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1	Motor Competence Interventions in Children and Adolescents - Theoretical and
2	Atheoretical Approaches: A Systematic Review
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## 30 Motor Competence Interventions in Children and Adolescents - Theoretical and Atheoretical Approaches: A 31 **Systematic Review** 32 Abstract 33 This study aimed to compare for the first time the immediate and retention effects of theory-based and atheoretical 34 motor competence (MC) interventions, by conducting a systematic review to determine which intervention approach 35 resulted in the most improvements for motor outcomes. In accordance with PRISMA guidelines, studies were 36 identified from searches across seven databases, for articles relating to theory-based (Achievement Goal Theory, 37 Dynamic Systems Theory, and Social-Cognitive Theory) and atheoretically-derived MC interventions in typically 38 developing children and adolescents. Publication bias was assessed using an adapted form of Consolidated 39 Standards of Reporting Trials statement. Of the thirty two included studies, seventeen utilized theory-based 40 intervention approaches. The majority of studies were grounded in Achievement Goal Theory. Also, the majority of 41 MC interventions elicited immediate (short) and/or long-term effects for children and adolescents. Studies varied 42 with regards to intervention components (content, frequency, length and provider) and MC assessment (MC tool, 43 dimension and retention period). Many studies scored poorly for risk of bias items. "Overall, the levels of success 44 for theoretical and atheoretical intervention programs were not distinguishable. Findings open up new horizons for 45 motor skills instruction to be taught using developmentally appropriate pedagogy, a research field which has gained 46 significant traction among stakeholders in recent years. 47 48 Key words: Motor competence; Motor development; Achievement Goal Theory; Dynamic Systems Theory; Social-49 **Cognitive Theory**

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### 55 **1 Introduction**

56 Motor competence (MC) is defined as a level of motor abilities (MA) (physical proficiency and perceptual-motor), 57 as well as gross motor coordination (GMC) and fundamental motor skills (FMS) proficiency, which underlie the 58 performance of a wide range of tasks, including fine and gross motor activities in daily life [1]. MC is an important 59 component of the motor development domain, and research shows that it can be directly related to major health and 60 physical fitness indicators, such as weight status, physical activity levels, and perceived motor competence [2, 3]. 61 According to cross-sectional and longitudinal studies, MC is a consequence, as well as a predictor, of many health-62 related behaviors [4-6]. Motor skills are not age-dependent, however, and they do not simply develop as a function 63 of age [7]. Evidence shows that physical growth and maturation alone do not automatically lead to motor skill 64 competence; rather, external factors such as instructional protocol, practice, and reinforcement play a crucial role in 65 motor skill development [8]. Based on longitudinal studies, MC appears to track throughout childhood [9] and into 66 adolescence [10, 11], suggesting that low MC may persist into older ages; therefore, well-tailored interventions should 67 occur during childhood and through adolescence to ensure the sufficient development of MC.

68 In the preceding decades, a concerted effort has been placed into developing motor skills interventions to ameliorate 69 the lack of MC in children and adolescents [12, 13]. Indeed, previous systematic reviews have reported that MC 70 interventions are, overall, beneficial for children [14-17]; however, they were mostly aimed at FMS, which is only 71 one component of MC within intervention studies. In a recent study by Jiménez-Díaz, Chaves-Castro, and Salazar, 72 the authors conducted a meta-analysis to quantify the data obtained from MC intervention programs. The authors 73 reported statistically significant improvements in MC, defined as FMS, motor coordination, motor fitness, and motor 74 ability, for the individuals who took part in these MC programs [18]. The authors, however, did not assess the retention 75 (short or long term) of these MC improvements and solely focused on the immediate post-intervention effects. In 76 2013, Morgan et al. conducted a systematic review which included some studies reporting a retention assessment of 77 MC beyond immediate post-intervention assessments. Accordingly, they found positive retention effects in six of the 78 twenty-two studies, including two with long-term (six years) follow-up assessments. Furthermore, only a few of the 79 interventions examined demonstrated a significant improvement in FMS [16]. This review by Morgan et al., (2013) 80 was limited to FMS intervention programs only, and since then, many more MC intervention studies have been

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published. This highlights the need for a systematic review of recent data to explicate the short- and long-term effectsof MC interventions in children and adolescents.

83 Naturally, no intervention program is infallible, and every approach has its merits and shortcomings; it is therefore 84 necessary to identify and compare the various characteristics of interventions to maximize their effectiveness, while 85 seeking to reduce the financial and time impacts, alongside the labour-related factors (staffing processes, training, 86 etc.). Cost- and time-effective strategies help to redirect resources to conduct more appropriate interventions. With 87 respect to the design of intervention studies, two distinct types of approaches are frequently discussed in the literature: 88 theoretical and atheoretical. Although many studies employ MC interventions that are grounded in theory, a 89 considerable number of MC interventions have been developed from an atheoretical basis, which in the current 90 manuscript will be characterized specifically as those studies that are not based on or concerned with theory, and are 91 also considered as studies in which there is insufficient information in the paper to determine a specific theory. Of the 92 MC intervention approaches which center around an empirical theoretical basis, research would suggest that three of 93 the most frequently cited and prevalent theories in MC interventions include: 1) Dynamic Systems Theory (specifically 94 Newell's Model of Constraints [19], 2) Achievement Goal Theory, 3) and the Social-Cognitive Theory (or socio 95 ecological model)[8, 14, 20-27]. While these three theories have different priority objectives and are not mutually 96 exclusive, their underpinning structures have received some notable attention within MC/motor outcomes related 97 fields, and are described briefly below.

