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# Motor Competence Interventions in Children and Adolescents - Theoretical and Atheoretical Approaches: A Systematic Review

# Motor Competence Interventions in Children and Adolescents - Theoretical and Atheoretical Approaches: A Systematic Review

**Abstract**

This study aimed to compare for the first time the immediate and retention effects of theory-based and atheoretical motor competence (MC) interventions, by conducting a systematic review to determine which intervention approach resulted in the most improvements for motor outcomes. In accordance with PRISMA guidelines, studies were identified from searches across seven databases, for articles relating to theory-based (Achievement Goal Theory, Dynamic Systems Theory, and Social-Cognitive Theory) and atheoretically-derived MC interventions in typically developing children and adolescents. Publication bias was assessed using an adapted form of Consolidated Standards of Reporting Trials statement. Of the thirty two included studies, seventeen utilized theory-based intervention approaches. The majority of studies were grounded in Achievement Goal Theory. Also, the majority of MC interventions elicited immediate (short) and/or long-term effects for children and adolescents. Studies varied with regards to intervention components (content, frequency, length and provider) and MC assessment (MC tool, dimension and retention period). Many studies scored poorly for risk of bias items. “Overall, the levels of success for theoretical and atheoretical intervention programs were not distinguishable. Findings open up new horizons for motor skills instruction to be taught using developmentally appropriate pedagogy, a research field which has gained significant traction among stakeholders in recent years.

**Key words**: Motor competence; Motor development; Achievement Goal Theory; Dynamic Systems Theory; Social-Cognitive Theory

# 1 Introduction

Motor competence (MC) is defined as a level of motor abilities (MA) (physical proficiency and perceptual-motor), as well as gross motor coordination (GMC) and fundamental motor skills (FMS) proficiency, which underlie the performance of a wide range of tasks, including fine and gross motor activities in daily life [1]. MC is an important component of the motor development domain, and research shows that it can be directly related to major health and physical fitness indicators, such as weight status, physical activity levels, and perceived motor competence [2, 3]. According to cross-sectional and longitudinal studies, MC is a consequence, as well as a predictor, of many health-related behaviors [4-6]. Motor skills are not age-dependent, however, and they do not simply develop as a function of age [7]. Evidence shows that physical growth and maturation alone do not automatically lead to motor skill competence; rather, external factors such as instructional protocol, practice, and reinforcement play a crucial role in motor skill development [8]. Based on longitudinal studies, MC appears to track throughout childhood [9] and into adolescence [10, 11], suggesting that low MC may persist into older ages; therefore, well-tailored interventions should occur during childhood and through adolescence to ensure the sufficient development of MC.

In the preceding decades, a concerted effort has been placed into developing motor skills interventions to ameliorate the lack of MC in children and adolescents [12, 13]. Indeed, previous systematic reviews have reported that MC interventions are, overall, beneficial for children [14-17]; however, they were mostly aimed at FMS, which is only one component of MC within intervention studies. In a recent study by Jiménez-Díaz, Chaves-Castro, and Salazar, the authors conducted a meta-analysis to quantify the data obtained from MC intervention programs. The authors reported statistically significant improvements in MC, defined as FMS, motor coordination, motor fitness, and motor ability, for the individuals who took part in these MC programs [18]. The authors, however, did not assess the retention (short or long term) of these MC improvements and solely focused on the immediate post-intervention effects. In 2013, Morgan et al. conducted a systematic review which included some studies reporting a retention assessment of MC beyond immediate post-intervention assessments. Accordingly, they found positive retention effects in six of the twenty-two studies, including two with long-term (six years) follow-up assessments. Furthermore, only a few of the interventions examined demonstrated a significant improvement in FMS [16]. This review by Morgan et al., (2013) was limited to FMS intervention programs only, and since then, many more MC intervention studies have been published. This highlights the need for a systematic review of recent data to explicate the short- and long-term effects of MC interventions in children and adolescents.

Naturally, no intervention program is infallible, and every approach has its merits and shortcomings; it is therefore necessary to identify and compare the various characteristics of interventions to maximize their effectiveness, while seeking to reduce the financial and time impacts, alongside the labour-related factors (staffing processes, training, etc.). Cost- and time-effective strategies help to redirect resources to conduct more appropriate interventions. With respect to the design of intervention studies, two distinct types of approaches are frequently discussed in the literature: theoretical and atheoretical. Although many studies employ MC interventions that are grounded in theory, a considerable number of MC interventions have been developed from an atheoretical basis, which in the current manuscript will be characterized specifically as those studies that are not based on or concerned with theory, and are also considered as studies in which there is insufficient information in the paper to determine a specific theory. Of the MC intervention approaches which center around an empirical theoretical basis, research would suggest that three of the most frequently cited and prevalent theories in MC interventions include: 1) Dynamic Systems Theory (specifically Newell's Model of Constraints [19], 2) Achievement Goal Theory, 3) and the Social-Cognitive Theory (or socio ecological model)[8, 14, 20-27]. While these three theories have different priority objectives and are not mutually exclusive, their underpinning structures have received some notable attention within MC/motor outcomes related fields, and are described briefly below.

Dynamic Systems Theory examines the behavior of systems whose internal states change over time and the interaction between these systems and exogenous inputs [28]. According to this theory, development is a probabilistic outcome of interactions between several levels and systems [29]. Previously established research by Corbetta [25] on Dynamic Systems Theory reported that this underpinning structure was often dominated by skilled performances and the coordination of limited parts of the body. Given this empirical platform, it is well accepted that there are multiple ways in which a task can be executed, and the popular convergence of constraints on action stems is gaining in prominence through Newell's model (1986) [19, 21]. The recurrent application of Dynamic Systems Theory through Newell's constraints model asserts that by modifying the environmental, task, and individual constraints, it is possible to create conditions that are conducive to motor development in children [30-33]. Also, with this model, researchers can better account for the complexity of age-related change in movement through the interactions of individual, environment, and task. Achievement Goal Theory, on the other hand, describes individuals' learning goals and attributions, as well as the impact of these goals on approaches and participation in learning settings [34]. This theory is based on the idea that children are born with an intrinsic desire to learn and explore their surroundings [23, 34]. An individual's learning goals and attributions, as well as the subsequent impact of these goals, determine how one approaches and engages in learning activities [35-44]. Seminal research from Ames supports that the optimal learning environments can be developed through the encouragement of students adopting a mastery orientation [23]. The work of Epstein has then further identified six learning environmental structures that facilitate children adopting a mastery orientation: namely, task, authority, recognition, grouping, evaluation, and time (TARGET) [22], and this proposed learning environment shifts the responsibility from the teacher to the student in terms of learning engagement. Palmer and colleagues (2017) [45] reported that *'Mastery-oriented learners are driven to learn and develop new skills, try to understand their work, improve their level of competence, and achieve a sense of mastery based on self-referenced standards* (p. 2570).*'* As part of this theoretical framework, Palmer and colleagues (2017) systematically reviewed MC interventions that specifically used Achievement Goal Theory, and the authors reported positive findings for improving motor skills in young children [45, 46]. Finally, while a smaller proportion of MC studies have adopted the Social Cognitive approach [20] to children's motor development, the focus of this theoretical method is on biological (individual) social interactions, experiential, and environmental contexts [47-50]. Specifically, in this model of reciprocal causation, Bandura (1986, 1989) champions action, cognitive, affective, personal factors, and environmental events as operating interacting determinants [20, 51]. To the authors' knowledge, no study to-date has compared the effectiveness of both theoretical and atheoretical studies, which are aimed at promoting MC in children and adolescents. Such information has the potential to help practitioners and researchers in maximizing the impact of MC intervention effectiveness, while minimizing the possible financial, time and labor-related issues.

When considered together, an up-to-date systematic review of the MC intervention literature is warranted. Accordingly, the aim of this current systematic review was to, for the first time, compare both the immediate (i.e., short-term) and retention (i.e., sustainable) effects of theory-based and atheoretical interventions, to determine which intervention approach resulted in the most improvements for motor outcomes. The information generated by this review will provide a more comprehensive understanding of the sustainability of different types of MC interventions in children and adolescents.

## 2 Methods

A systematic search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [52, 53].

### 2.1 Study Eligibility Criteria

The population samples included in the current study comprised of typically developing individuals between the ages of 3 to <18 years of age, from varied socioeconomic backgrounds, with no reported history of learning difficulties, or behavioral, physical, neurological, or orthopedic disorders and/or disabilities.

This systematic review includes both theoretical (namely Dynamic Systems Theory, Achievement Goal-Theory, or Social-cognitive theory) and atheoretical studies that have carried out follow-up (retention) assessments. For the purpose of the current manuscript's context, atheoretical studies are characterized specifically as those studies that are not based on or concerned with theory, and are also considered as studies in which there is insufficient information in the paper to determine a specific theory. Retention refers to the persistence or lack of persistence of the performance, and is considered at the behavioral level rather than at the theoretical level [54]. The following criteria was used for the inclusion of a study in this review: 1) the study must have measured MC performance as an outcome and included pre- or –post intervention assessment, or both, along with follow-ups. However, neither the type of MC battery assessment tool nor the measurement approach was a factor in inclusion or exclusion of a study 2) only articles published in English and in peer-reviewed journals were considered. Books, reviews, theses, dissertations, commentaries, qualitative studies, and case studies were excluded.

### 2.2 Data Sources

Seven databases, PubMed, MEDLINE, SPORTDiscus, CINAHL, Scopus, Web of Science, EMBASE, were searched without any date restrictions, up to November 2021, for articles relating to MC interventions with follow-up assessments in typically developing children and adolescents. The main search group terms were: ("motor competence" OR "motor skill" OR "movement skill" OR "motor development" OR "motor performance" OR "fundamental motor skill" OR "balance" OR "coordination" OR "physical activity" OR "motor ability") AND ("children" OR "adolescent" OR "youth", OR "preschooler") AND ("intervention" OR "program" OR "study" OR "trial") AND ("sustainability" OR "follow-up" OR "long term" OR "retention"). To exclude studies which specifically examined youth participants with disorders/disabilities, the following terms were used: AND NOT “disability” OR “disorder” OR “autism” OR “impairment” OR “cerebral palsy”.

