Fundamental Movement Skill Interventions in Youth: A Systematic Review and Meta-analysis

**BACKGROUND:** Fundamental movement skill (FMS) proficiency is positively associated with physical activity and fitness levels. The objective of this study was to systematically review evidence for the benefits of FMS interventions targeting youth.

**METHODS:** A search with no date restrictions was conducted across 7 databases. Studies included any school-, home-, or community-based intervention for typically developing youth with clear intent to improve FMS proficiency and that reported statistical analysis of FMS competence at both preintervention and at least 1 other postintervention time point. Study designs included randomized controlled trials (RCTs) using experimental and quasi-experimental designs and single group pre-post trials. Risk of bias was independently assessed by 2 reviewers.

**RESULTS:** Twenty-two articles (6 RCTs, 13 quasi-experimental trials, 3 pre-post trials) describing 19 interventions were included. All but 1 intervention were evaluated in primary/elementary schools. All studies reported significant intervention effects for $\geq 1$ FMS. Meta-analyses revealed large effect sizes for overall gross motor proficiency (standardized mean difference [SMD] = 1.42, 95% confidence interval [CI] 0.68–2.16, Z = 3.77, P < .0002) and locomotor skill competency (SMD = 1.42, 95% CI 0.56–2.27, Z = 3.25, P = .001). A medium effect size for object control skill competency was observed (SMD = 0.63, 95% CI 0.28–0.98, Z = 3.53, P = .0004). Many studies scored poorly for risk of bias items.

**CONCLUSIONS:** School- and community-based programs that include developmentally appropriate FMS learning experiences delivered by physical education specialists or highly trained classroom teachers significantly improve FMS proficiency in youth. 

*Pediatrics* 2013;132:e1361–e1383

**AUTHORS:** Philip J. Morgan, PhD, a Lisa M. Barnett, PhD, b Dylan P. Cliff, PhD, c Anthony D. Okely, PhD, c Hayley A. Scott, PhD, c Kristen E. Cohen, BTeach/BHealth & PhysEd, a and David R. Lubans, PhD a

*Priority Research Centre in Physical Activity and Nutrition, Faculty of Education and Arts, University of Newcastle, Newcastle, Australia; bSchool of Health and Social Development, Deakin University, Burwood, Australia; and cInterdisciplinary Educational Research Institute, Faculty of Social Sciences, University of Wollongong, Wollongong, Australia*

**KEY WORDS**

fundamental movement skills, children, systematic review, motor skills, intervention, physical activity

**ABBREVIATIONS**

CI—confidence interval
FMS—fundamental movement skills
PE—physical education
PRISMA—preferred reporting items for systematic reviews and meta-analyses
RCT—randomized controlled trial
SMD—standardized mean difference

Prof Morgan conceptualized the study and drafted the protocol and Introduction, Methods, and Discussion sections; checked all decisions made in the initial cull of records by title and screened all retrieved articles for inclusion; and revised the manuscript. Dr Barnett critically reviewed the systematic review protocol, screened all retrieved articles for inclusion, and revised and revised the manuscript. Dr Cliff critically reviewed the systematic review protocol, assessed the risk of bias in each included study and conferred with Prof Okely to achieve consensus on all discrepancies, and reviewed and revised the manuscript. Prof Okely critically reviewed the systematic review protocol, independently assessed the risk of bias in each included study and conferred with Dr Cliff to achieve consensus on all discrepancies, and reviewed and revised the manuscript. Dr Scott conducted the systematic database search, completed the initial cull of citations by title and abstract, and reviewed and revised the manuscript. Ms Cohen extracted study data relating to methodology, participant characteristics, intervention description, fundamental movement skill measure and the intervention effect on fundamental movement skills and reviewed and revised the manuscript. A/Prof Lubans critically reviewed the systematic review protocol, checked all extracted data for the review, conducted meta-analyses and drafted the Results section, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

*(Continued on last page)*
It is well established that physical activity is vitally important for the healthy growth and development of children; however, many children are not adequately active. Physical activity provides not only an opportunity to expend energy, but also a medium for the development of fundamental movement skills (FMS). Gallahue and Donnelly (2003) define a FMS as “an organized series of basic movements that involve the combination of movement patterns of two or more body segments” (p. 52). According to Gallahue, Ozman and Goodway, these movements are commonly categorized as locomotor (eg, running, jumping, and hopping; p. 448) and object control or gross manipulative skills (eg, catching, throwing, and kicking; p. 449). FMS are considered to be the foundation skills that lead to specialized movement sequences required for participation in many organized and nonorganized physical activities for children and adolescents. FMS are optimally developed in childhood and then refined into context and sport-specific skills. For instance, overarm throwing can be refined to “pitching” in baseball or a “serve” in tennis. FMS mastery or motor competence is more likely to be achieved with quality instruction and practice, while children who are not provided with opportunities to develop FMS may demonstrate developmental delays in their gross motor ability.

Children’s FMS proficiency is low in a number of countries, with many children entering adolescence having not mastered these basic movement skills. This is of particular concern, as a recent systematic review of the health benefits of FMS proficiency found consistent and positive associations between FMS proficiency and physical activity and fitness levels and an inverse association with weight status. There is also longitudinal evidence that motor skills track through childhood and into adolescence. FMS proficiency has been associated with subsequent physical activity and also with change in physical activity over time, highlighting that children with high FMS proficiency show little decline in physical activity. In addition, positive associations have been established between FMS proficiency and objectively measured physical activity in overweight children.

Efforts to promote physical activity in youth would benefit from a greater understanding of evidence-based strategies to improve FMS proficiency. Recommendations for school- and community-based physical activity programs from various countries have established FMS development as an integral aspect of physical education and school and community sport. However, little is known about the efficacy of interventions designed to improve FMS proficiency in typically developing children and adolescents. Reitmuller, Jones, and Okely conducted a systematic review of controlled trials on the efficacy of motor development interventions in young children (aged <5 years old) and reported the evidence base was limited in both quality and quantity. Another recent review and meta-analysis included both typically and nontypically developing children but only included studies that used a qualitative FMS assessment (with only 1 instrument meeting inclusion criteria). Another limitation recognized in this review was that most studies in the meta-analysis included children that were developmentally delayed and/or of preschool age.

Therefore, the aim of the current study was to conduct a systematic review and meta-analysis of the effectiveness of interventions designed to improve FMS proficiency in typically developing children and adolescents using both process- and product-oriented FMS assessment and including both randomized and nonrandomized trials.

**METHODS**

The conduct and reporting of this review adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) Statement.

**Eligibility Criteria**

**Types of Participants**

Children were enrolled in primary/elementary, middle, or high school. The age range of children in these levels of schooling may vary by country but in general covers the following ages: primary/elementary school (5–12 years), middle school (12–14 years), high school (12–18 years or 14–18 years in areas with middle schools). Studies targeting overweight/obese children or children from schools in disadvantaged areas were included but not those where participants had developmental coordination delays (ie, where study inclusion criteria specified these characteristics).

**Types of Interventions**

Any school-, home-, or community-based intervention for children and adolescents with clear intent to improve FMS proficiency.

**Types of Outcome Measures**

Studies were included if they reported statistical analyses of FMS competence at both preintervention and a minimum of 1 other poststudy time point. There must have been process (ie, technique) or product (ie, outcome) assessment of ≥1 of the following: run, vertical jump, horizontal jump, hop, dodge, leap, gallop, side gallop (slide), skip, roll, throw (under or over arm), stationary dribble, catch, kick, 2-handed strike, forehand strike, static balance, or categorized in groups of commonly
described similar skills such as locomotor or object control skills, or global FMS score.25

**Types of Studies**

Study designs included randomized controlled trials (RCTs) using experimental and quasi-experimental designs and single group pre-post trials.