98 Dynamic Systems Theory examines the behavior of systems whose internal states change over time and the interaction 99 between these systems and exogenous inputs [28]. According to this theory, development is a probabilistic outcome 100 of interactions between several levels and systems [29]. Previously established research by Corbetta [25] on Dynamic 101 Systems Theory reported that this underpinning structure was often dominated by skilled performances and the 102 coordination of limited parts of the body. Given this empirical platform, it is well accepted that there are multiple 103 ways in which a task can be executed, and the popular convergence of constraints on action stems is gaining in 104 prominence through Newell's model (1986) [19, 21]. The recurrent application of Dynamic Systems Theory through 105 Newell's constraints model asserts that by modifying the environmental, task, and individual constraints, it is possible 106 to create conditions that are conducive to motor development in children [30-33]. Also, with this model, researchers 107 can better account for the complexity of age-related change in movement through the interactions of individual,

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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.

### 135 2 Methods

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

#### 138 2.1 Study Eligibility Criteria

139 The population samples included in the current study comprised of typically developing individuals between the ages 140 of 3 to <18 years of age, from varied socioeconomic backgrounds, with no reported history of learning difficulties, or 141 behavioral, physical, neurological, or orthopedic disorders and/or disabilities.

142 This systematic review includes both theoretical (namely Dynamic Systems Theory, Achievement Goal-Theory, or 143 Social-cognitive theory) and atheoretical studies that have carried out follow-up (retention) assessments. For the 144 purpose of the current manuscript's context, atheoretical studies are characterized specifically as those studies that are 145 not based on or concerned with theory, and are also considered as studies in which there is insufficient information in 146 the paper to determine a specific theory. Retention refers to the persistence or lack of persistence of the performance, 147 and is considered at the behavioral level rather than at the theoretical level [54]. The following criteria was used for 148 the inclusion of a study in this review: 1) the study must have measured MC performance as an outcome and included 149 pre- or -post intervention assessment, or both, along with follow-ups. However, neither the type of MC battery 150 assessment tool nor the measurement approach was a factor in inclusion or exclusion of a study 2) only articles 151 published in English and in peer-reviewed journals were considered. Books, reviews, theses, dissertations, 152 commentaries, qualitative studies, and case studies were excluded.

#### 153 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

162 "disorder" OR "autism" OR "impairment" OR "cerebral palsy".

#### 163 2.3 Study Selection and Extraction

164 After conducting the initial search and removing duplicates, two disciplinary-specific reviewers independently 165 screened the remaining studies' titles and abstracts. Then, full-text articles were coded for inclusion according to the 166 approach "Yes, Maybe and No." Cohen's Kappa statistics were used to calculate the level of agreement between two 167 independent reviewers on title/abstract and full-text screening [55]. Kappa values between .40 and .59 were considered 168 as fair agreement, .60 to .74 as good agreement and greater than .75 was considered as excellent agreement [56]. 169 Authors had excellent agreement with Kappa values of .98 and .82 the titles and abstracts, respectively. A third author 170 was consulted in cases marked "Maybe" in order to resolve the issue and determine whether the article should be 171 included or excluded from the systematic review.

172 The same two reviewers worked independently to extract data from each included study, including study 173 characteristics (authors, year and country), intervention components (sample characteristics, details of grounded 174 theory (if any), theory operationalization, content of intervention and its continuation after post-test, intervention 175 dosage and intervention deliverer), MC assessment (MC assessed and MC assessment tool) and outcome measures 176 (immediate and follow-up post intervention assessment and adjustment by sex (including analysis of sex differences)). 177 To distinguish theoretical from atheoretical studies, the intervention must be explicitly based on one or more of the 178 theories listed above. Before being used in the screening process, this criterion was discussed and agreed upon among 179 reviewers. Two disciplinary-specific reviewers independently and further screened the introduction and methods of 180 articles and coded articles for inclusion according to the approach "Yes, Maybe, and No." A Kappa value of .78 was 181 obtained for the level of agreement between the reviewers on theoretical/theoretical screening. In instances of 182 "Maybe" and disagreements over the inclusion of a certain study or the data obtained, the matter was resolved through 183 discussion with a third author.

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......INSERT FIGURE I HERE.....

185 2.4 Risk of Bias Assessment

186	Risk of	bias within the included studies was assessed by two reviewers independently. The criteria for assessing the
187	risk of t	bias was a 9-item tool, adapted from the Consolidated Standards of Reporting Trials statement [57], and also
188	previou	sly-used quality criteria [58]. The criteria identified as relevant to the current study has been previously
189	reported	in another systematic review, within a similar area [16] and specifies the following:
190	A.	Randomization (generation of allocation sequence, allocation concealment and implementation) clearly
191		described and adequately completed.
192	B.	The use of valid measures of MC proficiency (validation in the same age group has been published or
193		validation data were provided by the author).
194	C.	Blinded outcome assessment (positive when those responsible for assessing MC were blinded to the group
195		allocation of individual participants).
196	D.	Participants were analyzed in the group they were initially allocated to, and participants were not excluded
197		from analyses because of non-compliance to treatment or because of missing data.
198	E.	Covariates accounted for in analyses (e.g., baseline score, group/cluster for cluster RCTs, and other relevant
199		covariates when appropriate such as age or sex).
200	F.	Power calculation reported for the primary MC outcome.
201	G.	Presentation of baseline characteristics separately for treatment groups (age + sex + $\geq$ 1 MC outcome
202		measure).
203	H.	Dropout for MC measure described
204	I.	Summary results for each group + estimated effect size (difference between groups) + its precision (e.g., 95%
205		Confidence Interval).
206	Each ite	em on the scale was evaluated as "explicitly described and present" ( $\checkmark$ ), "absent" (x) or "unclear or
207	inadequ	ately described" (?).

# 208 **3 Results**

## 209 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.

#### 213 **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.

#### 221 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].

#### 226 **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.

### 231 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]. 237 Three studies were community-based interventions, with two targeting overweight/obese children [35, 36], and one 238 targeting at-risk children for motor impairment [60]. Among the studies that have been reviewed, one study included 239 girls only [39], two studies did not specify the sex distribution of participants [48, 59], and the remaining were co-240 educational. Of the thirty two studies, seven administered interventions with participants from low socio-economic 241 backgrounds [30-32, 39, 47, 50, 60] and one research targeted children from a middle-class socio-economic 242 background [67]. Two studies included motor-developmentally at-risk children [60, 62], and one study included 243 developmentally delayed children [41]. Two studies targeted overweight/obese children [35, 36]. The remaining 244 studies did not describe the status of the participants. The sample sizes for the studies ranged from 11 [59] to 1045 245 [70, 73].