**2.3 Study Selection and Extraction**

After conducting the initial search and removing duplicates, two disciplinary-specific reviewers independently screened the remaining studies' titles and abstracts. Then, full-text articles were coded for inclusion according to the approach "Yes, Maybe and No." Cohen's Kappa statistics were used to calculate the level of agreement between two independent reviewers on title/abstract and full-text screening [55]. Kappa values between .40 and .59 were considered as fair agreement, .60 to .74 as good agreement and greater than .75 was considered as excellent agreement [56]. Authors had excellent agreement with Kappa values of .98 and .82 the titles and abstracts, respectively. A third author was consulted in cases marked "Maybe" in order to resolve the issue and determine whether the article should be included or excluded from the systematic review.

The same two reviewers worked independently to extract data from each included study, including study characteristics (authors, year and country), intervention components (sample characteristics, details of grounded theory (if any), theory operationalization, content of intervention and its continuation after post-test, intervention dosage and intervention deliverer), MC assessment (MC assessed and MC assessment tool) and outcome measures (immediate and follow-up post intervention assessment and adjustment by sex (including analysis of sex differences)). To distinguish theoretical from atheoretical studies, the intervention must be explicitly based on one or more of the theories listed above. Before being used in the screening process, this criterion was discussed and agreed upon among reviewers. Two disciplinary-specific reviewers independently and further screened the introduction and methods of articles and coded articles for inclusion according to the approach "Yes, Maybe, and No." A Kappa value of .78 was obtained for the level of agreement between the reviewers on theoretical/theoretical screening. In instances of “Maybe” and disagreements over the inclusion of a certain study or the data obtained, the matter was resolved through discussion with a third author.

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**2.4 Risk of Bias Assessment**

Risk of bias within the included studies was assessed by two reviewers independently. The criteria for assessing the risk of bias was a 9-item tool, adapted from the Consolidated Standards of Reporting Trials statement [57], and also previously-used quality criteria [58]. The criteria identified as relevant to the current study has been previously reported in another systematic review, within a similar area [16] and specifies the following:

A. Randomization (generation of allocation sequence, allocation concealment and implementation) clearly described and adequately completed.
B. The use of valid measures of MC proficiency (validation in the same age group has been published or validation data were provided by the author).
C. Blinded outcome assessment (positive when those responsible for assessing MC were blinded to the group allocation of individual participants).
D. Participants were analyzed in the group they were initially allocated to, and participants were not excluded from analyses because of non-compliance to treatment or because of missing data.
E. Covariates accounted for in analyses (e.g., baseline score, group/cluster for cluster RCTs, and other relevant covariates when appropriate such as age or sex).
F. Power calculation reported for the primary MC outcome.
G. Presentation of baseline characteristics separately for treatment groups (age + sex + ≥1 MC outcome measure).
H. Dropout for MC measure described
I. Summary results for each group + estimated effect size (difference between groups) + its precision (e.g., 95% Confidence Interval).

Each item on the scale was evaluated as “explicitly described and present” (✓), “absent” (x) or “unclear or inadequately described” (?).

# 3 Results

## 3.1 Overview of Studies

The flow of studies through the screening process and the reasons for exclusion are displayed in Figure 1. The electronic search identified 7,626, potentially relevant articles. Following screening and detailed assessment, thirty two studies were deemed suitable for final review and assessment.

### 3.2 Study Characteristics

All of the thirty two studies identified (Fig. 1) were published between 1998 and 2021. The authors extracted the data from the studies, and these data were confirmed by one of the authors. Tables I and II summarize study characteristics (authors, year and country), intervention components (sample characteristics, details of theory (if any), theory operationalization, content of intervention and its continuation after post-test, intervention dosage and intervention deliverer), MC assessment (MC assessed and MC assessment tool) and outcome measures (immediate and follow-up post intervention assessment and adjustment by sex (including analysis of sex differences)) for theoretical and atheoretical studies, respectively.

#### 3.2.1 Publication Year

Among the thirty two selected studies, five were published in 2017 [38, 39, 50, 59, 60], four in 2011 [33, 35, 40, 61], three in 2013 [32, 62, 63], two in 2021 [64, 65], 2020 [66, 67], 2015 [49, 68], 2012 [37, 69], and 2009 [42, 70]; one study was further published in each of the years 2019 [31], 2018 [48], 2016 [30] , 2010 [71], 2008 [47], 2007 [36], 2006 [72], 2004 [41], 2003 [73] and 1998 [74].

#### 3.2.2 Publication Country

Eight studies were conducted in the USA (8 out of 32) [30, 38-40, 42, 60, 66, 71], seven studies were conducted in Australia [32, 35, 36, 47, 69, 70, 73], three in Finland [33, 37, 49] and Ireland [48, 64, 74], two in Belgium [62, 65], Brazil [31, 41], Germany [61, 68], and the UK [50, 67]; while Canada [59], Slovenia [63], and Scotland [72] feature one study apiece.

#### 3.2.3 Participants' Demographics in Publications

The included studies reflected a range of participant ages within the preschool, primary and secondary school age groups (3 to 16 years old). The majority of interventions (20 out of 32) were administered among pre-school children [30-33, 38-42, 49, 50, 59, 60, 62, 66, 68, 69, 71, 72, 74], eight in primary/elementary school-aged children [35, 36, 47, 63, 64, 67, 70, 73], one in both pre-school and primary/elementary school-aged children [65], and only three in adolescents [37, 48, 61].

Three studies were community-based interventions, with two targeting overweight/obese children [35, 36], and one targeting at-risk children for motor impairment [60]. Among the studies that have been reviewed, one study included girls only [39], two studies did not specify the sex distribution of participants [48, 59], and the remaining were co-educational. Of the thirty two studies, seven administered interventions with participants from low socio-economic backgrounds [30-32, 39, 47, 50, 60] and one research targeted children from a middle-class socio-economic background [67]. Two studies included motor-developmentally at-risk children [60, 62], and one study included developmentally delayed children [41]. Two studies targeted overweight/obese children [35, 36]. The remaining studies did not describe the status of the participants. The sample sizes for the studies ranged from 11 [59] to 1045 [70, 73].

…………………….……………………INSERT TABLE I & II HERE…………...……………………..

### 3.3 Risk of Bias within Studies

**Table III** displays the risk of bias assessments for all studies. In twenty eight studies, participants were analyzed in their allocated group and were not excluded because of missing data or noncompliance and this was the most commonly reported item across the studies [30-33, 35-42, 47-50, 59-63, 67-69, 72, 74]. Twenty four of the thirty two studies used measures of MC that had published validity [30-33, 35-42, 47-50, 59, 60, 62, 64-66, 71, 72]. The randomization procedure, including sequence generation, allocation concealment, and implementation, was adequately described in only eight studies [31, 35, 39, 48, 50, 64, 68, 72]. Only four of the studies reported a power calculation for MC outcomes [48, 61, 64, 72].

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### 3.4 MC Intervention Characteristics

#### *3.4.1 Theoretical Frameworks*

Of the thirty-two included studies, seventeen utilized theory-based intervention approaches. The majority of studies were grounded in Achievement Goal Theory (10 of 19 studies) [35-41, 49, 64, 75], with one study combining both the Achievement Goal Theory and Dynamic Systems Theory [38]. Six studies were based on the Dynamic Systems Theory [30-33, 38]. Three studies applied Social-Cognitive Theory (or socio ecological model) [47-50], with one study using the combined theoretical frameworks of Social Cognitive Theory and the Theory of Planned Behavior [49]. Moreover, fifteen studies utilized atheoretically-derived interventions [59-63, 65-74].

### *3.4.2 Intervention Components*

Thirteen of the included thirty-two theoretical and atheoretical interventions compared a MC focused curriculum, with a traditional [32, 33, 64, 68, 69] or free play curriculum focus [30, 38, 39, 41, 42, 66, 71, 74], whereas some interventions supplemented the existing physical education (PE) curricula with an extra MC intervention, and compared these to the traditional PE curricula only [31, 47, 61-63, 67, 70, 73]. None of the included seventeen theoretical interventions continued their intervention implementation after post-test.

In addition to a focus on MC development in children and adolescents, some interventions either provided support/training for staff/parents [37, 48-50, 72] or focused on the diet of youth [35, 36, 60] within culturally appropriate curriculum structures and compared these interventions against the regular curricula alone.

The majority of interventions were delivered in preschool settings (17 of 32 studies) [30-33, 38-42, 50, 59, 60, 62, 66, 69, 71, 74], with one conducted after school [71]. Two studies targeted both preschool- and home-based [68, 72] environments, and only one study was family-based [49]. Eight interventions were administered in primary school settings [35, 36, 47, 63, 64, 67, 70, 73], with two conducted after school [35, 36]. Three interventions were conducted in secondary schools [37, 48, 61].

Nearly all studies provided a clear description of MC intervention dosage (frequency and duration), with the exception of four studies [49, 61, 70, 73]. Some of the interventions allocated weekly frequency and duration doses; however, the total amount of time allocated to the specific interventions was not specified [32, 48, 63, 65, 68, 72, 74]. The duration of the interventions varied from 4 weeks to 4 years, amounting to between 300 and 2160 minutes of MC-related intervention delivery. Most (twenty two) interventions were delivered by trained staff: six by trained PE teachers [35-37, 48, 62, 66], eight by trained PE/motor development specialists [38, 39, 41, 42, 47, 61, 63, 71], and eight by trained non-PE staff [31, 50, 64, 65, 68, 69, 72, 73].

There were nineteen quasi experimental studies [30, 33, 36, 37, 40-42, 59-63, 65, 66, 69-71, 73, 74]. Twelve intervention studies were conducted with randomized controlled trials (RCTs) designs [31, 32, 35, 38, 39, 47-50, 67, 68, 72], with eight cluster RCTs [31, 36, 47-50, 68, 72] and one repeated measure design [67]. Also, one study had a longitudinal cluster cross over design [64].

### *3.4.3 Measurement of MC*

From the included thirty-two theoretical and atheoretical interventions, many studies used a wide range and combination of measures to assess MC. The Test of Gross Motor Development (TGMD or TGMD-2 or both or TGMD-3) was the most commonly used assessment tool of MC (16 of 32 studies) [30, 35, 36, 38-42, 48, 50, 62, 64-67, 69]. Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) [31, 32, 60], Get Skilled/Get Active [70, 73], and the Movement Assessment Battery for Children-2 (MABC-2) [31, 72] were used only in a few studies. Only 4 studies measured MC with more than one MC assessment tool [31, 48, 49, 67].