Studies were excluded if they met any of the following criteria: (1) participants were targeted groups from special populations (eg, children with disabilities such as cerebral palsy or identified as having developmental coordination disorder or conditions such as mental illness); (2) not published in English; (3) used measurement batteries that incorporated an assessment of fine motor skills, motor coordination, motor ability or fitness or that included a focus on a skill unique to a particular sport; and (4) participants were children who were enrolled in preschools or child care centers.

**Information Sources and Search**

Studies were identified by searching electronic databases and scanning reference lists of included articles. Seven electronic databases were searched: Medline [Ovid], Embase, PsychInfo, SCOPUS Current Contents Connect, Sports Discus, ERIC [Ovid], and Informit. No publication date restrictions were imposed in any database, and the last search was completed in June 2013. Search terms were divided into 3 groups: (1) population (eg, children OR child* OR youth* OR adolescent OR school OR primary OR elementary OR high OR secondary); (2) study design (eg, random* OR clinic* OR trial OR intervention OR evaluation OR experiment OR program* OR pilot OR feasibility); and (3) intervention type (eg, physical activity OR exercise OR motor skill OR movement skill OR fundamental motor skill OR fundamental movement skill OR coordination OR motor development). The Boolean phrase “AND” was used between groups and the phrase “OR” was used within groups.

**Study Selection**

After the search, 1 of the authors (HAS) removed all duplicates and screened the title and abstract of remaining records in a nonblinded standardized manner. Only articles published or accepted for publication in refereed journals were considered. A second author (PJM) checked all decisions and any disagreements were resolved by discussion. If there was insufficient information available to make a decision, the article was retrieved for clarification. Consensus was reached by discussion when disagreement arose. Full text articles were then retrieved for all remaining records. Two authors (PJM and LMB) independently screened these articles for inclusion with a “yes, no, or maybe” approach. Both reviewers then conferred, and after discussion, full consensus was reached on all articles. The reference list of each included study was searched for additional studies.

**Data Collection Process**

One author (KC) extracted study data relating to methodology, participant characteristics, intervention description, FMS measure, and the intervention effect on FMS. Another reviewer (DRL) checked the extracted data.

**Risk of Bias in Individual Studies**

Risk of bias was independently assessed by 2 reviewers (DPC and ADO) using a 9-item tool adapted from the Consolidated Standards of Reporting Trials statement26 and previously used quality criteria27 (see Table 1). As recommended in the PRISMA statement, these items were not numerically summarized to give a final score; rather, each criteria was considered in isolation.28 In accordance with empirical evidence, criterion A, C, D, and H were regarded as the most significant items in which bias could have an impact on results.28,29 Each item on the scale was coded as “explicitly described and present” (√), “absent” (x) or “unclear or inadequately described” (?). Interrater reliability for the assessors was calculated on a dichotomous scale (√ = 1 vs x or ? = 0) using percentage agreement and Cohen’s k. Depending on the study design, some items were coded as not applicable (N/A) and not included in agreement calculations. Disagreements between

---

**TABLE 1 Risk of Bias Checklist**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Randomization (generation of allocation sequence, allocation concealment and implementation) clearly described and adequately completed</td>
</tr>
<tr>
<td>B</td>
<td>Valid measures of FMS proficiency used (validation in same age group has been published or validation data were provided by the author)</td>
</tr>
<tr>
<td>C</td>
<td>Blinded outcome assessment (positive when those responsible for assessing FMS proficiency were blinded to group allocation of individual participants)</td>
</tr>
<tr>
<td>D</td>
<td>Covariates accounted for in analyses (eg, baseline score, age, sex, group, cluster RCTs, and other relevant covariates when appropriate such as age or sex)</td>
</tr>
<tr>
<td>E</td>
<td>Power calculation reported for main FMS outcome</td>
</tr>
<tr>
<td>F</td>
<td>Presentation of baseline characteristics separately for treatment groups (age + sex + ≥1 FMS outcome measure)</td>
</tr>
<tr>
<td>G</td>
<td>Dropout for FMS measure described, with a ≥20% dropout for studies with follow-up of ≥6 mo and ≥30% dropout for studies with follow-up &gt;6 mo</td>
</tr>
<tr>
<td>H</td>
<td>Summary results for each group + estimated effect size (difference between groups) + its precision (eg, 95% CI)</td>
</tr>
</tbody>
</table>

---
assessors were resolved by discussion.

Synthesis of Results

Data were first collated and described in a narrative summary with emphasis given to results from RCTs. Meta-analyses were conducted for studies that provided composite scores (ie, ≥2 skills combined) for overall FMS proficiency, locomotor proficiency, and object control proficiency using RevMan version 5.1.30 Studies that included a control or comparison group and reported baseline and posttest values or change scores, along with measures of distribution (ie, SD or confidence intervals) were included in the meta-analyses. When studies compared multiple treatment groups with a single control group (n = 2), the sample size of the control group was divided to avoid double counting. For studies that included posttest and follow-up assessments, the assessments completed at the end of the intervention period (ie, posttest) were included in the meta-analyses. Because FMS proficiency was assessed using a range of instruments, the standardized mean difference (SMD) with 95% confidence intervals (CI) was reported. Estimates were obtained using the DerSimonian-Laird random effects estimator and studies were weighted by the inverse of their variance. Statistical heterogeneity was examined via $\chi^2$ and the $I^2$ Index tests. The standardized effect sizes were interpreted as small (0.3), medium (0.5), and large (0.8).32

RESULTS

Overview of Studies

The flow of studies through the review process and reasons for exclusion are displayed in Fig 1. The initial search identified 12 329 citations. After screening the titles and abstracts of potential studies, 59 full-text articles were retrieved. From this number, 22 studies (representing 19 unique interventions) were included.

Study Characteristics

Table 2 displays selected characteristics of eligible studies including FMS results. Eight studies were published between 2010 and 2013,33–40 11 between 2000 and 2009,41–51 2 between 1990 and 1999,52,53 and 1 in 1989.54 The majority of studies were conducted in the United States,34,37,47,52–54 Australia,35,42,48,50,51 and Sweden.36,43,44,49 The majority of interventions were evaluated in primary/elementary schools among children, with only 1 study in high school with adolescents.39 Two studies were community-based interventions targeting overweight and obese children.35,42 One study included boys only,33 1 girls only,55 and the remaining were co-educational.

There were 6 RCTs33,35,45,46,48,53 (including 3 cluster RCTs45,48,53), 13 quasi-experimental studies34,36–39,41,43,44,47,49–52 and 3 single group pre-post studies.40,42,54 Seven studies included follow-up assessments after a period of no intervention.35–37,39,42,48,51 Ericsson did not include an immediate postintervention assessment her but did include follow-up assessments at 1, 2,3,44 and 9 years46 after baseline. The sample sizes for the studies ranged from 1342 to 1464,34 and 10 studies had a sample size of >250.34,36,39,40,43,44,48,50,51,53