246 .....INSERT TABLE I & II HERE.....

### 247 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].

255 .....INSERT TABLE III HERE.....

### 256 3.4 MC Intervention Characteristics

### 257 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].

#### 264 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].

#### 289 3.4.3 Measurement of MC

#### Motor Competence Interventions in Youth

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].

296 Most of the studies included both immediate and follow-up post-intervention assessments; only three studies did not 297 include an immediate post-intervention assessment, but did include follow-up assessments [62, 66, 70]. The retention 298 period (time period between immediate and follow-up assessments) varied among studies and ranged from 2 weeks 299 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 300 nine studies reporting less than 10 weeks retention-periods [30, 38-40, 42, 59, 61, 62, 66] and seven studies reporting 301 between 10 to 16 weeks retention-periods [33, 48, 64, 67, 68, 71, 74]. Nine studies had 6-12 months retention-periods 302 [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 303 study having a 9-month retention-period [36], and two studies reporting a 12-month retention-period [32, 47]. Only 304 six of thirty two studies had a retention-period with a duration of 12 months or more; specifically one study had a 18-305 month-retention time frame [60], one study had a 3-year-retention time frame [69], two studies had a 6-year retention 306 time frame [65, 70, 73] and one study had a 7-year-retention time frame [63].

307 3.5 Evidence for MC Outcomes

#### 308 3.5.1 Theory-based Interventions

309 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  $\geq 1$  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].

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

321 Of the seventeen identified theory-based interventions, results observed that fourteen of the studies [30-33, 36-42, 48, 322 49, 64] reported statistically significant retention intervention effects for  $\geq 1$  item of MC. Cliff et al., (2007) study did 323 observe specific intervention effects at 9-months follow-up for overall gross motor quotient, however, this study did 324 not include a comparative control group assessment [36]. Interestingly, De Oliveira et al., (2019) found specific 325 intervention effects for gender at 18-months follow-up, however, these positive findings were observed for specific 326 MC items only (one-leg balance, catching, throwing) [31]. Similarly, Iivonen et al., (2011) found specific intervention 327 effects for gender at 3-months follow-up, and these positive findings were again observed for specific MC items only 328 (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  $\geq 1$  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  $\geq 12$  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 followup [32].

#### 337 3.5.2 Atheoretically-derived Interventions

### 338 Immediate (baseline to post-intervention) intervention effects

339 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  $\ge 1$  item of MC. The Bedard et al.,

341 (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.

#### 354 Retention (follow-up) intervention effects

355 Of the fifteen identified atheoretically-derived interventions, results observed that eleven of the studies [61, 62, 66-356 74] reported statistically significant retention intervention effects for  $\geq 1$  item of MC. Barnett et al., (2009) study did 357 observe specific retention intervention effects for MC at 6-year follow-up, when compared to the control group 358 comparison for individual MC skills (catch, side gallop, vertical jump) [70]. Similarly, at 6-year follow-up, Van 359 Beurden et al., (2003) observed specific retention intervention effects for individual MC skills [73], while Roth et al., 360 (2015) also observed intervention effects for individual MC skills, however, their retention follow-up period was 361 between 2- to 4- month approximately [68]. Duncan et al., (2020) study again observed specific 10-week retention 362 intervention effects for both age and particular MC skills (standing long jump, 10-metre sprint speed) [67], whereas 363 Zask et al., (2012) at 3-year follow-up observed specific gender-based intervention effects in the MC subsets of 364 locomotion and object-manipulation [69]. Mulvey et al., (2020) study did observe specific retention intervention 365 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].

### 374 **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 theoreticallyand atheoretically-derived interventions can elicit increases in MC in children and adolescents.

#### 381 Theory-based interventions

382 As detailed in Table I, Altunsoz et al, De Oliveira et al, Iivonen et al, Piek et al, and Robinson et al, respectively, all 383 developed and employed interventions based on the Dynamic Systems Theory [30-33, 38]. Only two of these studies 384 reported positive results immediately after the intervention, when compared to the control groups [30, 31]; however, 385 three studies reported sustained results in the intervention group, with the intervention group achieving higher MC 386 scores than the control group at retention follow-up. An additional approach to intervention design is the Achievement 387 Goal Theory, in which the emphasis is on designing the environment in such a way that it elicits a mastery-oriented 388 attitude to learning and a degree of relative autonomy through MC tasks. Typically, studies that utilize this approach 389 are child-centered, meaning that many parameters such as task type, level of difficulty and equipment are selected in 390 accordance with the children's desires and goals [43, 75, 76]. Indeed, in the present study, eight studies commenced 391 their interventions in alignment with the Achievement Goal Theory [35, 36, 38-42, 77], and in all eight studies, 392 beneficial outcomes, when compared to control groups were reported at post-intervention and retention. In a previous 393 systematic review, Palmer et al concluded that motor skill interventions grounded in the Achievement Goal Theory 394 are effective for improving motor skills in young children [45]. This research was consistent with current study 395 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 achievementbased 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.

402 In the present review, relatively fewer studies adopted the Social Cognitive Theory approach (or socio ecological 403 model) to children's MC; Foulkes et al, Laukkanen et al, McGrane et al, and Salmon et al developed interventions in 404 this regard [47-50]. The Social-Cognitive Theory may be regarded, essentially, as the process of learning through 405 observation and imitation [79]. Only in McGrane et al, however, were beneficial outcomes at post-intervention and 406 follow-up periods reported [48]. Indeed, adherence to this type of theoretical intervention is contingent on the program 407 possessing enough emotional appeal to motivate the participant to pay attention. Moreover, participants must also be 408 alert and interested enough to apportion attentional capacity to observing the intervention. Subsequent to this, further 409 motivation to arrange and cognitively remember the information in the retention and motor reproduction processes to 410 practice the observed behavior must present. Indeed, if perceived rewards outweigh the perceived costs, then the 411 behavior is more likely to be imitated, whilst, if the vicarious reinforcement is not regarded as important, behavior 412 imitation will not occur [80].