Most of the studies included both immediate and follow-up post-intervention assessments; only three studies did not include an immediate post-intervention assessment, but did include follow-up assessments [62, 66, 70]. The retention period (time period between immediate and follow-up assessments) varied among studies and ranged from 2 weeks to 7 years. This period was less than 6 months in 15 studies [30, 33, 38-40, 42, 48, 59, 61, 62, 66-68, 71, 74], with nine studies reporting less than 10 weeks retention-periods [30, 38-40, 42, 59, 61, 62, 66] and seven studies reporting between 10 to 16 weeks retention-periods [33, 48, 64, 67, 68, 71, 74]. Nine studies had 6-12 months retention-periods [31, 32, 35-37, 41, 47, 50, 72], with seven studies having a 6 months retention-period [35, 37, 41, 47, 49, 50, 72], one study having a 9-month retention-period [36], and two studies reporting a 12-month retention-period [32, 47]. Only six of thirty two studies had a retention-period with a duration of 12 months or more; specifically one study had a 18-month-retention time frame [60], one study had a 3-year-retention time frame [69], two studies had a 6-year retention time frame [65, 70, 73] and one study had a 7-year-retention time frame [63].

## 3.5 Evidence for MC Outcomes

### 3.5.1 Theory-based Interventions

*Immediate (baseline to post-intervention) intervention effects*

Of the seventeen identified theory-based interventions, results observed that fourteen of the studies reported statistically significant immediate intervention effects for ≥1 item of MC [30, 31, 33, 35-42, 48, 49, 64]. The Iivonen et al., (2011) study observed specific intervention effects by gender on individual MC skills (dynamic balance, standing broad jump, running speed) at the immediate completion of the intervention program [33]. Conversely, Valentini & Rudisill (2004b) found specific intervention effects for overall MC subsets (object control, locomotor skills) at the immediate completion of the intervention program [41].

Results observed that only three of the seventeen studies did not report any statistically significant immediate intervention effects for ≥1 item of MC [32, 47, 50]. Of these three studies, Foulkes et al., (2017) did observe some small (while not statistically significant), and potentially meaningful immediate intervention effects for elements of MC competence in their adjusted statistical modeling [50].

*Retention (follow-up) intervention effects*

Of the seventeen identified theory-based interventions, results observed that fourteen of the studies [30-33, 36-42, 48, 49, 64] reported statistically significant retention intervention effects for ≥1 item of MC. Cliff et al., (2007) study did observe specific intervention effects at 9-months follow-up for overall gross motor quotient, however, this study did not include a comparative control group assessment [36]. Interestingly, De Oliveira et al., (2019) found specific intervention effects for gender at 18-months follow-up, however, these positive findings were observed for specific MC items only (one-leg balance, catching, throwing) [31]. Similarly, Iivonen et al., (2011) found specific intervention effects for gender at 3-months follow-up, and these positive findings were again observed for specific MC items only (running speed etc.) [33].

Of the seventeen identified theory-based interventions, results observed that three of the studies [35, 47, 50] did not report any statistically significant follow-up intervention effects for ≥1 item of MC. Within these three studies, the retention period ranged from 6-month [50] to 12-month [35, 47] follow-up.

Finally, of the seventeen identified theory-based interventions, five of the studies had a retention duration period of ≥12 months [31, 32, 35, 47, 64]. Piek et al., (2013) had a follow-up time period of 18-months from the initial pre-test data collection, and the authors observed pre-test to retention MC intervention effects only [32]. These MC intervention effects were not observed between the 12-month time period between post-testing and retention follow-up [32].

### 3.5.2 Atheoretically-derived Interventions

***Immediate (baseline to post-intervention) intervention effects***

Of the fifteen identified atheoretically-derived interventions, results observed that eleven of the studies [59-61, 63, 65, 67-69, 71-73] reported statistically significant immediate intervention effects for ≥1 item of MC. The Bedard et al., (2017) study did observe specific immediate intervention effects for overall gross motor subtests, however, this study did not include a comparative control group assessment [59]. Duncan et al., (2020) study observed specific intervention effects for both age and individual MC skills (standing long jump, 10-meter sprint speed) [67], while van Beurden et al., (2003) observed specific intervention effects for both gender and individual MC skills (sprint run, side gallop, kick, throw, jump, catch and hop) upon the immediate completion of their respective intervention programs [73]. Conversely, both Jurak et al., (2013) and Roth et al., (2015) found specific intervention effects for individual MC skills only, at the immediate completion of their intervention programs [63, 68].

Of the fifteen identified atheoretically-derived interventions, results observed that only one study [74] did not report any statistically significant immediate intervention effects for ≥1 item of MC. In their study, Smyth and O'Keeffe (1998) observed that both the intervention (physical activity and MC focus) and control groups (free play only) similarly improved in their MC throwing proficiency after 4 weeks, following the initial baseline assessment [74]. Finally, of the fifteen identified theory-based intervention studies, three [62, 66, 70] did not include immediate intervention effects.

***Retention (follow-up) intervention effects***

Of the fifteen identified atheoretically-derived interventions, results observed that eleven of the studies [61, 62, 66-74] reported statistically significant retention intervention effects for ≥1 item of MC. Barnett et al., (2009) study did observe specific retention intervention effects for MC at 6-year follow-up, when compared to the control group comparison for individual MC skills (catch, side gallop, vertical jump) [70]. Similarly, at 6-year follow-up, Van Beurden et al., (2003) observed specific retention intervention effects for individual MC skills [73], while Roth et al., (2015) also observed intervention effects for individual MC skills, however, their retention follow-up period was between 2- to 4- month approximately [68]. Duncan et al., (2020) study again observed specific 10-week retention intervention effects for both age and particular MC skills (standing long jump, 10-metre sprint speed) [67], whereas Zask et al., (2012) at 3-year follow-up observed specific gender-based intervention effects in the MC subsets of locomotion and object-manipulation [69]. Mulvey et al., (2020) study did observe specific retention intervention effects for MC, however, this follow-up assessment period was completed at 2-weeks [66].

Of the fifteen identified atheoretically-derived interventions, results observed that four of the studies [59, 60, 63, 65] did not report any statistically significant follow-up intervention effects for ≥1 item of MC. Within these 3 studies, the retention period ranged from 5-week [59] to 6-7-year [63, 65] follow-up.

Finally, six of the fifteen studies [60, 63, 65, 69, 70, 73] had a retention duration period of ≥12 months. Jurak et al., (2013) had a follow-up time period of 7-year from the initial pre-test data collection, however, the authors did not observe pre-test to retention MC intervention effects. Specifically, the authors observed that the originally identified immediate intervention effects observed in some of the motor skills were no longer present at the 7-year follow-up assessment phase (e.g. polygon backwards, sit-ups, 600-metre run task) [63].

## 4 Discussion

The current study sought to compare both the immediate and retention effects of theory-based and atheoretical interventions, to determine which intervention approach resulted in the most improvements for motor outcomes. It fills a critical gap in the literature by assessing the relative merits of theoretically- as well as atheoretically-derived MC intervention programs. In accordance with the aforementioned aims, seventeen theoretical and fifteen atheoretical studies were reviewed as part of this study's focus. The primary finding from this review was that both theoretically- and atheoretically-derived interventions can elicit increases in MC in children and adolescents.

*Theory-based interventions*

As detailed in Table I, Altunsoz et al, De Oliveira et al, Iivonen et al, Piek et al, and Robinson et al, respectively, all developed and employed interventions based on the Dynamic Systems Theory [30-33, 38]. Only two of these studies reported positive results immediately after the intervention, when compared to the control groups [30, 31]; however, three studies reported sustained results in the intervention group, with the intervention group achieving higher MC scores than the control group at retention follow-up. An additional approach to intervention design is the Achievement Goal Theory, in which the emphasis is on designing the environment in such a way that it elicits a mastery-oriented attitude to learning and a degree of relative autonomy through MC tasks. Typically, studies that utilize this approach are child-centered, meaning that many parameters such as task type, level of difficulty and equipment are selected in accordance with the children's desires and goals [43, 75, 76]. Indeed, in the present study, eight studies commenced their interventions in alignment with the Achievement Goal Theory [35, 36, 38-42, 77], and in all eight studies, beneficial outcomes, when compared to control groups were reported at post-intervention and retention. In a previous systematic review, Palmer et al concluded that motor skill interventions grounded in the Achievement Goal Theory are effective for improving motor skills in young children [45]. This research was consistent with current study findings, irrespective of the intervention groups, duration, dosage, and the personnel responsible for implementing the intervention. Indeed, it has been asserted that adopting a mastery-motivational climate (i.e., the psychological environment that the researcher creates by designing sessions which provide instructions and feedback that will help to motivate the children and adolescents in training), is strongly associated with positive educational and achievement-based MC outcomes [34, 78]. Thus, it appears that by encouraging the adoption of a mastery-motivational climate, where children are encouraged to engage in tasks for the intrinsic value of learning, improvements in MC can be made, both in short, and longer-term assessments.

In the present review, relatively fewer studies adopted the Social Cognitive Theory approach (or socio ecological model) to children's MC; Foulkes et al, Laukkanen et al, McGrane et al, and Salmon et al developed interventions in this regard [47-50]. The Social-Cognitive Theory may be regarded, essentially, as the process of learning through observation and imitation [79]. Only in McGrane et al, however, were beneficial outcomes at post-intervention and follow-up periods reported [48]. Indeed, adherence to this type of theoretical intervention is contingent on the program possessing enough emotional appeal to motivate the participant to pay attention. Moreover, participants must also be alert and interested enough to apportion attentional capacity to observing the intervention. Subsequent to this, further motivation to arrange and cognitively remember the information in the retention and motor reproduction processes to practice the observed behavior must present. Indeed, if perceived rewards outweigh the perceived costs, then the behavior is more likely to be imitated, whilst, if the vicarious reinforcement is not regarded as important, behavior imitation will not occur [80].

*Atheoretical interventions*

In the present systematic review, fifteen studies of atheoretical intervention design, were included, and, in general, included an aerobic exercise component, in addition to varying amounts of resistance or strength-based activities. Indeed, previous systematic reviews and meta-analyses have documented that the addition of physical activities, whatever they may encompass, generally result in positive effects on the MC of children and adolescents [15, 16, 81]. These findings may indicate that the theoretical basis for MC interventions is not important, but rather the volume of the additional physical activity. Such a conclusion, however, is not necessarily supported in the present study, where some of the interventions highlighted no differences between those that followed prescribed programs and those that did not. This is an important observation as it indicates that, in order to firstly improve MC and then to sustain MC, an additional component, beyond the presence of an intervention is required.

*Theoretical vs. Atheoretical interventions*

According to the findings in this review, there is no clear distinction between theoretical or atheoretical MC interventions. In the identified studies using Achievement Goal Theory, success has largely been achieved where a mastery motivational climate is created. In such situations, the mastery motivational climate places emphasis on self-referenced improvement, exerting effort and striving for mastery [23].