Risk of Bias Within Studies

Table 3 displays the risk of bias assessments for all studies. Interrater reliability metrics for the risk of bias assessments indicated substantial
<table>
<thead>
<tr>
<th>Reference (author, year, country)</th>
<th>Design and Setting</th>
<th>Sample</th>
<th>Program Length and Total Minutes</th>
<th>Intervention Groups and Facilitator&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Intervention Content/Theory or Pedagogical Approach</th>
<th>FMS Measure and Outcomes</th>
<th>Posttest and Follow-Up Duration</th>
<th>Retention and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akbari et al (2009), Iran</td>
<td>Quasi-experimental, 1 primary school</td>
<td>N = 40 boys, aged 7–9 y</td>
<td>8 wk/1440 min</td>
<td>INT: Traditional games CON: Usual daily activities</td>
<td>Int. 3 × 60-min sessions/wk according to a specific lesson plan, including (1) warm-up; (2) traditional games, culturally appropriate and relevant for Iran with multiple skills practices for both locomotor and object control; (3) cool down; CON: Activities such as football, computer games, cycling.</td>
<td>TGMD-2 (locomotor: run, gallop, leap, jump, hop, slide; object control: throw, catch, kick, strike, dribble, roll)</td>
<td>PT: 8 wk; FU: None</td>
<td>RET: Not clear; PT: INT &gt; CON for gross motor skills (P &lt; .001), locomotor skills (P &lt; .001) and object control (P &lt; .001); Adjustments/effects by sex&lt;sup&gt;b&lt;/sup&gt;: N/A (boys only).</td>
</tr>
<tr>
<td>Bakhtiari et al (2011), Iran</td>
<td>RCT, 1 primary school</td>
<td>N = 40 girls, mean age = 8.9 ± 0.5 y, third grade</td>
<td>8 wk/1080 min</td>
<td>INT: Selected exercises; CON: Not clear</td>
<td>Int. 3 × 45-min sessions per week of selected exercises according to a specific lesson plan, including (1) heating, (2) selected exercises, (3) cooling; CON: Not described.</td>
<td>TGMD-2 (locomotor: run, gallop, hop, leap, jump, slide; object control: throw, catch, kick, strike, dribble, roll)</td>
<td>PT: 8 wk; FU: None</td>
<td>RET: 100%; PT: INT &gt; CON for locomotor skills (P = .001), object control skills (P = .001) and overall motor development (P = .001); Adjustments/effects by sex&lt;sup&gt;b&lt;/sup&gt;: N/A (girls only).</td>
</tr>
<tr>
<td>Boyle-Holmes et al (2010), United States</td>
<td>Quasi-experimental, 16 primary schools</td>
<td>N = 1464; 49% girls; aged 8–12 y (mean age = 9.8 y), fourth and fifth grades</td>
<td>2 y/3060 min p/y</td>
<td>INT: Michigan’s Exemplary PE Curriculum. CON: Existing PE curricula.</td>
<td>Int. A developmental PE curriculum that focuses on teaching and cumulative and connected motor skill learning progressions that strongly incorporated assessment and feedback. Lessons focused predominantly on the following 3 standards: motor skill and movement, values of physical activity for health and enjoyment, and regular physical activity. Fifty-one lessons</td>
<td>Measure developed for study (locomotor: leap; object control: forehand strike)</td>
<td>PT: 8-mo, 12-mo, 18-mo; FU: None</td>
<td>RET: 18-mo PT—1195/1464 (81.6%). PT: Overall average effects over time: INT &gt; CON for forehand strike (P &lt; .05), INT &gt; CON for leap (P &lt; .05) for the fifth-grade cohort; Adjustments/effects by sex: Not reported.</td>
</tr>
<tr>
<td>Reference (author; year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitators</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------------------------</td>
<td>------------------------</td>
<td>-------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Cliff et al (2011), Australia</td>
<td>RCT, After-school community</td>
<td>N = 165 (59% girls); aged = 5.5–9 y, Overweight or obese children (78% obese)</td>
<td>6 mo/900 min</td>
<td>INT 1: Physical activity skill development program (PA). INT 2: Dietary modification program (DIET). INT 3: Combined physical activity and dietary modification program (PA+DIET). Facilitator: INT 1: Researchers (PE qualified) INT 3: Researchers (PE qualified)</td>
<td>INT 1: Guided by CMT, 10-wk face-to-face program (weekly 90-min group session and weekly “home challenge” activities) and a minimal-contact 3-mo maintenance phase. INT 2: Parent-only program focused on improving food behaviors and diet quality. INT 3: Identical versions of PA and DIET interventions, with parents and children participating concurrently. Approach: INT 1 and 3: Based on CMT. Both direct instruction, movement exploration, TGMD-2 (locomotor: run, gallop, hop, leap, horizontal jump, slide; object control: strike, dribble, catch, kick, throw, roll)</td>
<td>PT: 6-mo; FU: 12-mo</td>
<td>RET: PT, 109/165 (66.1%); FU, 89/165 (53.9%); PT, INT 1 and INT 3 &gt; INT 2 for locomotor subscale (P &lt; .01), object control subscale (P &lt; .01), and GMQ (P &lt; .001) (GMQ gains of 11% to 13%). FU: There were no significant between-group differences for locomotor subscale, object control subscale or GMQ. Adjustments/effects by sex: No significant sex interaction effects in models.</td>
<td></td>
</tr>
<tr>
<td>Reference (author, year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitator</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Cliff et al (2007), Australia</td>
<td>Single group pretest–posttest design, After-school community</td>
<td>N = 13 (64% girls), aged 8–12 y (mean age 10.4 ± 2.2 y). Overweight or obese children (BMI 24.81 ± 3.1)</td>
<td>10 wk/1200 min</td>
<td>INT: SHARK. Facilitator: INT: Researcher (PE qualified)</td>
<td>guided discovery, and independent practice. INT: 10-wk after school program to develop 6 locomotor (run, gallop, hop, leap, horizontal jump, slide) and 6 object control (2-handed strike, stationary dribble, catch, kick, overhead throw, underhand roll) skills. Weekly 2-h group session focused on 2 or 3 skills and included introduction, skill-development, and skill application activities; debrief; and “home challenge” tasks. Each lesson used TARGET (task, authority, recognition, grouping, evaluation, time) structure. Approach: INT: Mastery motivational climate, based on CMT.</td>
<td>TGMD-2 (locomotor: run, gallop, hop, leap, horizontal jump, slide; object control: strike, dribble, catch, kick, throw, roll)</td>
<td>PT: 10 wk, FU: 9-mo</td>
<td>RET: PT and FU 11/13 (84.6%); PT: INT significant increase in GMQ (P &lt; .001). FU: INT GMQ remained significantly higher (P = .019). Adjustments/effects by sex: Not reported.</td>
</tr>
<tr>
<td>de Araujo et al (2012), Brazil</td>
<td>Quasi-experimental, Posttest only, 2 primary schools</td>
<td>N = 41 (39% girls), aged 9–11 y, fourth grade</td>
<td>Not reported</td>
<td>INT: Extreme sports classes. CON: Existing physical education. Facilitator: INT: PE teacher CON: PE teacher</td>
<td>INT: 3 × extreme sports weekly classes (including skateboarding, roller-skating, climbing, parkour activities) and 2 × weekly PE classes. CON: 2 × weekly PE classes. Approach: INT and CON. Not clear.</td>
<td>TGMD-2 (locomotor and object control subtests)</td>
<td>PT: Not reported FU: None</td>
<td>RET: Not clear; PT: INT &gt; CON for locomotor skills (P &lt; .05). No difference between groups for object control skills. Adjustments/effects by sex: Not reported.</td>
</tr>
<tr>
<td>Ericsson (2008a, 2008b), Sweden</td>
<td>Quasi-experimental, 1 primary school</td>
<td>N = 251, aged 6 y</td>
<td>Intervention length unclear, study duration 9 y/11700 min</td>
<td>INT: MUGI motor training program CON: Existing physical education. Facilitator: INT: PE teacher CON: PE teacher</td>
<td>INT: 5 × lessons of physical education and physical activities per week (3 × PE lessons and various local sports clubs took 2 × physical activity lessons), and, if needed, 1 × extra lesson (45 min) of motor training per week. MUGI includes MUGI observation checklist (eye-hand coordination: throw and catch, bounce ball, obstacle course; balance ability and bilateral coordination: skip, hop on one leg, balance on one leg, involuntary movements)</td>
<td>MUGI observation checklist</td>
<td>PT: School year 2 and 3</td>
<td>RET: Not clear. PT: School year 2: INT &gt; CON for motor skills (P &lt; .05) (Cramér’s index = 0.24). PT: school year 3: INT &gt; CON for motor skills (Cramér’s index = 0.37) and largest in the variable balance/bilateral coordination.</td>
</tr>
</tbody>
</table>
TABLE 2 Continued