#### 413 Atheoretical interventions

414 In the present systematic review, fifteen studies of atheoretical intervention design, were included, and, in general, 415 included an aerobic exercise component, in addition to varying amounts of resistance or strength-based activities. 416 Indeed, previous systematic reviews and meta-analyses have documented that the addition of physical activities, 417 whatever they may encompass, generally result in positive effects on the MC of children and adolescents [15, 16, 81]. 418 These findings may indicate that the theoretical basis for MC interventions is not important, but rather the volume of 419 the additional physical activity. Such a conclusion, however, is not necessarily supported in the present study, where 420 some of the interventions highlighted no differences between those that followed prescribed programs and those that 421 did not. This is an important observation as it indicates that, in order to firstly improve MC and then to sustain MC, 422 an additional component, beyond the presence of an intervention is required.

#### 423 Theoretical vs. Atheoretical interventions

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424 According to the findings in this review, there is no clear distinction between theoretical or atheoretical MC 425 interventions. In the identified studies using Achievement Goal Theory, success has largely been achieved where a 426 mastery motivational climate is created. In such situations, the mastery motivational climate places emphasis on self-427 referenced improvement, exerting effort and striving for mastery [23].

428 Theory-based interventions overwhelmingly utilized the TGMD (including its variants) to assess MC (11 out of 17); 429 the remaining studies utilized the BOT-2 (2 studies), the adapted APM inventory (manual test booklet for assessing 430 preschool children's perceptual and fundamental motor skills), the KTK, and the Victorian Fundamental Movement 431 Skills Manual. Whilst for the atheoretical interventions, of the fifteen studies; four used the TGMD, two used the Get 432 Skilled Get Active assessment, and the remaining studies evaluated MC using different tests (including; BOT-2, 433 PDMS-2, SLOfit, Fitnessgram, MABC-2, segmental analysis, study specific). Clearly, this wide array of tests, and 434 subsets of tests, makes quantitative comparisons difficult and highlights the need for a uniformed approach to the 435 assessment of MC in children and adolescents. Such an array of testing batteries may impede a clear conclusion 436 between different studies being made. Indeed, in some studies, the authors employed testing batteries that assessed 437 both fine and gross motor skills, yet the authors presented composite or combined scores only, in comparison to other 438 studies who operated their scoring criteria in contrast to the accepted and published manufacturer guidelines. 439 Furthermore, in some cases [77], fitness-style testing (e.g. shuttle run test) was used to represent MC, in addition to 440 balances tests (e.g. Flamingo Standing Test, force-plate and balance platform). A further consideration is that, as 441 highlighted in Holfelder and Schott (2014), in testing batteries such as the KTK or BOTMP, motor abilities and MC 442 are summarized or expressed as a quotient, thereby making comprehension of their meaning and efficacy on MC, 443 difficult [82]. However, despite methodological variances, it is evident that that an additional component (such as 444 individual's personality, motivation ...), beyond the presence of an intervention only is required to elicit improvements 445 in MC in children. This is supported, in the present study, by the overwhelming success of interventions ground in the 446 Achievement Goal Theory, when compared with the intermittent success of other theory-based and/or atheoretically-447 derived interventions.

#### 448 Strengths and Limitations

449 The present study represents a novel addition to the literature by examining how the effectiveness of theory-based and 450 atheoretical MC interventions for children and adolescents differ. Moreover, the research team highlight that both 451 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.

### 462 **5** Conclusion

463 The current study evaluated theoretical and atheoretical MC interventions. The results of this systematic review, with 464 the specific inclusion of follow-up MC intervention studies, suggests that the success of both theory-based and 465 atheoretically-derived interventions seems variable. Thus, when designing interventions for the improvement or 466 management of MC in children and adolescents, key stakeholders must consider the wider benefits, drawbacks, and 467 types of theory-based and atheoretically designed interventions. While it may seem sensible to anchor MC 468 interventions through a sound theoretical basis to increase successful motor outcomes in children and adolescents, 469 further financial and time resources may be required. Further longitudinal MC intervention evidence is indeed 470 warranted before determining such findings.

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- 478

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Table I. C	haracteris	stics of theory-base	ed intervention s	tudies								
Study	Sample		Interv	ention Componen	ıts			МС	assessment	Post-intervention	n Tests	Adjustments/effects by sex
	(number, SES, age[year])	Theory (Type & Operationalization)	Content of intervention (condition for the control if applicable) Continuation of intervention after proct.tet (Vac/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; Iow SES) 3-5 y	DST Task & environment constraints manipulation	INT1: SKIP INT1: SKIP INT2: SKIP + SKIP-PI (parents were trained to work with their child at home on simple motor skill activities) CON: regular Head Start curriculum (free play- no feedback and no instruction)	INT1: 30 min x 3 days/w regular program plus 30 min x 2 days/w SKIP 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) Int2: 8w (720- 840 min)	INT: researchers 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. 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 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. 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. GMQ remained significantly higher (p= .019)	Not reported
Cliff et al (2011, AU)[35]	Children (165, 59% girls, 78% obese) 8-12 y	AGT TARGET	INT1: Physical activity skill development program (PA). INT 2: Dietary modification program (DIET). INT 3: Combined physical activity and dietary modification program (PA+DIET). NO	90 min x 1 day/w	6 m (900 min)	INT1: researcher (PE qualified) 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) 6 m (posttest to follow- up) 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 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) 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) 12 m (posttest to follow-up)	Balance: The Group x Time interaction did not interact with sex (p = .552).