Theory-based interventions overwhelmingly utilized the TGMD (including its variants) to assess MC (11 out of 17); the remaining studies utilized the BOT-2 (2 studies), the adapted APM inventory (manual test booklet for assessing preschool children's perceptual and fundamental motor skills), the KTK, and the Victorian Fundamental Movement Skills Manual. Whilst for the atheoretical interventions, of the fifteen studies; four used the TGMD, two used the Get Skilled Get Active assessment, and the remaining studies evaluated MC using different tests (including; BOT-2, PDMS-2, SLOfit, Fitnessgram, MABC-2, segmental analysis, study specific). Clearly, this wide array of tests, and subsets of tests, makes quantitative comparisons difficult and highlights the need for a uniformed approach to the assessment of MC in children and adolescents. Such an array of testing batteries may impede a clear conclusion between different studies being made. Indeed, in some studies, the authors employed testing batteries that assessed both fine and gross motor skills, yet the authors presented composite or combined scores only, in comparison to other studies who operated their scoring criteria in contrast to the accepted and published manufacturer guidelines. Furthermore, in some cases [77], fitness-style testing (e.g. shuttle run test) was used to represent MC, in addition to balances tests (e.g. Flamingo Standing Test, force-plate and balance platform). A further consideration is that, as highlighted in Holfelder and Schott (2014), in testing batteries such as the KTK or BOTMP, motor abilities and MC are summarized or expressed as a quotient, thereby making comprehension of their meaning and efficacy on MC, difficult [82]. However, despite methodological variances, it is evident that that an additional component (such as individual's personality, motivation …), beyond the presence of an intervention only is required to elicit improvements in MC in children. This is supported, in the present study, by the overwhelming success of interventions ground in the Achievement Goal Theory, when compared with the intermittent success of other theory-based and/or atheoretically-derived interventions.

**Strengths and Limitations**

The present study represents a novel addition to the literature by examining how the effectiveness of theory-based and atheoretical MC interventions for children and adolescents differ. Moreover, the research team highlight that both approaches appear to be effective in improving MC in children and adolescents.

It is important to note that hypothesis driven theoretically based interventions are a key stone of scientific process and method, however, there remains a considerable number of studies using atheoretical approaches. While the effect of such approaches appears to be no different from those using theoretical based designs in terms of MC, a key strength of the current work is the identification of different studies that have used theory based, or atheoretically-derived interventions. Such an approach allows scientists, researchers, educationalists to extend their understanding and make informed decisions in regard to future intervention design.

Despite the strength and novelty of this work, there are some limitations that warrant future consideration. Clearly, a quantitative analysis would have been desirable, however, the range and variation in theory, type, modality, age, and assessment tools used in the included studies precluded the ability to conduct such an analysis, and, indeed, individually represent potential limitations.

## 5 Conclusion

The current study evaluated theoretical and atheoretical MC interventions. The results of this systematic review, with the specific inclusion of follow-up MC intervention studies, suggests that the success of both theory-based and atheoretically-derived interventions seems variable. Thus, when designing interventions for the improvement or management of MC in children and adolescents, key stakeholders must consider the wider benefits, drawbacks, and types of theory-based and atheoretically designed interventions. While it may seem sensible to anchor MC interventions through a sound theoretical basis to increase successful motor outcomes in children and adolescents, further financial and time resources may be required. Further longitudinal MC intervention evidence is indeed warranted before determining such findings.

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**Table I. Characteristics of theory-based intervention studies**

| Study | Sample (number, SES, age[year]) | Intervention Components | | | | | | MC assessment | | Post-intervention Tests | | Adjustments/effects by sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Theory (Type & Operationalization) | Content of intervention (condition for the control if applicable)<br><br>Continuation of intervention after post-test (Yes/NO) | Frequency | Length | Provider | Design (setting) | MC assessed | MC assessment tool | Immediate | Follow-up (retention period: posttest to follow-up) | |
| Altunsöz & Goodway (2016, USA)[30] | Children (72, 50% girls; low SES) 3-5 y | DST<br><br>Task & environment constraints manipulation | INT1: SKIP<br><br>INT2: SKIP + SKIP-PI (parents were trained to work with their child at home on simple motor skill activities)<br><br>CON: regular Head Start curriculum (free play- no feedback and no instruction)<br><br>NO | INT1: 30 min x 3 days/w regular program plus 30 min x 2 days/w SKIP<br><br>INT2: 30 min x 3 days/w regular program plus 30 min x 2 days/w SKIP plus 10-15 min x 24 session over 8 w- SKIP-PI | Int1: 8w (480 min)<br><br>Int2: 8w (720-840 min) | INT: researchers<br><br>CON: pre-school teacher (trained) | QE (PreS) | FMS (OCS) | TGMD-2 | INT1 > CON (p=.00); INT2 >CON (p=.00); INT1~INT2 (p=.93). INT1 & INT2 improved from pre to posttest. CON did not significantly improved. | 4 w.<br>INT1 > CON (p=.00); INT2>CON (p=.01); INT1~INT2 (p=.16). INT 1 & INT2 did not change from post to follow-up. | No significant difference between groups from pre to posttest and from posttest to follow-up. |
| Cliff et al (2007, AU)[36] | Children (13, 64% girls, OW/OB) 8-12 y | AGT<br><br>TARGET | INT: 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.<br><br>NO | 120 min x 1 day/w | 10 w (1200 min) | INT: researcher (PE qualified) | QE (After-PriS-COM) | FMS (OCS & LS) | TGMD-2 | INT significantly improved in GMQ (P < .001). . | 9 m.<br>GMQ remained significantly higher (p= .019) | Not reported |
| Cliff et al (2011, AU)[35] | Children (165, 59% girls, 78% obese) 8-12 y | AGT<br><br>TARGET | INT1: Physical activity skill development program (PA).<br><br>INT 2: Dietary modification program (DIET).<br><br>INT 3: Combined physical activity and dietary modification program (PA+DIET).<br><br>NO | 90 min x 1 day/w | 6 m (900 min) | INT1: researcher (PE qualified)<br><br>INT3: researcher (PE qualified) | RCT (After-PriS-COM) | FMS (OCS & LS) | TGMD-2 | INT 1 and INT 3 > INT 2 for LS (p <.01), OCS (p < .01), and GMQ (p < .001). | 12 m (pretest to posttest)<br>6 m (posttest to follow-up)<br><br>There were no significant between group differences for LS, OCS or GMQ. | No significant sex interaction effects in models was found. |
| De Oliveira et al (2019, BR)[31] | Children (511, 49.7% girls, low SES) 4-6 y | DST<br><br>Task & environment constraints manipulation | INT: Animal Fund Program embedded in normal curriculum; Activities are grouped into nine modules, the | 30 min x 4 day/w | 10 w (890 min Ave-Range: 450 min-1500 min) | INT: classroom teacher (trained)<br><br>CON: classroom teacher | Cluster RCT (PreS) | Balance, catching, throwing, jumping | MABC-2; BOT-2 SF | One-leg balance: there was an intervention effect (p=.048); there was a significant pre-post increase in one leg balance scores for both the intervention group (p < | 18 m (pretest to follow-up)<br>12 m (posttest to follow-up) | Balance:<br>The Group x Time interaction did not interact with sex (p = .552). |

| | | | | | | | | | | | | |
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| | | | first four involve gross motor development, the second four focus on fine motor development and last module targets socioemotional development.<br><br>CON: normal curriculum<br><br>NO | | | | | | | .001) and the control group (p < .001).<br><br>Catching: there was an intervention effect (p=.009); there was a significant increases in catching scores from pretest to post-test, (p < .001).<br><br>Throwing: INT & CON (p=.964) had comparable throwing at each of the three assessments; significant increase in throwing bean bag onto mat skills scores from pre-test to post-test (p = .001). | One-leg balance: There was no significant change in one leg balance scores from post-test to follow-up for either INT (p = .114) or the CON (p = .619). There was a significant increase for INT (p < .001) but not for CON (p = .200).<br><br>Catching: significant increases in catching scores from pretest to follow up, and post-test to follow up for both INT & CON (p < .001). The post-test to follow up increase was significantly greater for CON.<br><br>Throwing: INT~CON, significant increase in throwing bean bag onto mat skills scores from post-test to follow-up (p = .005), and from pre-test to follow-up (p < .001). | Catching: Group x Time did not interact with sex (p = .069).<br><br>Throwing:<br>In INT, the pattern of significant increases across time were comparable for boys (p < .001) and females (p < .001) with significant increases at posttest and follow-up.<br><br>In CON, from pre to posttest there was a significant pre-post increases in boys (p = .012) and the girls (p < .001),<br>From posttest to follow-up, only the females showed a significant increase (girls: p < .001; boys: p = .930) and from pre-test to follow-up (girls: p < .001; boys: p = .106). |
| Foulkes et al. (2017, UK)[50] | Children (162, 46.9% girls, low SES)<br>3-5 y | SCT<br><br>Social environment manipulation | INT: Active Play with support. Intervention was structured around the provision of staff development opportunities and on-going support for preschool educators.<br><br>CON: Active Play without support, active paly program, however, no professional development, session delivery, or post program support were provided + existing physical activity curriculum.<br><br>NO | 60 min x 1 day/w | 6 w (360 min) | INT: practitioner (trained)<br><br>CON: PE teacher | Cluster RCT (PreS) | FMS (OCS & LS) | TGMD-2 | No significant intervention effects on total, OCS, or LS scores between pretest and posttest.<br><br>Small, potentially practically meaningful, positive intervention effects were noted for total (p < .11) and OCS (p < .11) scores in the adjusted model between pretest and posttest. | 6 m.<br>No significant intervention effects on total, object-control, or locomotor scores between baseline and follow-up. In the adjusted model, positive effect had diminished at follow-up. | Between pretest and posttest, a significant<br>interaction (p < .09) was observed for LS score in the crude analysis, but<br>this was attenuated after adjusting for covariates.<br>No other significant sex interactions were observed. |
| Iivonen et al (2011, FI)[33] | Children (83, 45.2% girls)<br>4-5 y | DST<br><br>?? | INT: physical education lessons according to the Physical Education Curriculum (PEC) of the Early Steps Project.<br><br>CON: unstructured physical education. | 45 min x 2 days/w | 8 m (2160 min) | INT: pre-school teacher<br><br>CON: pre-school teacher | QE (PreS) | Static & dynamic balance, running, standing broad jump, and sum variable of three different | Adapted APM Inventory (OCS) | Girls:<br>Dynamic balance: INT~CON (p=.596) & Running speed: INT~CON (p=.248), Sum variable of manipulative skills: INT~CON (p=.904), there were no significant difference between measurement 2 to 3 for three skills.<br>Standing board-jump: | 3 m.<br>Girls:<br>Dynamic balance: INT~CON (p=.596),<br>Standing board-jump: INT~CON (p=.220),<br>Sum variable of manipulative skills: INT~CON (p=.904), there was no significant | Reported for boys and girls separately |