<table>
<thead>
<tr>
<th>Reference (author, year, country)</th>
<th>Design and Setting</th>
<th>Sample</th>
<th>Program Length and Total Minutes</th>
<th>Intervention Groups and Facilitator</th>
<th>Intervention Content/Theory or Pedagogical Approach</th>
<th>FMS Measure and Outcomes</th>
<th>Posttest and Follow-Up Duration</th>
<th>Retention and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ericsson (2011), Sweden</td>
<td>Quasi-experimental prospective controlled longitudinal study, 2 schools</td>
<td>N = 263 (51% girls)</td>
<td>3 lessons of school’s ordinary PE per week (90 min)</td>
<td>Motor skill observations, information to teachers and parents, and identification and additional support for children with motor skill problems. Principles of MUGI include (1) success instead of failure; (2) no training of skills the child cannot perform; (3) automatization of skills in earlier development.</td>
<td>“ski hop,” imitate movements</td>
<td>DFM</td>
<td>PT: School year 9—RET: School year 9—243/263 (92.2%).</td>
<td>Differences between boys and girls motor skills in CON increased (46% boys 83% girls had good motor skills in year 3). No differences between boys and girls motor abilities in INT (90% boys 94% girls had good motor skills in year 3).</td>
</tr>
<tr>
<td>Foweather et al (2008), England</td>
<td>Cluster RCT, After-school (2 primary schools in areas of high deprivation)</td>
<td>N = 34 (62% girls), aged 8–9 y, fourth grade</td>
<td>9 wk/1080 min</td>
<td>INT: Multiskills club. CON: Normal routines. Facilitator: INT: experienced coaches with sports coaching qualifications. CON: N/A</td>
<td>INT: Semi-weekly after-school club with 2 × 1 hr sessions each week (total 18 h) focusing on FMS (vertical jump, leap, sprint run, kick, catch, throw, static balance) development. Program consisted of a variety of games, drills and self-learning activities. CON: normal routines and not engaged in additional sport programs. Modified checklist developed using ‘Get Skilled: Get Active’ (vertical jump, leap, sprint run, kick, catch, throw, static balance)</td>
<td>PT: 9 wk; FU: None</td>
<td>RET: 34/47 (72.3%). Children attended 80% of sessions. PT: INT &gt; CON for static balance (P = .005).</td>
<td>Adjustments/effects by sex: No adjustments or interactions reported. Preliminary analysis revealed intervention effects “did not significantly differ by sex” (P value not reported).</td>
</tr>
</tbody>
</table>
**TABLE 2 Continued**