			first four involve gross motor development, the second four focus on fine motor development and last module targets socioemotional development. CON: normal curriculum NO							.001) and the control group (p < .001). Catching: there was an intervention effect (p=.009); there was a significant increases in catching scores from pretest to post-test, (p < .001). 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). 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 significant increase in throwing: INT-CON, significant increase in throwing: bean bag onto mat skills scores from post-test to follow-up (p < .001).	Catching: Group x Time did not interact with sex (p = .069). Throwing: 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. In CON, from pre to posttest there was a significant pre-post increases in boys (p = .012) and the girls (p < .001). 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) 3-5 y	SCT 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. CON: Active Play without support, active paly program, however, no professional development, session delivery, or post program support were provided + existing physical activity curriculum.	60 min x 1 day/w	6 w (360 min)	INT: practitioner (trained) 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. 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. 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 interaction (p < .09) was observed for LS score in the crude analysis, but this was attenuated after adjusting for covariates. No other significant sex interactions were observed.
Iivonen et al (2011, FI)(33]	Children (83, 45.2% girls) 4-5 y	DST ??	INT: physical education lessons according to the Physical Education Curriculum (PEC) of the Early Steps Project. CON: unstructured physical education.	45 min x 2 days/w	8 m (2160 min)	INT: pre-school teacher CON: pre-school teacher	QE (PreS)	Static & dynamic balance, running, standing broad jump, and sum variable of three different	Adapted APM Inventory (OCS)	Girls: 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. Standing board-jump:	3 m. Girls: Dynamic balance: INT-CON (p=.596), Standing board-jump: INT-CON (p=.220), Sum variable of manipulative skills: INT-CON (p=.904), there was no significant	Reported for boys and girls separately

Kalaja et al	Adolescents	AGT	NO	25 min x 22	33 w (825	INT: PE teacher	OF	manpulati ve skills (throwing catching combinatio n, throwing kicking)	Flamingo standing	INT ~ CON (p=.220), there was significant improvement from measurement 2 to 3. Boys: Dynamic balance: INT ~ CON (p=.944), Standing board-jump: INT ~ CON (p=.314), Sum variable of manipulative skills: INT~CON (p=.372), there was no significant difference between measurement 2 and 3. Running speed: Only INT improved from measurement 2 to measurement 3.	improvement between measurement 3 and 4 for all three motor skills. Running speed: INT-CON ( $p=248$ ), there was significant difference between measurement 3 and 4 ( $p<.001$ ). There was not a significant improvement between measurement 3 and 4. Boy: Dynamic balance: INT ~ CON ( $p=.344$ ), Standing board-jump: INT ~ CON ( $p=.314$ ), Sum variable of manipulative skills: INT-CON ( $p=.372$ ), there were no significant difference between measurement 3 and 4. Running speed: There was significant improvement from measurement 3 to 4.	Not reported
Kalaja et al (2012, FI)[37]	Adolescents (46, 51.6% girls) ~13 y, 7 grade	AGT TARGET	INT: intervention included FMS training sessions focusing on developing I dimension 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). CON: regular PE classes NO	25 min x ?? days/w	33 w (825 min)	INT: PE teacher CON: PE teacher	QE (SecS)	Balance, rolling, leaping, running, roping, throwing, dribbling	Flamingo standing test, rolling test, leaping test, shuttle run test, rope jumping test, accuracy throwing test, figure-8 dribbling test	INT > CON for flamingo standing test (P = .001), INT > CON for rolling test (P = .000), INT > CON for balance skill sum score (P = .000), INT > CON for movement skills sum score (P = .000).	6 m INT > CON for flamingo standing test (P = .046), INT > CON for balance skill sum score (P = .014).	Not reported
Kelly et al. (2021, IR)[64]	Children (255, 50% girls) 6-8 y	TARGET	IN1: 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	δ w (/20 min)	INT: an instructor with specialist FMS knowledge CON: class teacher	Longitud inal cluster crossove r design (PriS)	FMS: LS & OC	IGMD-3	Significant group × time interaction effects for locomotor, ball skills and total FMS scores (all p < .001) following engagement in the FMS intervention.	15 m 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 $p > 0.05$ ).

			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 CON: Usual PE 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 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 CON: ??	??	6 m (??)	INT: researchers CON:??	Cluster RCT (F)	Coordinati on, throwing and catching ball (TCB)	KTK and APM inventory	KTK: INT- CON TCB: INT>CON (p = .051).	6 m. KTK: INT-CON TBC: INT-CON (p=.984) 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 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) 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. CON improved in total OC (p=.01), total FMS (p<.0001) and total LS (p=.04).	3 m. INT improved in total OC (p<001), total LS (p<.0001) and total FMS (p=.04). 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).

			during school time, and 4) The website component: resources are made available online. CON: regular PE lessons NO									
Piek et al (2013, AU)[32]	Children (335, 49.7% girls; low SES) 4-6 y	DST Task & environment constraints manipulation	INT: lessons including different modules of the Animal Fun Program (body management, locomotion, object control, etc.) CON: regular curriculum NO	30 min x 4 days/w	6 m (??)	INT: pre-school teacher (trained) CON: pre-school teacher	RCT (PreS)	Gross & fine motor skills	BOT-2 SF (total score)	INT~CON; Pre to posttest were not significant for CON (p=.291) and INT (p=.077).	18 m (pretest to follow-up)         12 m (posttest to follow-up)         11 m (posttest to follow-up)         INT ~ CON; Posttest to follow-up were not significant for CON (p=.692) and INT (p=.080).         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). 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 TARGET	INT 1: low autonomy (teacher centered)- direct instruction INT 2: mastery motivational climate (student-centered). 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. CON: Control (no instruction)- Regularly scheduled free play NO	30 min x 2 days/w	9 w (540 min)	INT: researcher + doctoral student in motor development 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. 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. Between group difference: INT1-INT2 (p=.42) in OC scores. INT 1& INT2 > CON in OC scores (P = .001). Within-group difference: In INT 1&2 OC scores decreased significantly from posttest to follow-up (p=.001). In CON, there no significant change from posttest to follow-up (p=.90). 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 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: ?? CON: ??	QE (PreS)	FMS (OS)	TGMD-2	INT>CON (p<.001)	18 w (pretest to follow- up) 9 w (posttest to follow- up) Pretest to follow-up: INT>CON (p<.001) Posttest to follow-up: INT>CON (p<.001)	Not reported