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| | | | NO | | | | | manipulative skills (throwing catching combination, throwing kicking) | | INT~CON (p=.220), there was significant improvement from measurement 2 to 3.<br><br>Boys:<br>Dynamic balance:<br>INT ~ CON (p=.944), Standing board-jump: INT ~ CON (p=.314), Sum variable of manipulative skills:<br>INT~CON (p=.372), there was no significant difference between measurement 2 and 3.<br>Running speed:<br>Only INT improved from measurement 2 to measurement 3. | improvement between measurement 3 and 4 for all three motor skills.<br>Running speed:<br>INT~CON (p=.248), there was significant difference between measurement 3 and 4 (p<.001).<br><br>There was not a significant improvement between measurement 3 and 4.<br><br>Boy:<br>Dynamic balance:<br>INT ~ CON (p=.944), Standing board-jump:<br>INT ~ CON (p=.314), Sum variable of manipulative skills:<br>INT~CON (p=.372), there were no significant difference between measurement 3 and 4.<br>Running speed: There was significant improvement from measurement 3 to 4. | |
| Kalaja et al (2012, FI)[37] | Adolescents (46, 51.6% girls)<br>~13 y, 7 grade | AGT<br><br>TARGET | INT: intervention included FMS training sessions focusing on developing 1dimension of FMS (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).<br><br>CON: regular PE classes<br><br><br>NO | 25 min x ?? days/w | 33 w (825 min) | INT: PE teacher<br><br>CON: PE teacher | QE (SecS) | Balance, rolling, leaping, running, roping, throwing, dribbling | Flamingo standing test,<br>rolling test,<br>leaping test,<br>shuttle run test,<br>rope<br>jumping test,<br>accuracy<br>throwing test,<br>figure-8<br>dribbling test | INT > CON for flamingo standing test (P = .001),<br>INT > CON for rolling test (P = .000), INT > CON for balance skill sum score<br>(P = .000), INT > CON for movement skills sum score (P = .000). | 6 m<br>INT > CON for flamingo<br>standing test<br>(P = .046), INT > CON for balance skill sum score (P = .014). | Not reported |
| Kelly et al. (2021, IR)[64] | Children (255, 50% girls)<br>6-8 y | AGT<br><br>TARGET | INT: Each lesson started with a warm-up, which also included a quick discussion on the skills being targeted in the session (10 min), two or three separate | 45 min x 2 days/w | 8 w (720 min) | INT: an instructor with specialist FMS knowledge<br><br>CON: class teacher | Longitudinal cluster crossover design (PriS) | FMS: LS & OC | TGMD-3 | Significant group × time interaction effects for locomotor, ball skills and total FMS scores (all p < .001) following engagement in the FMS intervention. | 13 m<br><br>Significant improvements for locomotor, ball skills and total FMS scores were reported for both | No significant group x time x gender or group x time x weight status interaction effects were reported (all p > 0.05). |

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| | | | games/activities (30 min) and a cool-down which also incorporated some questioning and discussion on the skills just practiced (5 min). Intervention sessions were delivered using the principles of the TARGET acronym (i.e. task, authority, recognition, grouping, evaluation and time) to facilitate a mastery-motivational climate<br><br>CON: Usual PE<br><br>NO | | | | | | | No significant changes were observed following engagement in the control condition | groups at follow-up compared to baseline (all p < 0.001). | |
| Laukkanen et al (2015, FI)[49] | Children (91, 52.7% girls) 4-7 y | SCT & TPB<br><br>Behavioral change based on several counseling processes | INT: Tailored counseling to support parents in changing behavior to increase PA in their children. The behavior change techniques used in this study were based on nine items conducted in one or several parts of the counseling process: 1) a lecture, 2) individual face-to-face counseling and goal setting, and 3) counseling by phone<br><br>CON: ??<br><br>NO | ?? | 6 m (??) | INT: researchers<br><br>CON:?? | Cluster RCT (F) | Coordination, throwing and catching ball (TCB) | KTK and APM inventory | KTK: INT~ CON<br><br>TCB:<br>INT>CON (p = .051). | 6 m.<br>KTK: INT~CON<br><br>TBC:<br>INT~CON (p=.984)<br><br>Mean score of KTK (p<.001) and TBC (p<.001) improved in INT group from pretest to follow-up. | Boys ~Girls in development of KTK and TCB. |
| McGrane et al. (2018, IR)[48] | Adolescent (482, ??% girls) 12-13 y | SCT<br><br>Individual & social (teacher and site) environment manipulation | INT: Youth-Physical Activity Towards Health (Y-PATH) program: The Y-PATH intervention is a multi-component school-based intervention which consists of four components; 1) The student component: specific focus on health related activity and FMS in PE, 2) Parent/guardian component: parents and guardians are educated about the health benefit of PA, 3) Teacher component: all school staff participate in two workshops with the main objective to promote PA participation among staffs and students | 70 min x 1 day/w | 8 m (??) | INT: PE teacher (trained)<br><br>CON: PE teacher | Cluster RCT (SecS) | FMS: LS & OCS& skipping, vertical jumping, balance | TGMD, TGMD-2, VFMS manual | INT improved in total OC (p=.002) and in total LS (p<.0001), but did not improve in total FMS.<br><br>CON improved in total OC (p=.01), total FMS (p<.0001) and total LS (p=.04). | 3 m.<br>INT improved in total OC (p<.0001), total LS (p<.0001) and total FMS (p=.04).<br><br>CON improved in total OC (p=.06), total FMS (p<.0001) and total LS (p=.001). | The effects of the intervention were significant and positive for all children in the Intervention group regardless of gender (p=.03 to <.0001). |

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| | | | during school time, and 4) The website component: resources are made available online.<br><br>CON: regular PE lessons<br><br>NO | | | | | | | | | |
| Piek et al (2013, AU)[32] | Children (335, 49.7% girls; low SES) 4-6 y | DST<br><br>Task & environment constraints manipulation | INT: lessons including different modules of the Animal Fun Program (body management, locomotion, object control, etc.)<br><br>CON: regular curriculum<br><br>NO | 30 min x 4 days/w | 6 m (??) | INT: pre-school teacher (trained)<br><br>CON: pre-school teacher | RCT (PreS) | Gross & fine motor skills | BOT-2 SF (total score) | INT~CON;<br>Pre to posttest were not significant for CON (p=.291) and INT (p=.077). | 18 m (pretest to follow-up)<br>12 m (posttest to follow-up)<br><br>INT ~ CON; Posttest to follow-up were not significant for CON (p=.692) and INT (p=.080).<br><br>INT>CON; Pretest to follow-up was not significant for CON (p=.435), it was significant for INT (p=.001) | Girls ~Boys; Pre to posttest comparisons and the post-follow-up comparisons were not significant for girls (p = .735, p = .612) or boys (p = .981, p = .08).<br><br>Boys > Girls; The pre-follow-up comparison for the girls was also non-significant (p = .833), it was significant for boys (p=.047) |
| Robinson & Goodway (2009, USA)[42] | Children (117, 46.1% girls; at-risk) 46.7 to 48.3 m | AGT<br><br>TARGET | INT 1: low autonomy (teacher centered)- direct instruction<br><br>INT 2: mastery motivational climate (student-centered).<br><br>INT 1&2: Each session consists of 2-3 min warm-up, followed by 24 min of motor skill instruction and 2-3 min closure activity.<br><br>CON: Control (no instruction)- Regularly scheduled free play<br><br>NO | 30 min x 2 days/w | 9 w (540 min) | INT: researcher + doctoral student in motor development<br><br>CON: pre-school teacher | QE (PreS) | FMS (OC) | TGMD-2 | Between group difference: INT1~ INT 2 (p=.60) in OC scores. INT1&2>CON (p=.001) in OC scores.<br><br>Within group difference: INT 1&2 improved from pre to post test (p=.001), CON did not changed significantly from pre to posttest (p=.90). | 9w.<br>Between group difference:<br>INT1~INT 2 (p=.42) in OC scores.<br>INT 1& INT2 > CON in OC scores (P = .001).<br><br>Within-group difference:<br>In INT 1&2 OC scores decreased significantly from posttest to follow-up (p=.001).<br>In CON, there no significant change from posttest to follow-up (p=.90).<br><br>Both INT1 & 2 improved in OC scores from pretest to follow-up (P=.001). | Not reported |
| Robinson et al. (2011, USA)[40] | Children (40, 40% girls) 52.48 m | AGT<br><br>TARGET | INT: Instruction for the movement program was based on a developmental approach, with reflection on participants' current developmental level, and a content analysis was used to establish task progressions for each lesson. Each lesson used TARGET | 30 min x 2 days/w | 9 w (432 min) | INT: ??<br><br>CON: ?? | QE (PreS) | FMS (OS) | TGMD-2 | INT>CON (p<.001) | 18 w (pretest to follow-up)<br>9 w (posttest to follow-up)<br>Pretest to follow-up: INT>CON (p<.001)<br>Posttest to follow-up: INT>CON (p<.001) | Not reported |