<table>
<thead>
<tr>
<th>Reference (author, year, country)</th>
<th>Design and Setting</th>
<th>Sample</th>
<th>Program Length and Total Minutes</th>
<th>Intervention Groups and Facilitator</th>
<th>Intervention Content/Theory or Pedagogical Approach</th>
<th>FMS Measure and Outcomes</th>
<th>Posttest and Follow-Up Duration</th>
<th>Retention and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignico (1991), United States</td>
<td>Quasi-experimental, N = 30, grade K</td>
<td>1 primary school</td>
<td>10 wk/480 min</td>
<td>INT: Competency-based assessment and instructional program.</td>
<td>INT: Students rotated between 3 stations (3-min each). Received instruction, demonstration, and feedback on specific performance criteria of 12 motor skills. Student/teacher ratio was 6:1. Total instruction time ~28 min daily. Preservice teachers received training in motor skill assessment for 3 wk.</td>
<td>TGMD (locomotor: run, hop, jump, slide, gallop, skip, leap; object control: dribble, kick, throw, catch, strike)</td>
<td>PT: 10 wk; FU: None</td>
<td>RET: 100%. PT: INT &gt; CON for GMQ (P = .0001). Adjustments/effects by sex: Intervention effects did not differ by sex (P = .27).</td>
</tr>
<tr>
<td>Kalaja et al (2012), Finland</td>
<td>Quasi-experimental, N = 446 (52% girls), aged ~13 y, grade 7</td>
<td>3 secondary schools</td>
<td>33 wk/825 min</td>
<td>INT: Professional development for teachers and FMS training sessions for students.</td>
<td>INT: 33-wk intervention included FMS training sessions focusing on developing 1 dimension of FMS (ie, locomotion, manipulation, or balance). FMS sessions were 25 min in duration and scheduled at the beginning of PE class. Sessions included differentiation and promoted a mastery climate. After the FMS session, PE teachers followed regular school PE program (involving practicing sport skills, such as orienteering, volleyball, and skiing).</td>
<td>Flamingo standing test, rolling test, leaping test, shuttle run test, rope jumping test, accuracy throwing test, figure-8 dribbling test</td>
<td>PT: 10 mo; FU: 17 mo.</td>
<td>RET: Not clear. PT: INT &gt; CON for flamingo standing test (P = .001), INT &gt; CON for rolling test (P = .000), INT &gt; CON for balance skill sum score (P = .000). FU: INT &gt; CON for flamingo standing test (P = .048), INT &gt; CON for balance skill sum score (P = .014). Adjustments/effects by sex: Not reported.</td>
</tr>
<tr>
<td>Reference (author, year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitator*</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
<td>---------------------------------------------------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Karabourniotis et al (2002), Greece</td>
<td>RCT, 1 primary school</td>
<td>N = 45 (47% girls), mean age = 79 mo, first grade</td>
<td>12 wk/960 min</td>
<td>INT: Skill-orientated program with focus on self-testing activities. CON: Regular PE school program.</td>
<td>Facilitator: INT: PE specialists; CON: PE specialists</td>
<td>Approach: INT: Mastery climate; CON: Direct instruction. INT: 12-wk experimental movement skill curriculum with an increasing allotment of time spent on self-testing activities (including FMS, sports skills, fitness activities, activities with small and large equipment) that allow students opportunities to perform individually. Two 40-min sessions per week. CON: PE curriculum 12-wk program originally suggested by the Greek Ministry of National Education and Religious Affairs (space and time perception activities; visual-motor coordination activities; static and dynamic balance; sideways movement).</td>
<td>TGMD (locomotor: run, gallop, hop, horizontal jump, leap, skip, slide, object control: throw, catch, dribble, kick, strike)</td>
<td>PT: 12 wk; FU: None</td>
</tr>
<tr>
<td>Martin et al (2009), United States</td>
<td>Quasi-experimental, 2 primary schools (economically disadvantaged)</td>
<td>N = 64 (53% girls), INT mean age = 5.7 y, CON mean age = 5.4 y grade K</td>
<td>6 wk/900 min</td>
<td>INT: Mastery motivational climate. CON: Low autonomy climate.</td>
<td>Facilitator: INT: Researcher/PE specialist (6 y experience); CON: PE specialist (8 y experience)</td>
<td>Approach: INT: Movement exploration (mastery/self-testing); CON: Direct instruction. INT: Mastery motivational climate where students moved freely throughout FMS stations and had choice in which stations to visit, time, level of task difficulty, and grouping. Teacher provided private individual feedback about effort or progress. Thirty 30-min lessons.</td>
<td>TGMD-2 (locomotor: run, gallop, hop, leap, jump, slide; object control: strike, dribble, catch, kick, throw, roll)</td>
<td>PT: 6 wk; FU: None</td>
</tr>
<tr>
<td>Reference (author, year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitator&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------------------</td>
<td>-------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Matvienko et al (2010), United States</td>
<td>Quasi-experimental, After-school, 4 primary schools</td>
<td>N = 70 (50% girls), grades K and 1</td>
<td>4 wk, 2100 min</td>
<td>INT: NutriActive (morning walk and after-school program); CON: Control. Facilitator: INT: PE specialist; CON: N/A</td>
<td>CON: Low-autonomy climate that used direct teaching methods, skill drills, sport skills and large group activities. Thirty × 30-min lessons. Both INT and CON lessons consisted of 3 parts: (1) 3–5 min introduction, (2) 22–25 min of skill instruction and practice; (3) 2–3 min closure. Approach: INT: Mastery motivational climate; CON: Direct instruction.</td>
<td>Fitnessgram throwing distance test. Additional measures developed for study: rope jumping (number of basic jumps over the jump rope in 30 s); kicking (kicking a ball into the goal from a 10-m line)</td>
<td>PT: 4 wk; FU: 4 mo</td>
<td>RET: PT, 100%, FU—59/70 (84.3%). PT: INT &gt; CON for jumps over rope, throwing and kicking (P &lt; .05). FU: INT &gt; CON for jumps over rope (P &lt; .001) and throwing (P &lt; .001). Adjustments/effects by sex: Not reported.</td>
</tr>
</tbody>
</table>
| McKenzie et al (1998), United States | Cluster RCT, 7 primary schools | N = 709 (50% girls); mean age girls = 9.4 y, boys = 9.6 y; grades 4 and 5 | 6 mo/ 2160 min | INT 1: PE specialists; INT 2: Trained teachers. CON: Usual PE. Facilitator: INT 1: PE specialists + additional SPARK training (1 had 11 y experience, others newly credentialed). INT 2: Trained classroom teachers. | INT 1: PE specialists implemented the SPARK PE curriculum focused on fitness (15 min) and motor skills (15 min) and included all lesson plans. Three 30-min lessons/wk. Received bimonthly meetings offsite including review and feedback. INT 2: Classroom teachers implemented the SPARK PE curriculum. Three Overhand throw (overhand throw a ball to hit a target); catch (catch a ball that was tossed underhand); kick (kick a stationary ball into a target) | Overhand throw (overhand throw a ball to hit a target); catch (catch a ball that was tossed underhand); kick (kick a stationary ball into a target) | PT: 6 mo; FU: None | RET: 100% (55 removed from baseline analysis, 12 unavailable). PT: INT 2 > CON for catching (P = .05) and throwing (P = .009). For total skill percent gains INT 1 increased by 21%, INT 2 by 19% and CON by 13%. Adjustments/effects by sex<sup>x</sup>: Significant main effect of sex for all skill changes.
<table>
<thead>
<tr>
<th>Reference (author, year, country)</th>
<th>Design and Setting</th>
<th>Sample</th>
<th>Program Length and Total Minutes</th>
<th>Intervention Groups and Facilitatora</th>
<th>Intervention Content/Theory or Pedagogical Approach</th>
<th>FMS Measure and Outcomes</th>
<th>Posttest and Follow-Up Duration</th>
<th>Retention and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ross et al (1989), United States</td>
<td>Single group pretest-posttest design, 1 primary school</td>
<td>N = 120 (45% girls), aged 5–14 y; grades K–8</td>
<td>36 wk/K–3: 2160 min; grades 4–8: 3240 min</td>
<td>INT: Dance/ movement education (D/ME). Facilitator: INT: PE specialist (10 y experience) + 2 dance teachers.</td>
<td>Ohio State University Scale of Intra Gross Motor Assessment (SIGMA) (running, stair climbing, jumping, hopping, skipping) (only assessed K–3 n = 63). The Short</td>
<td>PT: 9-mq; FU: None</td>
<td>RET: Not clear. Approach: INT: D/ME in conjunction with the school’s regular PE program instructed by the school’s regular physical educator in cooperation with 2 dance educators. D/ME. Adjustments/effects by sex: K–3 boys made gains in the number of mature gross motor patterns for running, jumping and hopping (no P value reported). K–3 girls</td>
<td></td>
</tr>
</tbody>
</table>

CON: Classroom teachers. Classroom teachers received training (Classroom Teacher Professional Development Program. Year 1 = 32 h over 11 sessions, year 2 = 9 h over 3 sessions). Also received onsite support by PE specialist (biweekly to bimonthly) including observations, modeling, feedback etc.

CON: Continued with usual PE programs. Approach: INT: Direct instruction; CON: Not detailed. (all P < .001). Both improved but boys made significantly greater motor skill gains than girls. Intervention effects did not differ by sex.
### TABLE 2 Continued