			(task, authority, recognition, grouping, evaluation, time) structure. NO									
Robinson et al. (2017, USA)[38]	Children (124, 46.7% girls) 48.14 m	AGT TARGET	INT: Each lesson used TARGET (task, authority, recognition, grouping, evaluation, time) structure. CON: free play NO	30 min x 2 days/w	9 w (432-468 min)	INT: motor development specialist 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) 9 w (posttest to follow- up) INT>CON in OC scores from to pretest to follow-up (p<.001), and posttest to follow- up (p<.001).	Pre to post: INT girls > CON boys & girls; INT boys > CON boys & girls; INT girls ~ INT boys; CON boys ~ CON girls in OC scores. Posttest to follow-up: INT girls > CON boys & girls; INT boys > CON boys & girls; INT girls ~ INT boys; CON boys ~ CON girl. Pretest to follow-up: INT girls > CON boys & girls; INT boys > CON boys & girls; 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 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. 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. INT 3: Received both BM and FMS. CON: Usual curriculum	40-50 min x ?? days/w (19 sessions)	9 m (855 min)	INT: PE specialist 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) 6 m (posttest to follow- up) No significant intervention effects on FMS z-scores.	INT 1 girls > CON girls for FMS z scores (p<.05); INT 2 girls> CON girls for FMS z scores (p<.01).

									1			
Valentini &	Children	AGT	INT: Mastery climate:	35 min x 2	12 w (840	INT 2: motor	QE	FMS: LS	TGMD	LS:	6m.	Not reported
Rudisill	(67, 64.1%		Each session lasted 35	days/w	min)	development	(Kin)	& OC		INT > CON (p=.002); LS	LS:	
(2004b,	girls; DD)	TARGET	min and consisted of			specialists +				development increased for both	INT>CON	
BR)[41]	5.45 y		three parts: (a) 3 min of			university				group (p=.001).	(p=.0001);	
/L ]			introduction (b) 30			students (trained)				5 1 1	INT maintained the	
			min of skill instruction			students (trunted)				00	same skill	
			and preatice and (a) a			CON 2: 22				INT. CON	development whereas	
			and practice, and (c) a			CON 2. 11				(a AAC) both second increased	CON shares d	
			2-min closure of the							(p= .446); both groups improved	CON showed	
			lesson. Each lesson							from pretest to posttest.	significant decreases.	
			used TARGET (task,									
			authority, recognition,								OC:	
			grouping, evaluation,								INT>CON	
			time) structure.								(p=.001); there was no	
											significant change for	
			CON: Low autonomy-								INT, but CON showed	
			free play								a significant decrease	
			1 5								in skill development.	
			NO									
Veldman et al	Girls (54	Yes (AGT - TARGET)	INT: Children's Health	30 min x 2	9 w (540 min-	INT: Ph D	RCT	FMS:	TGMD-2	INT>CON $(n < 001)$	9w	Single gender study
(2017	100% girls	105 (1101 1111(021))	Activity Motor	days/w	423_468 min	students in Motor	(PreS)	throwing	10002	Girls in INT group significantly	$INT \ge CON (p < 001)$	Single gender study
(2017, USA)[30]	low SES)		Program (CHAMP)	days/w	of pure motor	Behavior	(1105)	catching,		improved their ball skills $(p < 001)$	Girls in the INT group	
USA)[57]	2.5 v		Flograni (CHAMF).		of pure motor	Denavior		catching,		whereas the control group did not	significantly increased	
	5-5 y		CONTRACTOR		SKIII	CON		surking on		whereas the control group did not	significantly increased	
			CON: the standard		instruction)	CON: no		a tee,		change ( $p > .05$ ).	in ball skills ( $p < .001$ )	
			movement			instructor		kicking,			whereas the control	
			opportunities of the					dribbling,			group did not $(p > .05)$ .	
			preschool. This time is					and				
			predominately self-					rolling.				
			directed and does not									
			incorporate specific									
			instruction, feedback.									
			and practice in motor									
			skills from an									
			instructor									
			mstructor.									
			NO									
New ACT: A L			NO	h1 -1-11da2			(L. A., et al. 1	DL Dalaham Dr	OT: Desisiste Or 1	The fMater De Calence D. D. 11	Charles Chille Charles	Manager Lang COM
Note: AGT: Achie	evement Goal The	eory, APM-Inventory: Manual te	NO st booklet for assessing presc	hool children's per	ceptual and fundar	nental motor skills; Al	U: Australia, I	BL: Belgium, BO	OT: Bruininks-Oseretsk	y Test of Motor Proficiency, Br: Brazil,	CA: Canada, CMJ: Counter	Movement Jump, COM:
Note: AGT: Achie Community, CON	evement Goal The	eory, APM-Inventory: Manual te evelopmentally Delayed, DST: D	NO st booklet for assessing press lynamic Systems Theory, F:	chool children's per Family, FI, Finland	ceptual and fundat , FMS: Fundament	nental motor skills; Al tal Motor Skills, GE: C	U: Australia, I Germany, GM	BL: Belgium, BC Q: Gross Motor	OT: Bruininks-Oseretsk Quotient, QE: Quasi E	ry Test of Motor Proficiency, Br: Brazil, xperimental, GS: Graduate Students, H: I	CA: Canada, CMJ: Counter Home, INT: intervention, IR	Movement Jump, COM: : Ireland, KTK:
Note: AGT: Achie Community, CON Körperkoordinatic	evement Goal The V: control, DD: De onstest für Kinder,	eory, APM-Inventory: Manual te evelopmentally Delayed, DST: D , LS: Locomotor Skills, MABC:	NO st booklet for assessing press bynamic Systems Theory, F: Movement Assessment Batt	hool children's per Family, FI, Finland ery for Children, M	ceptual and fundar , FMS: Fundament IF: Maximal Isom	nental motor skills; Al tal Motor Skills, GE: C etric Force, OCS: Obje	U: Australia, I Germany, GM ect Control Sk	BL: Belgium, BO Q: Gross Motor ills, OW: Overv	OT: Bruininks-Oseretsk Quotient, QE: Quasi E veight, OB: Obese, PDI	ty Test of Motor Proficiency, Br: Brazil, xperimental, GS: Graduate Students, H: I MS: Peabody Developmental Motor Scale	CA: Canada, CMJ: Counter Home, INT: intervention, IR es, PP: pre-post experimenta	Movement Jump, COM: : Ireland, KTK: I 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. Cha	racteristics	of atheoretical intervention	on studies								
Study	Sample (number, SES,		Intervention C	components			MC asses	sment	Post-inte	rvention Tests	Adjustments/effects by sex
	age[year])	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) 3.6-5.1 y	INT: usual PE-curriculum + developmentally appropriate motor program (not detailed) CON: usual PE-curriculum	60 min x 2 days/w	10 w (1200 min)	INT: PE teacher (trained) CON: ??	QE (NS)	FMS (OCS)	TGMD-2 (total & OCS)	None	5 w. GMQ of INT > GMQ of CON (p < 0.001), while the GMQ score of the CON tended to decrease over time (p = 0.009). 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 over time (p = 0.988), while	Girls' GMQ: INT had improved significantly (p = 0.004) while CON decreased over time (p < 0.001). Boy's GMQ: There were no effects of time on the GMQ in either INT or CON. Both girls (p<001) and
										the performance on OCS decreased (p < 0.001). For GMQ (p<.001), LS (p= .007) and OCS (p<.001): INT> CON.	boy (p=.017) in INT > girls and boys in CON. Girls' OCS: in INT improved significantly (p = 0.004) while the score of girls from the CON decreased over time (p < 0.001). 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. No significant difference between boys and girls in LS was found.
Barnett et al. (2009, AU)[70]	Children (1045, 47% girls) 10.1 y	INT: Move It Groove It CON: ??	??	1 y (??)	INT: researcher and research assistant (trained) COT: ??	QE (PriS)	Catch, kick, throw, vertical jump, side gallop	Get Skilled Get Active	None	6 y. 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.
Bedard et al. (2017, CA)[59]	Children (11, ??% girls) 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 (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 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) 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 CON: ??	QE (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.?? 18 m. (posttest to follow-up) In balance, both INT & CON remained significantly lower in balance (p < 0.001).	Not reported