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| | | | (task, authority, recognition, grouping, evaluation, time) structure.<br><br>NO | | | | | | | | | |
| Robinson et al. (2017, USA)[38] | Children (124, 46.7% girls) 48.14 m | AGT<br><br>TARGET | INT: Each lesson used TARGET (task, authority, recognition, grouping, evaluation, time) structure.<br><br>CON: free play<br><br>NO | 30 min x 2 days/w | 9 w (432-468 min) | INT: motor development specialist<br><br>CON: ?? | RCT (PreS) | FMS (OC) | TGMD-2 | INT>CON in OC scores from pretest to post test (p<.001) | 18 w (pretest to follow-up)<br>9 w (posttest to follow-up)<br>INT>CON in OC scores from to pretest to follow-up (p<.001), and posttest to follow-up (p<.001). | Pre to post:<br>INT girls > CON boys & girls;<br>INT boys > CON boys & girls;<br>INT girls ~ INT boys; CON boys ~ CON girls in OC scores.<br><br>Posttest to follow-up:<br>INT girls > CON boys & girls;<br>INT boys > CON boys & girls;<br>INT girls ~ INT boys; CON boys ~ CON girl.<br><br>Pretest to follow-up:<br>INT girls > CON boys & girls;<br>INT boys > CON boys & girls;<br>INT girls ~ INT boys; CON boys ~ CON girl. |
| Salmon et al (2008, AU)[47] | Children (306, 50.9% girls; low SES) 10-11 y | SCT<br><br>Designing lessons for behavioral modification and FMS change | INT 1: Behavioral Modification (BM) condition: lessons 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.<br><br>INT 2: FMS condition: lessons focused on mastery of 6 FMS with an emphasis on enjoyment and fun through games and maximum involvement for all children.<br><br>INT 3: Received both BM and FMS.<br><br>CON: Usual curriculum<br><br>NO | 40-50 min x ?? days/w (19 sessions) | 9 m (855 min) | INT: PE specialist<br><br>CON: ?? | Cluster RCT (PriS) | FMS: dodge, sprint run, vertical jump, overhand throw, 2-handed strike, kick | VFMS manual | No significant intervention effects on FMS z-scores. | 12 m. (pretest to follow-up)<br>6 m (posttest to follow-up)<br>No significant intervention effects on FMS z-scores. | INT 1 girls > CON girls for FMS z scores (p<.05);<br>INT 2 girls> CON girls for FMS z scores (p<.01). |

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| Valentini & Rudisill (2004b, BR)[41] | Children (67, 64.1% girls; DD) 5.45 y | AGT<br><br>TARGET | INT: Mastery climate: Each session lasted 35 min and consisted of three parts: (a) 3 min of introduction, (b) 30 min of skill instruction and practice, and (c) a 2-min closure of the lesson. Each lesson used TARGET (task, authority, recognition, grouping, evaluation, time) structure.<br><br>CON: Low autonomy-free play<br><br>NO | 35 min x 2 days/w | 12 w (840 min) | INT 2: motor development specialists + university students (trained)<br><br>CON 2: ?? | QE (Kin) | FMS: LS & OC | TGMD | LS:<br>INT > CON (p=.002); LS development increased for both group (p=.001).<br><br>OC:<br>INT~CON<br>(p= .446); both groups improved from pretest to posttest. | 6m.<br>LS:<br>INT>CON (p=.0001);<br>INT maintained the same skill development, whereas CON showed significant decreases.<br><br>OC:<br>INT>CON (p=.001); there was no significant change for INT, but CON showed a significant decrease in skill development. | Not reported |
| Veldman et al (2017, USA)[39] | Girls (54, 100% girls; low SES) 3-5 y | Yes (AGT - TARGET) | INT: Children's Health Activity Motor Program (CHAMP).<br><br>CON: the standard movement opportunities of the preschool. This time is predominately self-directed and does not incorporate specific instruction, feedback, and practice in motor skills from an instructor.<br><br>NO | 30 min x 2 days/w | 9 w (540 min-423–468 min of pure motor skill instruction) | INT: Ph.D. students in Motor Behavior<br><br>CON: no instructor | RCT (PreS) | FMS: throwing, catching, striking off a tee, kicking, dribbling, and rolling. | TGMD-2 | INT>CON (p < .001)<br>Girls in INT group significantly improved their ball skills (p < .001) whereas the control group did not change (p > .05). | 9w<br>INT>CON (p < .001)<br>Girls in the INT group significantly increased in ball skills (p < .001) whereas the control group did not (p > .05). | Single gender study |

Note: AGT: Achievement Goal Theory, APM-Inventory: Manual test booklet for assessing preschool children's perceptual and fundamental motor skills; AU: Australia, BL: Belgium, BOT: Bruininks-Oseretsky Test of Motor Proficiency, Br: Brazil, CA: Canada, CMJ: Counter Movement Jump, COM: Community, CON: control, DD: Developmentally Delayed, DST: Dynamic Systems Theory, F: Family, FI, Finland, FMS: Fundamental Motor Skills, GE: Germany, GMQ: Gross Motor Quotient, QE: Quasi Experimental, GS: Graduate Students, H: Home, INT: intervention, IR: Ireland, KTK: Körperkoordinationstest für Kinder, LS: Locomotor Skills, MABC: Movement Assessment Battery for Children, MIF: Maximal Isometric Force, OCS: Object Control Skills, OW: Overweight, OB: Obese, PDMS: Peabody Developmental Motor Scales, PP: pre-post experimental design, PreS: Pre-school, PriS: Primary School, NS: Nursery School, PPR: pre–post–retention experimental design, RCT: Randomized Controlled Trial, RFD: Rate of Force Development, SC: Scotland, SecS: Secondary School, SES: Socio Economic Status, SL: Slovenia, SCT: Social Cognitive Theory, SKIP: Successful Kinesthetic Instruction for Preschoolers, TGMD: Test of Gross Motor Development, TPB: Theory of Planned Behavior, UK: United Kingdom, USA: United States of America, VFMS manual: Victorian Fundamental Movement Skills Manual, ??: not detailed.

## Table II. Characteristics of atheoretical intervention studies

| Study | Sample (number, SES, age[year]) | Intervention Components | | | | | MC assessment | | Post-intervention Tests | | Adjustments/effects by sex |
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| | | Content of intervention (condition for the control if applicable) | Frequency | Length | Provider | Design (setting) | MC assessed | MC assessment tool | Immediate | Follow-up (period) | |
| Bardid et al. (2013, BE)[62] | Children (93, 55.9% girls; at-risk)<br>3.6-5.1 y | INT: usual PE-curriculum + developmentally appropriate motor program (not detailed)<br><br>CON: usual PE-curriculum | 60 min x 2 days/w | 10 w (1200 min) | INT: PE teacher (trained)<br><br>CON: ?? | QE<br>(NS) | FMS (OCS) | TGMD-2 (total & OCS) | None | 5 w.<br>GMQ of INT > GMQ of CON ($p < 0.001$), while the GMQ score of the CON tended to decrease over time ($p = 0.009$).<br><br>LS of INT improved ($p < 0.001$), however no progress was made in OCS ($p = 0.090$). In CON, LS remained stable over time ($p = 0.988$), while the performance on OCS decreased ($p < 0.001$).<br><br>For GMQ (p<.001), LS (p= .007) and OCS (p<.001): INT> CON. | Girls' GMQ: INT had improved significantly ($p = 0.004$) while CON decreased over time ($p < 0.001$).<br><br>Boy's GMQ: There were no effects of time on the GMQ in either INT or CON.<br>Both girls (p<.001) and boy (p=.017) in INT > girls and boys in CON.<br><br>Girls' OCS: in INT improved significantly ($p = 0.004$) while the score of girls from the CON decreased over time ($p < 0.001$).<br>Girls in the INT scored significantly better than girls in the con after the intervention. No significant difference between INT and CON for boys was found.<br><br>No significant difference between boys and girls in LS was found. |
| Barnett et al. (2009, AU)[70] | Children (1045, 47% girls)<br>10.1 y | INT: Move It Groove It<br><br>CON: ?? | ?? | 1 y (??) | INT: researcher and research assistant (trained)<br><br>COT: ?? | QE<br>(PriS) | Catch, kick, throw, vertical jump, side gallop | Get Skilled Get Active | None | 6 y.<br><br>INT > CON for catch (p = .001).<br><br>INT maintained advantage compared with CON for side gallop and vertical jump | No interactions effects reported at posttest. Results adjusted for sex at 6 y follow-up. |
| Bedard et al. (2017, CA)[59] | Children (11, ??% girls)<br>45.6 m | INT: Each weekly session consisted of movement skill instruction, free play and an interactive reading circle during which children read a storybook and were taught 1–2 pre-literacy skills | 60 min x 1 days/w | 10 w (600 min) | INT: graduate students (experienced in implementing movement program ) | QE<br>(EYC) | Balance, underhand rolling, leaping and galloping, underhand throwing, jumping, overhand throwing, catching, hopping, kicking, striking | PDMS-2 (gross motor subtests) | Significant change from pretest to posttest (p =.015). | 5-6 w<br>No statistically significant change from posttest to follow-up. | Not reported |
| Bellows et al. (2017, USA)[60] | Children (250, 52.4% girls; at-risk, low SES)<br>3-5 y | INT: Intervention sites received The Food Friends Fun with New Foods Nutrition and Mighty Moves physical activity programs in preschool and 'booster' programming in kindergarten and first grade. Mighty Moves: Each week focused on a specific FMS and movement concepts were integrated into daily activities. Five monthly 'booster' | 15-20 min x 4 days/w | 18 w (720-1080 min) | INT: classroom teacher<br><br>CON: ?? | QE<br>(COM-school) | Balance, running speed and agility, upper-limb coordination (OCS) and strength | BOT-2 | Children in both groups significantly improved FMS over time as shown by a significant increase in mean total points in all four BOT-2 subtests. In all subtests, INT>CON (all p<.001) | 6 m.??<br><br>18 m. (posttest to follow-up)<br><br>In balance, both INT & CON remained significantly lower in balance ($p < 0.001$). | Not reported |