<table>
<thead>
<tr>
<th>Reference (author, year, country)</th>
<th>Design and Setting</th>
<th>Sample</th>
<th>Program Length and Total Minutes</th>
<th>Intervention Groups and Facilitator</th>
<th>Intervention Content/Theory or Pedagogical Approach</th>
<th>FMS Measure and Outcomes</th>
<th>Posttest and Follow-Up Duration</th>
<th>Retention and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary schools (low socio-economic status areas)</td>
<td>N = 306 (51% girls), mean age 10 y 8 mo, grade 5</td>
<td>9 mo/ 855 min (FMS condition)</td>
<td>INT 1: Behavioral modification (BMI) condition. INT 2: FMS condition. INT 3: Combined BMI/FMS condition. CON: Control. Facilitator: INT: PE specialist; CON: Not detailed.</td>
<td>Interventions guided by SCT and BCT and delivered in addition to usual PE and sports classes. INT 1: 19 lessons (40–50 min) were delivered in the classroom and incorporated self-monitoring, health benefits of PA, awareness of home and community PA and sedentary behavior environments, decision-making, identifying alternate activities, intelligent TV viewing and reducing viewing time, advocacy of reduced screen time, use of pedometers, group games, contracts, and parent newsletter. INT 2: 19 lessons (40–50 min) focused on mastery of 6 FMS (run, dodge, vertical jump, throw, strike, kick) with an emphasis on enjoyment.</td>
<td>Department of Education Victoria Fundamental Motor Skills: A Manual for Classroom Teachers (locomotor: dodge, sprint run, vertical jump; object control: overhand throw, 2-handed strike, kick)</td>
<td>PT: 9 mo; FU: 12 mo</td>
<td>RET: Not clear; PT and FU: No significant intervention effects on FMS z-scores. Adjustments/effects by sex: Some group × sex interactions noted for FMS. INT 1 girls &gt; CON girls for FMS z scores (P &lt; .05); INT 2 girls &gt; CON girls for FMS z scores (P &lt; .01).</td>
</tr>
<tr>
<td>Reference (author, year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitator</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------</td>
<td>--------</td>
<td>----------------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------------------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Sollerhed et al (2008), Sweden</td>
<td>Quasi-experimental, 2 primary schools</td>
<td>N = 132 (45% girls), age = 6–9 y</td>
<td>3 y/ 10,580 min/y</td>
<td>INT: Expanded PE lessons. CON: Stipulated curricular time.</td>
<td>INT: Increase of allocated time for PE. Four 40-min PE lessons and one 1 h outdoor physical activities per wk. Obese children had option of 1 extra lesson per wk. Quality of lessons and variety of activities were emphasized. One PE lesson boys and girls separate, the other was co-educational. CON: Followed the stipulated curricular time. One 40-min lesson per week for children aged 6–9 y and 2 40-min lessons per week for children aged 10–12 y.</td>
<td>EUROFIT (plate tapping, shuttle run, balance). Tests constructed (rope skipping; number of correct skips with the rope in 30 s; ball bouncing; number of correct bounce catches in 30 s)</td>
<td>PT: 1 y, 2 y, and 3 y; FU: None</td>
<td>RET: 3 y PT. 126/132 (95.5%). PT: 3 y INT &gt; CON for motor skill index (P = .010). Adjustments/effects by sex: Results adjusted for sex.</td>
</tr>
<tr>
<td>Van Beurden et al (2003), Australia</td>
<td>Quasi-experimental, 18 primary schools</td>
<td>N = 1045 (47% girls) Aged 7–10 y, grades</td>
<td>1 y</td>
<td>INT: Move It Groove It (MIGI) CON: Control.</td>
<td>INT: Move It Groove It: whole school approach: school project teams; buddy program (matching third-year preservice teacher with generalist teachers); professional development for teachers (1 to introduce study, 1 midstudy to share progress, and 2 to improve teaching of FMS and dance); project Web site with lesson plans.</td>
<td>'Get Skilled Get Active' (locomotor: static balance, sprint run, vertical jump, hop, side gallop, object control: kick, catch, overhand throw)</td>
<td>PT: 1 y; FU: 6 y</td>
<td>RET: Not clear PT: INT &gt; CON for all skills combined (P &lt; .0001). INT &gt; CON for boys for sprint run (P &lt; .001), side gallop (P &lt; .001), kick (P &lt; .001), throw (P = .034), jump (P = .004) and catch (P &lt; .001). INT &gt; CON for girls for side gallop (P = .049), kick (P = .023), throw (P = .042), jump (P = .002), hop (P = .037), catch (P &lt; .001).</td>
</tr>
<tr>
<td>Reference (author, year, country)</td>
<td>Design and Setting</td>
<td>Sample</td>
<td>Program Length and Total Minutes</td>
<td>Intervention Groups and Facilitator&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Intervention Content/Theory or Pedagogical Approach</td>
<td>FMS Measure and Outcomes</td>
<td>Posttest and Follow-Up Duration</td>
<td>Retention and Results</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>---------------------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------------------</td>
<td>-------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Barnett et al (2009), Australia</td>
<td>6-y follow-up</td>
<td>6-y</td>
<td>6-y</td>
<td>INT: Direct instruction. CON: Not detailed.</td>
<td>‘Get Skilled Get Active’ (catch, kick, throw, vertical jump, side gallop)</td>
<td>RET: FU—268/328 (82.9%). FU: INT &gt; CON for catch (P = .001). INT maintained advantage compared with CON for side gallop and vertical jump. Adjustments/effects by sex: No interactions effects reported at posttest. Results adjusted for sex at 6 y follow-up.</td>
<td>Overall, 16.8% improvement for all skills combined (z = 3.64, P &lt; 0.0001).</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Facilitator refers to the individual(s) who delivered the intervention.

<sup>b</sup> TGMD standardized scores are all adjusted for age and sex.

BCT, behavioral choice theory; CMT, competence motivation theory; CON, control; FMS, fundamental movement skills; FU, follow-up—assessments conducted after the completion of the intervention and the initial posttest assessments; GMQ, Gross Motor Quotient; INT, intervention; K, kindergarten; MUGI, Motorisk Utveckling som Grund för Inlärning—motor skills as foundation for learning; PE, physical education; PT, posttest—assessments conducted after baseline assessments and/or immediately after completion of the intervention; p/y, per year; RCT, randomized controlled trial; RET, retention; SCT, social cognitive theory; SHARK, Skills Honing and Active Recreation for Kids; TGMD-2, Test for Gross Motor Development; y, year.
<table>
<thead>
<tr>
<th>Study</th>
<th>Randomization Clearly Described and Adequately Completed</th>
<th>Valid Measure of FMS</th>
<th>Assessor Blinding</th>
<th>Participants Analyzed in Allocated Group and Not Excluded Because of Missing Data or Noncompliance</th>
<th>Covariates Accounted for in Analyses</th>
<th>Power Calculation Reported for FMS</th>
<th>Baseline Results Reported Separately for Each Group</th>
<th>Dropout ≤20% for ≤6 Mo Follow-Up and ≤30% &gt;6 Mo Follow-up</th>
<th>Summary Results Presented + Estimated Effect Sizes + Precision Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akbari et al 2009</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bakhshi et al 2011</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Barnett et al 2009</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Boyle–Holmes et al 2009</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Cliff et al 2007</td>
<td>N/A</td>
<td>✓</td>
<td>N/A</td>
<td>✓</td>
<td>N/A</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cliff et al 2011</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>de Araujo et al (2012)</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Ericsson et al 2008a</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Ericsson et al 2008b</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Ericsson et al 2011</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Foweather et al 2008</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ignico et al 1991</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Kalaja et al (2012)</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Karabourniotis et al 2002</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Martin et al 2009</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Matvienko et al 2010</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>McKenzie et al 1998</td>
<td>?</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Mitchell et al 2013</td>
<td>N/A</td>
<td>✓</td>
<td>N/A</td>
<td>?</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Ross et al 1989</td>
<td>N/A</td>
<td>x</td>
<td>N/A</td>
<td>x</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Salmon et al 2008</td>
<td>?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Sollerhed et al 2008</td>
<td>N/A</td>
<td>✓</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Van Beurden et al 2003</td>
<td>N/A</td>
<td>x</td>
<td>x</td>
<td>?</td>
<td>✓</td>
<td>x</td>
<td>?</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

✓, explicitly described and present; X, absent; ?, unclear or inadequately described; N/A, not applicable because of study design.
agreement for all 187 items (percentage agreement 95%, $k = 0.84$). Seventeen of the 22 studies used measures of FMS proficiency that had published validity, $14,35,38–44,46–49,52$ and this was the most commonly reported item across the studies. Nine studies met the criteria for adequate retention, $33,34,36,37,42,47,48,52,53$. Assessor blinding was reported in 3 studies, $34,35,48$ and in 6 studies, participants were analyzed in their allocated group and were not excluded because of missing data or non-compliance, $33,35,39,42,48,52$. Of the 6 RCTs, the randomization procedure, including sequence generation, allocation concealment, and implementation, was adequately described in only 1 study. $33,35$ None of the studies reported a power calculation for FMS outcomes.

Measurement of FMS

Studies used a combination of process and product measures to assess FMS competency. The Test of Gross Motor Development (TGMD) was the most common measure of FMS with TGMD used in 2 studies $46,52$ and TGMD-2 used in 7 studies. $33,35,38,40–42,47$ The ‘Get Skilled Get Active’ measure was used to evaluate 2 interventions. $45,56,51$ Matvienko et al $37$ and McKenzie et al $53$ developed product measures designed to assess children’s catching, kicking, distance, and throwing accuracy.

Types of Interventions

Nearly all interventions were delivered in the primary school setting, with 4 conducted after school $35,37,42,45$ and 1 in high school. $39$ Most interventions were delivered by physical education (PE) teachers $34–39,42,43,44,46–49,53,54$ or experienced coaches, $45$ with some using trained classroom teachers $55$ or trained pre-service teachers $50,51,52$ or PE specialists to help classroom teachers. $40,49$ Interventions ranged in duration from 4 weeks $57$ to 3 years. $48$ On average, interventions offered between 8 and 195 hours of instruction and ran for 12 weeks (median). Many of the interventions followed a structured format and included a prescribed number of lessons per week, although a number did not provide detailed intervention descriptions (eg, $33,41,45,52$).