		activities were conducted in the kindergarten and first grade classrooms 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). There were no significant differences for running speed and agility (locomotor skills) or strength	
Coppens et al. (2021, BE)[65]	Children (399, 6% girls) 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). CON: ??	60 min x 1 day/w	30 w (??)	INT: experienced examiners CON: ??	QE (??)	FMS: LS & OC	TGMD-2	The intervention group outperformed the control group (p<.001).	6 y 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) 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: Balance, coordination, underhand throwing, catching, striking, running, jumping, and correct use of a racquet (to grip and swing) CON: normal PE curriculum	50 min x 1 day/w	6 w (300 min)	INT: principal investigators and a school teacher CON: PE teacher	Cluster Randomi zed 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: In 6-7 y children: INT > CON in total FMS (p =.0001)In 10-11 y children: INT ~ CON (p = 0.431)For all INT and CON children, total FMS significant increased pre to post intervention (all p < 0.05).Ten-Meter Sprint Speed: INT ~ CON in all children in age groups. Ten-meter sprint speed decreased pre to post intervention groups aged 6-7 years (p = 0.0001, d = 0.001, d = 0.2) compared to control.Standing Long Jump: 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).One-kilogram Medicine Ball Throw: INT ~ CON in all children (p>.05).	10 w FMS: In 6-7 y children: INT > CON in total FMS (p =.0001) In 10-11 y children: INT ~ CON (p = 0.361). 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). Ten-Meter Sprint Speed: INT ~ CON in all children in age groups. 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. Standing Long Jump: were also significantly greater at 10 weeks post intervention, compared to post, for the INT group (p = 0.0001, d = 0.5, small to moderate) but not the CON group (p = 0.56), 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: boys > girls Ten-Meter Sprint Speed: Boys ~ girls Standing Long Jump: Boys ~ girls One-kilogram Medicine Ball Throw: Boys>girls (p = 0.001)

									to post (p = 0.0001, d = 0.3) for the INT group.	One-kilogram Medicine Ball Throw: INT ~ CON in all children (p>.05).	
Granacher et al. (2011, GE)[61]	Adolescents (28, 62.5% girls) 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 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 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. MIF (p = 0.04) still present after INT.	Not reported
Jurak et al. (2013, SL)[63]	Children (324, 48.7% girls) 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. CON: standard PE classes.	45 min x 5 days/w	4 y (??)	INT: specialist PE teacher + classroom teacher 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. INT-CON in polygon backwards, sit-ups, bent arm hang, and 600- metre run.	7 y. INT-CON: 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) 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 CON: non-structured active play	20 min x 7 days/w	4 w (2100 min)	INT: PE specialist 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. 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) 47.38 m	INT: SKIP CON: free play	30 min x 2 days/w	10 w (600 min)	INT: doctoral student (trained, with PE teaching certification) CON: ??	QE (PreS)	FMS (LS & OC)	TGMD-2	None	2 w. INT > CON (p = .004)	Effects for gender ( $p = .14$ ), and Gender x Condition ( $p = .40$ ), were not significant.
Reiily et al. (2006, SC)[72]	Children (545, 47.7% girls) 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 CON: usual curriculum, with the head	30 min x 3 days/w	6 m (??)	INT: nursey staff (trained) CON: nursey staff	Cluster RCT (NS & H)	Gross & fine motor skills	MABC-2 (total score)	INT>CON	6 m INT>CON (p=.0027) after adjustment for sex and baseline performance.	Girls improved more than boys (p = 0.001)