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| | | activities were conducted in the kindergarten and first grade classrooms<br><br>CON: ?? | | | | | | | There was a significant main effect of time for balance (p < 0.001), running speed and agility (p < 0.001), strength (p < 0.001), and OC skills (p < 0.001). | In OCS: CON < norm-referenced sample (p < 0.001). No significant difference between INT and the norm-referenced sample (p =0.32).<br><br>There were no significant differences for running speed and agility (locomotor skills) or strength | |
| Coppens et al. (2021, BE)[65] | Children (399, 6% girls)<br>3-8y | INT: Multimove for Kids: developmentally appropriate activities for each skill theme (two or three FMS every session). For instance, hitting can be performed in different ways (e.g. underhand, overhand), alone or in a group, with different tools (e.g. hand, racket, stick) and objects (e.g. balloon, beach ball, tennis ball), stationary or moving, in various setups (e.g. even-inclined, high-low), and with different targets (e.g. small-large, close-distant).<br><br>CON: ?? | 60 min x 1 day/w | 30 w (??) | INT: experienced examiners<br><br>CON: ?? | QE<br>(??) | FMS: LS & OC | TGMD-2 | The intervention group outperformed the control group (p<.001). | 6 y<br><br>The intervention group made less progress in MC than the control group (p<.05). | Not reported |
| Duncan et al (2020, UK)[67] | Children (124, 45.9% girls; Mid-range SES)<br>6-11 y | INT: Badminton World Federation Shuttle Time program embedded in normal curriculum. It based on the exercises and activities specified by the BWF and consisted of a warm-up section (10 min) and a main body section (approximately 40 min). The intervention focused on development of the following:<br>Balance, coordination, underhand throwing, catching, striking, running, jumping, and correct use of a racquet (to grip and swing)<br><br>CON: normal PE curriculum | 50 min x 1 day/w | 6 w (300 min) | INT: principal investigators and a school teacher<br><br>CON: PE teacher | Cluster Randomized Design (PriS) | Running, jumping, catching, throwing, striking, 10 m flying sprint time, standing long jump (SLJ), and seated medicine ball (1 kg) throw (MBT) | TGMD-2, Smart Speed gates, Peterson's procedures, 1 kg medicine ball, Davis' procedures | FMS:<br>In 6-7 y children: INT > CON in total FMS (p =.0001)<br><br>In 10-11 y children: INT ~ CON (p = 0.431)<br><br>For all INT and CON children, total FMS significant increased pre to post intervention (all p < 0.05).<br><br>Ten-Meter Sprint Speed:<br>INT ~ CON in all children in age groups.<br>Ten-meter sprint speed decreased pre to post intervention groups aged 6–7 years (p = 0.0001, d = 0.6) and 10–11 years (p = 0.001, d = 0.2) compared to control.<br><br>Standing Long Jump:<br>SLJ distance increased pre to post for the INT group (p = 0.0001, d = 0.8, moderate) but not the CON group (p = 0.728).<br><br>One-kilogram Medicine Ball Throw:<br><br>INT ~ CON in all children (p>.05).<br><br>Medicine ball throw performance increased pre | 10 w<br>FMS:<br>In 6-7 y children: INT > CON in total FMS (p =.0001)<br><br>In 10-11 y children: INT ~ CON (p = 0.361).<br><br>Total FMS scores in children aged 6-7 years old in the INT and CON groups and children aged 10–11 years in the INT group (all p < 0.05).<br><br>Ten-Meter Sprint Speed:<br>INT ~ CON in all children in age groups.<br><br>Ten-meter sprint speed decreased and was maintained at ten-weeks post for the intervention groups aged 6–7 years (p = 0.0001, d = 0.6) and 10–11 years (p = 0.001, d = 0.2) compared to control.<br><br>Standing Long Jump: were also significantly greater at 10 weeks post intervention, compared to post, for the INT group<br>(p = 0.0001, d = 0.5, small to moderate) but not the CON group (p = 0.956), but were not different from post intervention to 10 weeks post intervention for the INT (p = 0.306) or CON groups (p = 0.737). | FMS:<br>boys > girls<br><br>Ten-Meter Sprint Speed:<br>Boys ~ girls<br><br>Standing Long Jump:<br>Boys ~ girls<br><br>One-kilogram Medicine Ball Throw:<br>Boys>girls (p = 0.001) |

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| | | | | | | | | | to post (p = 0.0001, d = 0.3) for the INT group. | One-kilogram Medicine Ball Throw:<br>INT ~ CON in all children (p>.05). | |
| Granacher et al. (2011, GE)[61] | Adolescents (28, 62.5% girls)<br>16.8 y | INT: The intervention class participated in a short-term lower extremity Ballistic strength Training (BST) program integrated in their regular physical education lessons<br><br>CON: No specific resistance exercises were performed during their physical education lessons (standard PE classes) | ?? x 2 days/w | 8 w (??) | INT: PE teacher + an expert on INT program<br><br>CON: PE teacher | QE (SecS) | MIF, RFD, CMJ, static and dynamic postural control | Force plate & balance platform | Statistically significant improvements in MIF (p = 0.001) and CMJ height (p < 0.001) | 7 w.<br>MIF (p = 0.04) still present after INT. | Not reported |
| Jurak et al. (2013, SL)[63] | Children (324, 48.7% girls)<br>7.76 y | INT: enhanced PE classes: The program is delivered in the first four years of schooling, and includes three standard PE lessons and two extra lessons of PE per week. It includes a wider selection of PE content, and additional outdoor education.<br><br>CON: standard PE classes. | 45 min x 5 days/w | 4 y (??) | INT: specialist PE teacher + classroom teacher<br><br>CON: PE teacher | QE (PriS) | Arm plate tapping, standing long jump, polygon backwards, sit-ups, standing reach touch, bent arm hang, 60-meter run, and 600-meter run | SLOfit | INT>CON in all motor skills in pretest, over time the differences decreased. In posttest: INT>CON in standing reach touch, standing long jump, arm plate tapping.<br><br>INT~CON in polygon backwards, sit-ups, bent arm hang, and 600-metre run. | 7 y.<br>INT~CON:<br>Differences between INT and CON deceased in most motor skills especially in the polygon backwards, sit-ups and 600-metre run tasks. | Boys > Girls |
| Matvienko & Ahrabi-Fard (2010, USA)[71] | Children (70, 50% girls)<br>K-1 grade | INT: Daily 15-min morning walk and 90-min afterschool physical activity lesson with an emphasis on motor skill development (20 min), nutrition/health lesson (30 min), snack, and non-structured active play<br><br>CON: non-structured active play | 20 min x 7 days/w | 4 w (2100 min) | INT: PE specialist<br><br>CON: ?? | QE (After School-PreS) | Throwing distance test, rope jumping, kicking | 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) | INT > CON for jumps over rope, throwing and kicking (P<.05). | 3 m.<br>INT>CON for jumps over rope (P<.001) and throwing (P<.001). | Not reported |
| Mulvey et al. (2020, USA)[66] | Children (93, 49.5% girls)<br>47.38 m | INT: SKIP<br><br>CON: free play | 30 min x 2 days/w | 10 w (600 min) | INT: doctoral student (trained, with PE teaching certification)<br><br>CON: ?? | QE (PreS) | FMS<br>(LS & OC) | TGMD-2 | None | 2 w.<br>INT > CON<br>(p = .004) | Effects for gender (p = .14), and Gender x Condition (p = .40), were not significant. |
| Reilly et al. (2006, SC)[72] | Children (545, 47.7% girls)<br>4.2 y | INT: lessons intending to increase PA levels of children and meet the requirements of the ‘physical development and movement’ component of the nursery curriculum of Scotland; training sessions for nurses; resource pack of materials for home based intervention (health education leaflets); posters displayed at nurseries for 6 weeks<br><br>CON: usual curriculum, with the head | 30 min x 3 days/w | 6 m (??) | INT: nursey staff (trained)<br><br>CON: nursey staff | Cluster RCT (NS & H) | Gross & fine motor skills | MABC-2 (total score) | INT>CON | 6 m<br>INT>CON (p=.0027) after adjustment for sex and baseline performance. | Girls improved more than boys (p = 0.001) |