Some of the interventions had a greater focus on providing teacher professional development (eg, $39,53$) or additional support to teachers (eg, $40,50,51$). These interventions tended to be longer in duration and often included multiple strategies and intensive support for teachers. $48,50,51,53$ For example, the Move It Groove It intervention $50,51$ involved a whole-school approach, which included school project teams, a buddy program with pre-service teachers, professional development (5 days of training and 4 workshops), and a project Web site. Similarly, for the trained classroom teacher study arm in the SPARK intervention, $53$ teachers received 32 hours training in year 1 and 9 hours in year 2 and also received on-site support by a PE specialist (bi-weekly to bimonthly) that included observations, modeling, feedback, and other assistance.

Theoretical Framework or Pedagogical Approach Guiding the Interventions

A number of the PE-based interventions tested an “enhanced” PE curriculum with a focus on optimal FMS development versus traditional PE $34,39,46,47$ or free play, $52$ whereas some compared both enhanced PE and additional time spent in PE $36,38,43,44,48,50,51,53$ or simply evaluated the benefit of an increased time allotment for PE. $49$ Many of the interventions did not provide detail about the theoretical or pedagogical approach that the intervention was based on. Some were based on 1 approach, and others used a combination of approaches. The following approaches or theories were described: mastery motivational climate, $42,46,47$ competence motivation theory, $35,42$ hypothetic-deductive $36,43,44$ self-learning, $45$ and movement exploration and self-testing $48,54$. Martin and colleagues $47$ used a mastery motivational climate that allowed students to move freely throughout FMS stations and were encouraged to self-regulate the time spent at each station, the level of task difficulty, and their grouping. Most other interventions were based on direct instruction (teacher-led activities, games) or not described.

Evidence for FMS Outcomes

All studies reported statistically significant intervention effects for $\geq 1$ FMS. Twelve studies reported significant intervention effects for overall motor skill competency, $33,35,36,39–41,42,43,46,49,50,52$ and 1 study found improvements in girls only. $48$ Alternatively, McKenzie and colleagues $53$ found that changes in total skill competency among students in the intervention groups were greater but not significantly different to those observed in the control group who continued with their usual PE programs.

Both short-term (ie, 4–8 weeks) and long-term (>6 months) interventions were successful in increasing FMS competency. Of those studies that reported results beyond post-intervention assessments, $35–37,39,41,48,51$ 6 reported positive intervention effects on at least 1 outcome. $36,37,39,42,48,51$ Both Barnett et al $51$ and Ericsson $36$ reported significant long-term effects after 6 and 9 years, respectively. Some studies reported their results separately for boys and girls or included sex as an interaction term/covariate in their analysis. $35,44–48,54$ Some found both boys and girls improved $44,50,52,54$ others reported boys made greater gains in the intervention $49$ or control group, $44$ and 1 found the intervention favored girls. $48$
Meta-analysis of FMS Intervention Effects

Because there was considerable heterogeneity among interventions, the random effects models were used for all analyses. The meta-analyses revealed large effect sizes for overall gross motor skill proficiency (SMD = 1.42, 95% CI 0.68–2.16, Z = 3.77, P < .0002; Fig 2) and locomotor skill competency (SMD = 1.42, 95% CI 0.56–2.27, Z = 3.25, P = .001; Fig 3). A medium effect size for object control skill competency was observed (SMD = 0.63, 95% CI 0.28–0.98, Z = 3.53, P < .0004; Fig 4). A funnel plot to assess publication bias was not produced as the meta-analyses included <10 interventions.55
DISCUSSION
The aim of this systematic review was to synthesize the evidence on the effectiveness of FMS interventions among typically developing youth. Of the 22 eligible studies (including 6 RCTs), 19 unique interventions were evaluated with all reporting intervention effects for ≥1 FMS. Meta-analyses revealed statistically significant intervention effects for overall gross, locomotor, and object control motor skill proficiency. Although these findings are promising, there was a high risk of bias in many of the included studies.

The evaluation of FMS interventions is a relatively new area of research. Although the first study was conducted in 1989,86 86% have been published since 2000. There was considerable variation in both intervention design and duration, but most were delivered in the primary school setting by PE specialists. Only 1 study was conducted with adolescents, which is not surprising given that FMS are optimally developed and ideally targeted in childhood. However, the lack of studies is of concern, given the poor FMS proficiency of many children who are now entering high school.9,10,56 and this may be an important area for future work. Intervention effects for ≥1 FMS outcomes were reported in all studies, with 12 reporting significant effects for overall motor skill competence. In studies conducting follow-up assessments beyond the postintervention assessment, 6 reported positive intervention effects, including 2 that had long-term follow-up.36,51 However, significant effects were not observed for all FMS measured.

The effect sizes found in the current review were large and greater than those observed in a previous meta-analysis of FMS interventions in mostly younger children.21 However, there were only a relatively small number of heterogeneous studies included in the meta-analyses. We found the effect size for locomotor skills was greater than for object control skills. This is in contrast to a recent meta-analysis by Logan et al, which found no difference. This disparity may be due to the different age groups sampled as Logan et al’s meta-analysis included mostly studies of children with developmental delays or of preschool age. Our findings may suggest that object control skills are more difficult to improve than locomotor skills. This may be due to the greater skill component complexity and perceptual demand of object control skills, which may require more intensive skill instruction and practice.

Although the findings are positive for FMS improvements, these results should be interpreted with some caution because of the high risk of bias identified and because less than one-third of studies were RCTs. The high risk of bias was similar to a recent review of FMS interventions in young children,22 although the number of studies demonstrating significant intervention effects was higher in the current review. In the current review, most studies used a valid FMS measure, but no studies reported a power calculation for an FMS outcome. Moreover, studies scored poorly for risk of bias items that are most likely to bias the estimate of an intervention’s effectiveness,28,29 particularly for assessor blinding, participants being excluded because of missing data, retention, and poor descriptions of the randomization process for the RCTs.

Evidence From RCTs
For all RCTs, the effect on FMS outcomes was in favor of the intervention group. The risk of bias was lower than the other studies but still quite high for two-thirds of studies. The RCTs evaluated 5 programs in the primary school33,46,48,53 or after school settings45 in 5 countries and 1 study for overweight children in a community setting.25 The school-based RCTs were conducted with generally small samples (<100) and differed slightly in terms of their FMS impact, with some reporting effects on overall motor competence (both locomotor and object control),33,46,53 and others having an impact on a select number of individual skills45 or in a subgroup analysis favoring girls.48

FMS Intervention Characteristics and Pedagogical Approaches
Many studies did not describe their intervention sessions or teaching strategies in detail (eg,33,38,41,45,52), and although intervention components varied across studies, they generally involved multiple lessons per week. Similar heterogeneity was also found in the review of young children.22 A number of the PE-based interventions tested an “enhanced” PE curriculum with a focus on optimal FMS development versus traditional PE4,39,46-47 or free play,52 whereas some compared both enhanced PE and additional time spent in PE46,38,44,48,50,51,53 or simply evaluated the benefit of an increased time allotment for PE.49

Of those studies that compared enhanced PE (ie, targeting FMS development) versus typical PE (eg, games)34,39,46,47 or free play,52 findings demonstrated the benefits of pedagogical approaches that enabled the learner to experience autonomy, developmentally appropriate tasks, and mastery and receive individualized feedback. This is of note, given that the control groups in these studies received the same time in PE or “dose” as the intervention group and both intervention and control groups had PE specialists deliver the respective programs. For example, Karabourniotis et al46 demonstrated the benefits of a motor skill-focused program characterized by self-testing activities and
many opportunities for individual practice, compared with usual PE lessons using a games approach. Martin et al.\textsuperscript{47} showed greater gains in FMS proficiency of children in a mastery climate compared with a low-autonomy group, although as the intervention was delivered by the research team, it is possible that a teacher effect may have contributed to the group differences. However, a mastery climate, focusing on success, optimal challenge, and autonomy led to improvements in FMS in multiple other studies,\textsuperscript{39,42,46,52} highlighting the benefits of this pedagogical approach. Although research in PE pedagogy has demonstrated the value of direct instruction,\textsuperscript{57,58} student-centered approaches in which students are given choice may enhance intrinsic motivation,\textsuperscript{59} on-task behavior, effort, and FMS proficiency. However, more research is needed to determine optimal pedagogical approaches.

