVPA = moderate to vigorous physical activity; NM = not mentioned or not assessed; PA = physical activity; PE = physical education; PF = physical fitness.

[a] Instead of 1 × 39 min.

With regard to targets, ingredients and dosing parameters, interventions with medium to high effect sizes focused more often on PF than PA behaviour, had slightly higher frequency of activities and had a shorter duration than less effective interventions. Of the 6/20 studies targeting a combination of PA behaviour and PF, 5/6 had small to negative effect sizes on CRF. Frequencies of essential ingredients were slightly higher in studies with medium to high effect sizes, although there was large variation in frequencies. Participants in the 8/20 studies with medium to high effect sizes trained 4.4 times a week on average (SD = 1.8), while participants in studies with lower effect sizes trained 3.2 times a week on average (SD = 3.0). Frequencies and session duration of the essential ingredients ranged from once a week for 40 min[34] to five times a week for 80 min.[35] The lowest accumulated training time per week was 18 min[31] and the highest was 400 min.[35] Average duration of interventions with medium to high effect sizes was 12 weeks (SD = 10), compared to 27 weeks (SD = 12) in interventions with small to negative effect sizes (omitting one intervention of 104 weeks).[34]

Finally, relative training intensity was reported and monitored more often in the 8/20 studies with high to medium effect sizes than in less effective studies. In four studies, the intended relative intensities were quantified as a percentage of $VO_{2peak}$[32] or Maximal Aerobic Speed (MAS),[17,31,36] either with progressing intensities[1,32,42] or a fixed training intensity throughout the intervention.[31] These studies had effect sizes of at least 0.49. In this review, the minimal intended relative training intensity was defined as a progressive training intensity of 80–100% of MAS[36] or a $VO_{2peak}$ of 50–80%.[32] In five studies the intensity of essential ingredients was monitored using heart rate monitors[30,32,35,43] or accelerometers.[27] However, in most cases, it was not reported whether the monitoring information was used to adjust training intensity if necessary. Four of the five studies that monitored training intensity had effect sizes of at least 0.49.[27,30,32,43] Attendance to the intervention was reported in 10/23 studies. In some studies, a minimum level of individual attendance was required for inclusion in the analysis,[29,36,42] in other studies, overall attendance rates were reported.[26,27,30,35,37,38,44] Studies that reported attendance, as well as PEDro scores, were noticeably divided among studies with different effect sizes.

## 4. Discussion

The aim of this review was to gain insight into the characteristics of PA interventions in healthy children aged 6–12 years, and to examine the effects on CRF. Eight of the 20 studies for which effect sizes could be calculated had medium to large effect sizes and 14/20 showed at least a small effect size. The improvement in CRF of the intervention group over the control group was statistically significant in 13/23 studies included. This ratio of 13/23 (57%) is in line with the findings of previous reviews evaluating CRF and other aspects of PF. In one review, 55% of the studies included reported significant improvements in $VO_{2peak}$.[17] In another review, 60% of the studies included reported significant effects on fitness.[13] Although this success rate is promising, it is clear that not every training effort automatically leads to success. As the current review encompasses a more recent timeframe, this suggests that interventions have not become any more effective over recent years. This emphasizes the need to carefully develop and evaluate PA interventions if we are to increase our understanding and establish effective interventions.

The mechanism of action in improving CRF relies on the principles of specificity and training overload. The principle of specificity holds that "the training effect is specific to the fiber types recruited, the principal energy system involved (aerobic versus anaerobic), the velocity of contraction and the type of muscle contraction (eccentric, concentric, or isometric)" (p. 262–263).[45] Most studies used measurements that matched the mode of locomotion utilized during training (e.g. running/walking, cycling). However, the principal energy system used could not be ascertained for most studies. As many studies used a variety of activities, characterization of the effective essential ingredients was not feasible. In addition, the type of energy system involved largely depends on the intensity of these activities, which was not monitored in most cases.

The principle of overload identifies three additional parameters for essential ingredients: "for a training effect to occur, a system or tissue must be challenged with an intensity, duration, or frequency of exercise to which it is unaccustomed" (p. 262–263).[45] In this review, the monitoring and reporting of training intensity was found to be a characteristic of the studies with larger effect sizes, since these studies monitored and reported the intended relative training intensity more often than less effective studies. Possibly studies which did not report training intensity, or did not adhere to a training protocol, were of lower intensity than those which did pay attention to intensity, as it is challenging to attain and maintain high training intensities.