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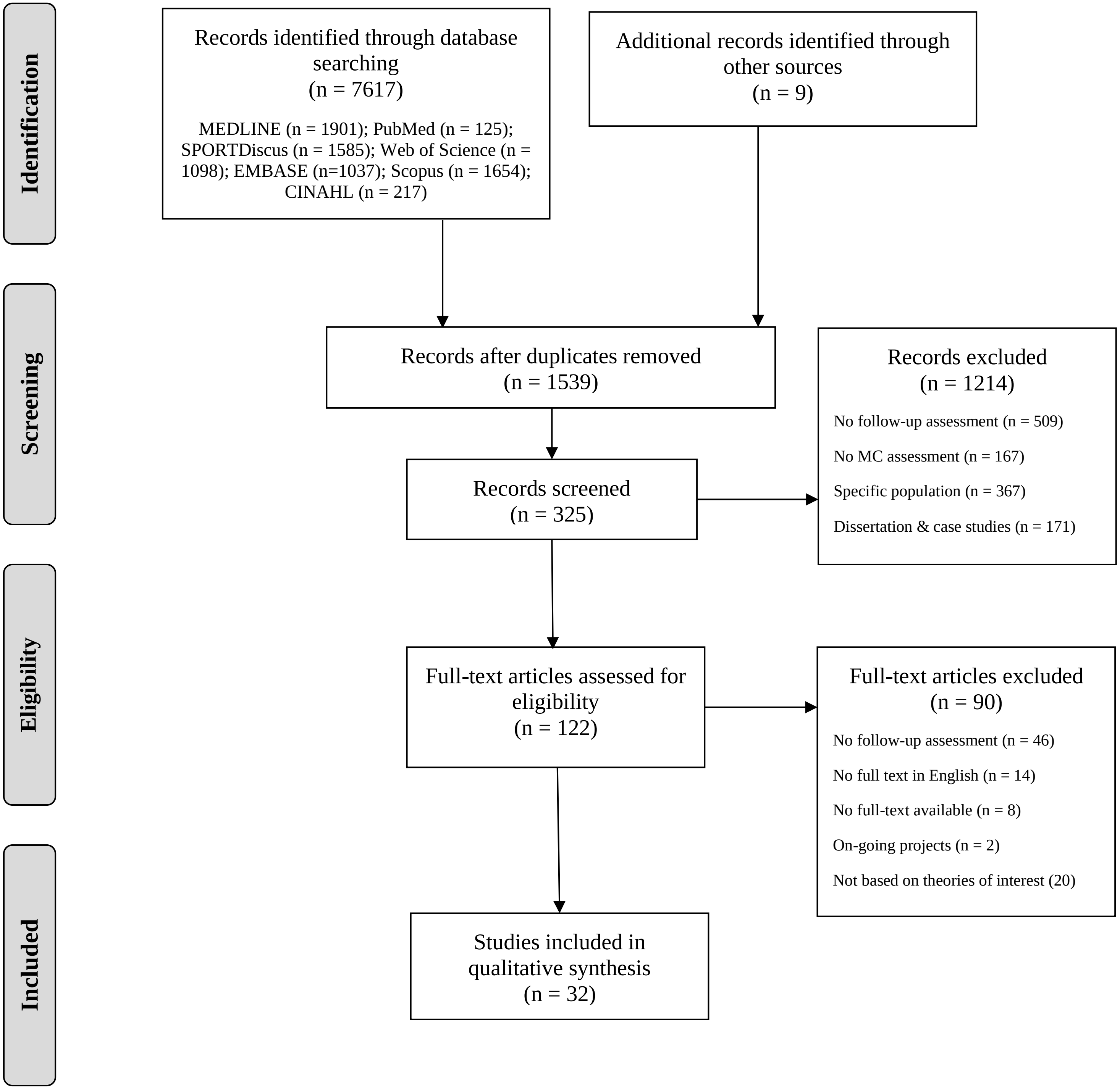
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | teachers agreeing not to enhance physical development and movement curriculum | | | | | | | | | |
| Roth et al. (2015, GE)[68] | Children (709, 49.5% girls)<br>4-5 y | INT: PA lessons including exercises to enhance coordinative skills and perception; manual, collection of games, and exercises for preschools; PA homework cards 1 or 2/week; letters comprising games/exercises for holidays<br><br>CON: routine schedule, including common daily activity and weekly PA class | 30 min x 5 days/w | 11 m (??) | INT: pre-school teacher (trained)<br><br>CON: pre-school teacher | Cluster RCT (PreS & H) | Obstacle course, standing long jump, balancing on one foot, jumping to and from sideway | Measures developed for study | INT > CON<br>(p = 0.001).<br>INT showed significant improvements in explosive leg strength, jumping coordination, and static balance, but there were no significant improvements in agility, dynamic balancing, or throwing ability. | 2-4 m.<br><br>INT>CON (p = 0.007).<br>INT showed significantly better improvements in agility and in explosive leg strength, whereas positive effects on static balance did not persist. | Not reported |
| Smyth & Q'Keeffe (1998, IR)[74] | Children (28, 50% girls)<br>5-6 y | INT: lesson focused on demonstration and teaching of throwing and feedback on performance<br><br>CON: free play | 30 min x 1 day/w | 4 w (??) | INT: ??<br><br>CON: ?? | QE (PreS) | Throwing | Roberton's segmental analysis profile | INT~CON (p>.05);<br>both the taught and play groups improved significantly (p<0.05) | 2 m.<br>INT>CON (p<.05) | Not reported |
| Van Beurden et al (2003, AU)[73] | Children (1045, 47% girls )<br>7-10 y | 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 mid-study to share progress, and 2 to improve teaching of FMS and dance); project Web site with lesson plans ideas and activities; and funding for purchase of equipment. Included all elements recommended by Ottawa Charter for Health Promotion. Included 5 days training + 4 professional development workshops for teachers<br><br>CON: ?? | ?? | 1 y (??) | INT: classroom teacher (trained) and preservice teacher<br><br>CON: classroom teacher | QE (PriS) | Static balance, sprint run, vertical jump, hop, side gallop, kick, catch, overhand throw | Get Skilled Get Active | INT > CON for all skills combined (p<.0001).<br>INT > CON for boys for sprint run (p<.001), side gallop (p<.001), kick (p<.001), throw (p = .034), jump (p = .004) and catch (p<.001).<br>INT>CON for girls for side gallop (p= .049), kick (p= .023), throw (p= .042), jump (p = .002), hop (p = .037), catch (p<.001). | 6 y.<br>INT>CON for catch (p = .001). INT maintained advantage compared with CON for side gallop and vertical jump. | No interactions effects reported at posttest. Results adjusted for sex at 6 y follow-up. |
| Zask et al (2012, AU)[69] | Children (137, 53% girls)<br>3-6 y | INT: Tooty Fruity Vegie in Preschools (TFV), an obesity prevention ten month intervention with a movement skill focus ('Fun Moves'). The 'Fun Moves' program was games-based and influenced by the 'Moving with Young Children' program for preschoolers. Each session included a warm up and cool down time and a number of short games, usually three. lessons including warm-up (5 min), games in groups (15–20 min), and cool-down (5 min); small grant for equipment; playground review to encourage more active behavior; workshops and monthly newsletter for parents; healthy eating intervention<br><br>CON: regular curriculum | 25-30 min x 2 days/w | 10 m (500-600 min) | INT: trained staff<br><br>CON: ?? | QE (PreS) | FMS: LS & OC | TGMD-2 | INT > CON | 3y<br>LS: INT ~ CON (p = .063) from pre-test to follow-up.<br><br>OC:<br>Girls: INT > CON from pre-test to follow-up.<br>Boys: INT ~ CON from pre-test to follow-up. | LS: boys ~ girls (p = .179)<br><br>OC: boys > girls (p = 0.036) |

Note: APM-Inventory: Manual test booklet for assessing preschool children's perceptual and fundamental motor skills; AU: Australia, BL: Belgium, BOT: Bruininks-Oseretsky Test of Motor Proficiency, Br: Brazil, CA: Canada, CMJ: Counter Movement Jump, COM: Community, CON: control, DD: Developmentally Delayed, F: Family, FI, Finland, FMS: Fundamental Motor Skills, GE: Germany, GMQ: Gross Motor Quotient, QE: Quasi Experimental, GS: Graduate Students, H: Home, INT: intervention, IR: Ireland, KTK: Körperkoordinationstest für Kinder, LS: Locomotor Skills, MABC: Movement Assessment Battery for Children, MIF: Maximal Isometric Force, OCS: Object Control Skills, OW: Overweight, OB: Obese, PDMS: Peabody Developmental Motor Scales, PP: pre-post experimental design, PreS: Pre-school, PriS: Primary School, NS: Nursery School, PPR: pre–post–retention experimental design, RCT: Randomized Controlled Trial, RFD: Rate of Force Development, SC: Scotland, SecS: Secondary School, SES: Socio Economic Status, SL: Slovenia, SKIP: Successful Kinesthetic Instruction for Preschoolers, TGMD: Test of Gross Motor Development, UK: United Kingdom, USA: United States of America, VFMS manual: Victorian Fundamental Movement Skills Manual, ??: not detailed.

**Table III**. Risk of Bias Assessment in Intervention Studies Examining Changes in MC in Youth

| Study | Randomization clearly Described and adequately completed | Valid measure of MC | Assessor blinding | Participants analyzed in allocated group and not excluded because of missing Data or noncompliance | Covariates accounted for in analyses | Power calculation reported for MC | Baseline results reported separately for each group | Dropout ≤20% for ≤6 months follow-up and ≤30% >6 months follow-up | Summary results presented + estimated effect Sizes + precision estimates; (3 items) |
|---|---|---|---|---|---|---|---|---|---|
| **Theory-based Intervention Studies** | | | | | | | | | |
| Altunsöz et al (2016)[30] | ? | ✓ | X | ✓ | X | X | ✓ | X | ✓ |
| Cliff et al (2007)[36] | N/A | ✓ | N/A | ✓ | N/A | X | ✓ | ✓ | X |
| Cliff et al (2011)[35] | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | X | ✓ |
| De Oliveira et al (2019)[31] | ✓ | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | ✓ |
| Foulkes et al. (2017)[50] | ✓ | ✓ | ✓ | ✓ | X | X | ✓ | ? | ✓ |
| Iivonen et al (2011)[33] | X | ✓ | X | ✓ | X | X | ✓ | X | X |
| Kalaja et al (2012)[37] | N/A | ✓ | X | ✓ | X | X | X | X | ? |
| Kelly et al. (2021)[64] | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Laukkanen et al (2015)[49] | ? | ✓ | X | ✓ | ✓ | X | ✓ | ? | X |
| McGrane et al. (2018)[48] | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Piek et al (2013)[32] | ? | ✓ | X | ✓ | X | X | ✓ | X | X |
| Robinson & Goodway (2009)[42] | X | ✓ | X | ✓ | X | X | ✓ | X | ✓ |
| Robinson et al. (2011)[40] | X | ✓ | X | ✓ | N/A | X | ✓ | X | X |
| Robinson et al. (2017)[38] | ? | ✓ | X | ✓ | X | X | ✓ | ✓ | ✓ |
| Salmon et al (2008)[47] | ? | ✓ | ✓ | ✓ | ✓ | X | X | ? | X |
| Valentini & Rudisill (2004b)[41] | ? | ✓ | X | ✓ | X | X | ✓ | X | ✓ |
| Veldman et al (2017)[39] | ✓ | ✓ | ✓ | ✓ | X | X | ✓ | X | X |
| **Atheoretical Intervention Studies** | | | | | | | | | |
| Bardid et al. (2013)[62] | ? | ✓ | ✓ | ✓ | X | X | ✓ | ✓ | ✓ |
| Barnett et al. (2009)[70] | N/A | X | X | X | X | X | X | X | ✓ |
| Bedard et al. (2017)[59] | N/A | ✓ | N/A | ✓ | N/A | X | ✓ | ? | X |
| Bellow et al. (2017)[60] | X | ✓ | X | ✓ | X | X | ✓ | X | ✓ |
| Coppens et al. (2021)[65] | X | ✓ | X | X | ✓ | X | ✓ | ✓ | ✓ |
| Duncan et al (2020)[67] | ? | X | X | ✓ | X | X | ✓ | X | ✓ |
| Granacher et al. (2011)[61] | ? | ? | X | ✓ | X | ✓ | ✓ | X | X |
| Jurak et al. (2013)[63] | X | X | X | ✓ | ✓ | X | ✓ | ✓ | X |
| Matvienko et al (2010)[71] | N/A | ✓ | X | X | X | X | ✓ | ✓ | ? |
| Mulvey et al. (2020)[66] | ? | ✓ | X | X | X | X | ✓ | ✓ | ✓ |
| Reilly et al. (2006)[72] | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ? | ✓ |
| Roth et al. (2015)[68] | ✓ | X | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ |
| Smyth et al (1998)[74] | ? | X | X | ✓ | X | X | ✓ | X | X |
| Van Beurden et al (2003)[73] | N/A | X | X | ? | ✓ | X | X | ? | X |
| Zask et al (2012)[69] | N/A | X | X | ✓ | X | X | X | X | X |

✓, explicitly described and present; X absent; ?, unclear or inadequately described; N/A, not applicable because of study design. MC: Motor Competence
In last column, only those were marked as ✓ that had at least 2 of 3 items.


Identification
Screening
Eligibility
Included
Records identified through database searching (n = 7617)
MEDLINE (n = 1901); PubMed (n = 125); SPORTDiscus (n = 1585); Web of Science (n = 1098); EMBASE (n=1037); Scopus (n = 1654); CINAHL (n = 217)
Additional records identified through other sources (n = 9)
Records after duplicates removed (n = 1539)
Records excluded (n = 1214)
No follow-up assessment (n = 509)
No MC assessment (n = 167)
Specific population (n = 367)
Dissertation & case studies (n = 171)
Records screened (n = 325)
Full-text articles assessed for eligibility (n = 122)
Full-text articles excluded (n = 90)
No follow-up assessment (n = 46)
No full text in English (n = 14)
No full-text available (n = 8)
On-going projects (n = 2)
Not based on theories of interest (20)
Studies included in qualitative synthesis (n = 32)