		teachers agreeing not to enhance physical development and movement curriculum									
Roth et al. (2015, GE)[68]	Children (709, 49.5% girls) 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 CON: routine schedule, including common daily activity and weekly PA class	30 min x 5 days/w	11 m (??)	INT: pre-school teacher (trained) 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 (p = 0.001). 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. INT>CON (p = 0.007). 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) 5-6 y	INT: lesson focused on demonstration and teaching of throwing and feedback on performance CON: free play	30 min x 1 day/w	4 w (??)	INT: ?? CON: ??	QE (PreS)	Throwing	Roberton's segmental analysis profile	INT~CON (p>.05); both the taught and play groups improved significantly (p<0.05)	2 m. INT>CON (p<.05)	Not reported
Van Beurden et al (2003, AU)[73]	Children (1045, 47% girls) 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 CON: ??	??	1 y (??)	INT: classroom teacher (trained) and preservice teacher 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). 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). 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. INT SCON 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) 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 CON: regular curriculum	25-30 min x 2 days/w	10 m (500-600 min)	INT: trained staff CON: ??	QE (PreS)	FMS: LS & OC	TGMD-2	INT > CON	3y LS: INT ~ CON (p = .063) from pre-test to follow-up. OC: Girlis: INT > CON from pre- test to follow-up. Boys: INT ~ CON from pre- test to follow-up.	LS: boys ~ girls (p = .179) 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, NPR: 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]	?	$\checkmark$	X	$\checkmark$	Х	Х	$\checkmark$	Х	$\checkmark$	
Cliff et al (2007)[36]	N/A	$\checkmark$	N/A	√	N/A	Х	√	√	Х	
Cliff et al (2011)[35]	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	Х	√	X	$\checkmark$	
De Oliveira et al (2019)[31]	$\checkmark$	~	√	$\checkmark$	Х	X	√	$\checkmark$	√	
Foulkes et al. (2017)[50]	$\checkmark$	~	√	$\checkmark$	Х	X	√	?	√	
Iivonen et al (2011)[33]	X	~	Х	$\checkmark$	X	×	√	X	X	
Kalaja et al (2012)[37]	N/A	$\checkmark$	Х	$\checkmark$	Х	×	X	Х	?	
Kelly et al. (2021)[64]	$\checkmark$	~	Х	$\checkmark$	√	√	√	$\checkmark$	√	
Laukkanen et al (2015)[49]	?	$\checkmark$	×	$\checkmark$	$\checkmark$	×	$\checkmark$	?	Х	
McGrane et al. (2018)[48]	$\checkmark$	~	Х	$\checkmark$	√	√	√	$\checkmark$	√	
Piek et al (2013)[32]	?	$\checkmark$	Х	$\checkmark$	X	×	√	X	X	
Robinson & Goodway (2009)[42]	Х	~	Х	$\checkmark$	Х	X	√	X	√	
Robinson et al. (2011)[40]	Х	$\checkmark$	Х	√	N/A	Х	√	Х	Х	
Robinson et al. (2017)[38]	?	$\checkmark$	Х	√	X	Х	√	√	$\checkmark$	
Salmon et al (2008)[47]	?	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	Х	Х	?	Х	
Valentini & Rudisill (2004b)[41]	?	$\checkmark$	Х	√	X	Х	√	Х	$\checkmark$	
Veldman et al (2017)[39]	√	$\checkmark$	$\checkmark$	$\checkmark$	Х	Х	$\checkmark$	Х	Х	
Atheoretical Intervention Studies										
Bardid et al. (2013)[62]	?	$\checkmark$	√	√	×	Х	√	√	√	
Barnett et al. (2009)[70]	N/A	×	Х	Х	X	Х	Х	×	$\checkmark$	
Bedard et al. (2017)[59]	N/A	$\checkmark$	N/A	√	N/A	Х	√	?	X	
Bellow et al. (2017)[60]	×	$\checkmark$	Х	$\checkmark$	X	Х	$\checkmark$	×	$\checkmark$	
Coppens et al. (2021)[65]	×	$\checkmark$	×	Х	$\checkmark$	Х	$\checkmark$	$\checkmark$	$\checkmark$	
Duncan et al (2020)[67]	?	×	×	$\checkmark$	×	×	$\checkmark$	×	$\checkmark$	
Granacher et al. (2011)[61]	?	?	Х	$\checkmark$	Х	$\checkmark$	$\checkmark$	Х	X	
Jurak et al. (2013)[63]	×	×	×	$\checkmark$	$\checkmark$	×	$\checkmark$	$\checkmark$	×	
Matvienko et al (2010)[71]	N/A	$\checkmark$	Х	Х	X	×	√	$\checkmark$	?	
Mulvey et al. (2020)[66]	?	$\checkmark$	X	X	X	×	$\checkmark$	$\checkmark$	$\checkmark$	
Reilly et al. (2006)[72]	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	X	$\checkmark$	√	?	$\checkmark$	
Roth et al. (2015)[68]	$\checkmark$	X	√	$\checkmark$	$\checkmark$	X	√	$\checkmark$	$\checkmark$	
Smyth et al (1998)[74]	?	Х	×	$\checkmark$	Х	×	$\checkmark$	X	Х	
Van Beurden et al (2003)[73]	N/A	Х	Х	?	$\checkmark$	Х	X	?	Х	
Zask et al (2012)[69]	N/A	Х	X	$\checkmark$	Х	X	X	Х	Х	
√, 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										