With respect to the dosing parameters intensity, duration and frequency, only small differences between studies with high and lower effect sizes were found. In this review, the minimal relative training intensity reported was defined as a progressive training intensity of 80–130% of MAS[36] or a $VO_{2peak}$ of 50–80%.[32] The interventions using these intensities had medium effect sizes. Duration was shorter for more effective interventions, most likely because those interventions were based on a pre-set, more tightly regulated protocol and provided sufficient intensity. In this review, a training duration as short as six weeks yielded an improvement in CRF.[31] Training frequencies were slightly higher in studies with higher effect sizes. The training frequency was, on average 4.4 times a week, and at least two to three times a week for interventions with medium and high effect sizes. As intensity was not set or monitored for most interventions, it was not feasible to ascertain the optimal combination of dosing parameters. In the current review, we focused on essential ingredients and their dosing parameters but there may be other ingredients that contribute to intervention success. These 'other active ingredients' moderate the effect of the essential ingredients and may include motivational aspects of the intervention, as described below.[19]

Overall, studies with larger effect sizes had relatively small sample sizes. Although it could not be ascertained from the studies, it is possible that the activities and their intensity were tailored more to the individual child, or groups were smaller, allowing for closer supervision and thereby higher training intensity. Moreover, 4/5 studies that only included children with overweight or obesity had large and medium effect sizes.[27,30–33] One possible interpretation might be that these children had the largest room for improvement and thus benefited most, resulting in large effect sizes. However, considering the fact that the interventions in the latter were specifically developed for children with overweight or obesity, our hypothesis is that the level of tailoring to the specific needs of such children may also be an important factor. Tailoring may concern the type of activity (e.g. a different degree of impact on the joints), the parameters of active ingredients, such as the rate of progression or the way training intensity was set (e.g. relative and thereby tailored to the child's starting level). Tailoring also relates to other active ingredients, such as motivational components. A child with overweight may have negative experiences with PA or may experience more physical discomfort during PA and thus be less motivated to adhere to the intervention. Interventions that systematically include appropriate ingredients to address this may be more effective than others. One study included in the current review supports this hypothesis. The intervention in that study was not specifically tailored to obese children and proved to be more effective for children with normal weight status than for obese children.[46] The results of another study were also considered to be due to a lack of tailoring.[35] Contrary to the expectations of the authors of that study, children with a higher attendance rate improved less on CRF than children with a lower attendance rate. This could be explained by the fact that the children with high attendance rates showed slightly higher CRF at baseline compared to the children with lower attendance rates and thus had less room for improvement. It was also hypothesized that children with lower baseline CRF were less motivated to participate in the intervention. Children with low CRF may have specific needs and may benefit more from tailored interventions.

An innovative aspect of this review is the use of treatment theory, demonstrating how we can improve treatment design and reporting. First, treatment theory provides a method to distinguish direct treatment targets from more distal enablement aims. Doing so allows one to attend to the mechanism of action in each specific target. This, in turn, shapes the process of selecting appropriate ingredients. In the studies included, the targets and aims of the intervention, as well as the mechanism of action and expected relationships between targets and aims, were not explicitly mentioned in most cases. This precluded detailed comparison of interventions and, more importantly, where targets and aims were not clearly distinguished, this may have hindered the development of the intervention. Second, specifying targets may shift the focus from statistically significant improvements to the specification of clinically meaningful changes, quantifying the intended change instead of merely aiming for change. Third, specifying the mechanism of action guides the selection of activities (e.g. specific to the child's habitual PA pattern) and the type of measurement (specific to the type of activities). It points out the essential dosing parameters, which call for monitoring of intensity and attendance, as well as a potential need to continuously adjust training intensity. Therefore, treatment theory may facilitate development, evaluation and comparison of interventions and may systematically enhance our understanding of what constitutes effective intervention.

Some caution is warranted when interpreting the findings of this review. The selection of studies in this review only encompassed those published and written in English, which may have resulted in some degree of publication bias. The majority of the studies included did not report concealed allocation and assessor blinding (related to selection and detection bias). Moreover, in evaluating the effectiveness of the studies, the focus was exclusively on CRF. However, not all studies identified CRF-related outcomes as the primary outcome measure. Power calculations for the required sample size may have been based on outcome measures other than CRF-related measures. In addition, some studies reported different corresponding outcome measures, which differed in sensitivity to change and thus also in their effect size.[31,43]

## 5. Conclusion

The success rate of 13/23 studies showing statistically significant improvements in CRF is promising but also emphasizes the need to keep improving research methods and the development and execution of interventions. Interventions specifically designed for overweight children had relatively high effect sizes. Interventions with larger effect sizes seemed to be more controlled, as they usually relied on smaller sample sizes and the ingredients of these interventions encompassed protocolled training sessions which defined and monitored the relative training intensity intended. Interventions with larger effect sizes were of shorter duration and had slightly higher frequencies than less effective interventions. Based on these findings, a duration of at least six weeks is recommended and a training frequency of three to four times a week.

## Practical implications

- Defining and applying pre-set relative training intensity, as well as monitoring and adjusting relative training intensity, seem to be important aspects of successful interventions.
- A duration of at least six weeks is recommended.
- A frequency of three to four times a week is recommended.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jsams.2017.07.015.

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