Other studies in our review compared the effects of additional teacher training and/or time for PE lessons\textsuperscript{50,58,43,44,48,50,51,53} with usual PE practice and demonstrated improved FMS outcomes. For example, McKenzie et al.\textsuperscript{53} demonstrated that classroom teachers who received extensive training and ongoing support had a meaningful impact on their students’ FMS. Ericsson\textsuperscript{56,44} found superior FMS gains from a greater dose of PE (5 lessons per week) compared with the school’s ordinary PE (2 lessons per week).

Given the issues identified in primary school PE internationally, including the constraints of a “crowded curriculum”\textsuperscript{60–63}, further strategies to integrate FMS learning beyond the school may have merit. This was a successful strategy used in 4 studies in the after-school setting\textsuperscript{35,37,42,45} and by using supplementary home-based FMS tasks.\textsuperscript{35,42,53} Matvienco et al.\textsuperscript{57} found a short, intense after-school program produced significant and sustained FMS changes in the short term. Few studies\textsuperscript{35,42,43} reported using parents as part of the intervention, as also found in Reithmuller’s et al.\textsuperscript{42} FMS review in young children. Given the limited PE curriculum time in primary schools, strategies to engage parents in both school-based lessons and to support practice opportunities outside of school may be a worthwhile target for future interventions.

Overall, it is difficult to ascertain which intervention characteristics were most important given the differences in design, program length and limited detail provided. Most studies did not detail the “dose” received (eg, attendance, FMS on-task time). Interestingly, the Logan et al. review\textsuperscript{23} found no association between FMS effect size and intervention duration, likely because of a disparity between intervention length and dose, with most studies not reporting actual FMS on-task time (ie, the actual time a child is engaged in an activity in which he or she is practicing or applying a FMS). This is an important area for future research because motor skill development theory shows that a key factor is the number of correct practice trials a child completes.\textsuperscript{37}

In addition, a longer intervention may not result in better FMS outcomes because some children (particularly older) may experience a “ceiling effect” with some FMS measures. Process-oriented assessment batteries distinguish well at the lower end of skill ability but not as well at the higher end. As children grow and develop, they are more likely to be proficient in an FMS, or even excel at it, but the child who “excels” may score the same as a child who simply displays proficiency in the core skill components. Ceiling effects are less likely to occur with product assessments because there is always the possibility to perform better when the scoring is related to speed, distance, or accuracy.

**Implications and Recommendations**

Quality of instruction and time spent in practice are of utmost importance in improving FMS competence.\textsuperscript{4} PE is a critical medium for providing this opportunity and is recognized as one of the most influential factors in FMS development.\textsuperscript{64} Most of the school-based interventions targeted PE and PE specialists as facilitators. The interventions that used classroom teachers\textsuperscript{40,50,51,53} involved substantial professional development. Because many countries employ classroom teachers to deliver primary school PE, it is critical that FMS lessons are delivered appropriately and frequently.\textsuperscript{65} Many studies have confirmed the tendency of classroom teachers to deliver PE programs consisting of inappropriate lesson content including large-sided team games or free play\textsuperscript{66,67} Therefore, schools should ensure FMS lessons are delivered in a pedagogically appropriate manner\textsuperscript{60} and that PE specialists are engaged. Given that the primary school years are considered the optimal time to develop FMS and current issues with FMS learning contexts in primary schools,\textsuperscript{68} training and resources need to be prioritized so that children can receive quality instruction. Researchers and education authorities may also need to consider the adoption of evidence-based programs and determine how these could be translated and sustained without researcher support.

Although risk of bias was high overall, it is possible that studies were inadequately reported rather than conducted, and thus actual study quality may have been underestimated. Future research should use the Consolidated Standards of Reporting Trials and Transparent Reporting of Evaluations.
REFERENCES


With Nonrandomized Designs statements. In particular, it is imperative that researchers report their interventions in greater detail (eg, intensity, duration and fidelity of FMS tasks, characteristics of facilitators and participants). More evidence is needed to determine which pedagogic approach and program components are associated with enhanced FMS competence and the optimal dose, duration, and intensity of interventions. In addition, because most of the studies only included assessments immediately after the intervention, future studies should include follow-up assessments beyond the postintervention time point to determine any sustained or long-term effects. Additional studies are needed that report results separately by sex given established differences in FMS proficiency between boys and girls and that findings from a few studies highlighted the need for increased attention on girls’ FMS proficiency.

**Strengths and Limitations**

This review has a number of strengths: (1) a comprehensive search strategy across multiple databases with no date restrictions, (2) extensive study detail extracted and broad inclusion criteria, (3) high agreement levels for risk of bias assessments, and (4) alignment with the PRISMA Statement. Limitations included the following: (1) studies were required to be published in English, (2) inclusion of a generally modest number of heterogeneous studies, (3) inability to rule out publication bias, and (4) potential study comparison difficulties due to the different types of FMS measures used.

**Conclusions**

Given the established associations between FMS and a range of health-related benefits, future research is needed to evaluate high-quality trials with long-term follow-up. We found evidence for the positive influence of programs of enhanced PE to improve FMS proficiency of children. Although the evidence-base is promising, results must be treated with some caution given the high risk of bias identified in many studies. It is clear that PE has a vital role to play in developing FMS for children and that PE specialists or classroom teachers with extensive and ongoing professional development are required to deliver such programs.
27. van Sluijs EMF, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ. 2006;333(7522):703–707


Fundamental Movement Skill Interventions in Youth: A Systematic Review and Meta-analysis
Philip J. Morgan, Lisa M. Barnett, Dylan P. Cliff, Anthony D. Okely, Hayley A. Scott, Kristen E. Cohen and David R. Lubans
Pediatrics 2013;132;e1361; originally published online October 28, 2013;
DOI: 10.1542/peds.2013-1167

Updated Information & Services
including high resolution figures, can be found at:
/content/132/5/e1361.full.html

References
This article cites 56 articles, 4 of which can be accessed free at:
/content/132/5/e1361.full.html#ref-list-1

Citations
This article has been cited by 5 HighWire-hosted articles:
/content/132/5/e1361.full.html#related-urls

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
/site/misc/Permissions.xhtml

Reprints
Information about ordering reprints can be found online:
/site/misc/reprints.xhtml
Fundamental Movement Skill Interventions in Youth: A Systematic Review and Meta-analysis

Philip J. Morgan, Lisa M. Barnett, Dylan P. Cliff,Anthony D. Okely, Hayley A. Scott, Kristen E. Cohen and David R. Lubans

*Pediatrics* 2013;132:e1361; originally published online October 28, 2013; DOI: 10.1542/peds.2013-1167

The online version of this article, along with updated information and services, is located on the World Wide Web at:

/content/132/5/e1361.full.html