Fundamental movement skills in children and adolescents: Review of associated health benefits

Running title: Benefits of FMS competency in youth

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Figure 1: Flow of studies through the review process

Abstract

The mastery of fundamental movement skills (FMS) has been purported as contributing to children's physical, cognitive and social development and is thought to provide the foundation for an active lifestyle. Commonly developed in childhood and subsequently refined into context- and sport-specific skills, they include locomotor (e.g. running and hopping), manipulative or object control (e.g. catching and throwing) and stability (e.g. balancing and twisting) skills. The rationale for promoting the development of FMS in childhood relies on the existence of evidence on the current or future benefits associated with the acquisition of FMS proficiency. The objective of this systematic review was to examine the relationship between FMS competency and potential health benefits in children and adolescents. Benefits were defined in terms of psychological, physiological and behavioral outcomes that can impact public health. A systematic search of six electronic databases (EMBASE, OVID MEDLINE, PsychINFO, PubMed, Scopus, and SPORTDiscus) was conducted on the 22nd June 2009. Included studies were cross-sectional, longitudinal or experimental studies involving healthy children or adolescents (aged 3-18 years) that quantitatively analyzed the relationship between fundamental movement skills and potential benefits. The search identified 21 articles examining the relationship between FMS competency and eight potential benefits (i.e. global self-concept, perceived physical competence, cardio-respiratory fitness [CRF], muscular fitness, weight status, flexibility, physical activity and reduced sedentary behavior). We found strong evidence for a positive association between FMS competency and physical activity in children and adolescents. There was also a positive relationship between FMS competency and CRF and an inverse association between FMS competency and weight status. Due to an inadequate number of studies, the relationship between FMS competency and the remaining benefits was classified as uncertain. More longitudinal and intervention research examining the relationship between

FMS competency and potential psychological, physiological and behavioral outcomes in children and adolescents is recommended.

Fundamental movement skills (FMS) are considered to be the building blocks that lead to specialized movement sequences required for adequate participation in many organized and non-organized physical activities for children, adolescents and adults [1, 2]. Commonly developed in childhood and subsequently refined into context- and sport-specific skills [2-4], they include locomotor (e.g. running and hopping), manipulative or object control (e.g. catching and throwing) and stability (e.g. balancing and twisting) skills [1]. The mastery of FMS has been purported as contributing to children's physical, cognitive and social development [5] and is thought to provide the foundation for an active lifestyle [1, 3]. Recently, FMS competency has been proposed to interact with perceptions of motor competence and health-related fitness to predict physical activity and subsequent obesity throughout development from childhood to adulthood [3].

While children may naturally develop a rudimentary form of fundamental movement pattern, a mature form of FMS proficiency is more likely to be achieved with appropriate practice, encouragement, feedback, and instruction [1, 2]. Children who do not receive adequate motor skill instructions and practice typically demonstrate developmental delays in their gross motor ability [6]. As such, early childhood physical activity guidelines, such as the National Association for Sport and Physical Education's (NASPE) *Active Start*, indicate that the development of movement skills should be a key component of early childhood education programs [7]. Likewise, FMS competency is identified in National Standards as a primary goal of quality elementary school physical education in the U.S. [8] and represents an indicator of achievement for elementary school children in England's national physical education curriculum [9]. Despite this focus, the prevalence of FMS mastery among children in some countries appears inadequately low [10, 11]. For example, in a recent U.S. study of 9- to 12-year-old children, only half of the students assessed demonstrated proficiency in basketball throwing and dribbling motor tasks [11]. Similarly, an Australian study [12] involving students from Years 4, 6, 8, and 10 (aged 9 to 15 years) found that the prevalence of mastery only exceeded 40% for one skill in one group (i.e. overarm throw, Year 10 boys).

The rationale for promoting the development of FMS in childhood relies on the existence of evidence on the current or future benefits associated with the acquisition of FMS proficiency. Despite support for FMS promotion among motor behaviorists [3] and physical educators [13], the potential benefits of FMS competency have not yet been methodically evaluated. The purpose of this review is to systematically examine the potential psychological, physiological and behavioural public health benefits associated with FMS competency in children and adolescents.

1. Methods

1.1 Identification of studies

The Quality of Reporting of Meta-analyses statement (QUOROM) [14] was consulted and provided the structure for this review. A systematic search of six electronic databases (EMBASE, OVID MEDLINE, PsychINFO, PubMed, Scopus, and SPORTDiscus) was conducted from their year of inception to 22nd June 2009. Individualized search strategies for the different databases included combinations of the following key words ‘child’, ‘adolescent’, ‘youth’, ‘movement skill’, ‘motor skill’, ‘actual competence’, ‘object control’, ‘locomotor skill’, and ‘motor proficiency’. Only articles published or accepted for publication in refereed journals were considered for review. Conference proceedings and abstracts were not included. In the first stage of the research, titles and abstracts of identified articles were checked for relevance. In the second stage, full-text articles were retrieved and considered for inclusion. In the final stage, the reference lists of retrieved full-text articles were searched and additional articles known to the authors were assessed for possible inclusion. Eighteen expert informants in the area were also contacted to suggest or provide relevant manuscripts.

1.2 Criteria for inclusion/exclusion

Two authors (DRL and DPC) independently assessed the eligibility of the studies for inclusion according to the following criteria: (i) participants were aged 3 to 18 years (research articles that focused on youth from special populations were not included, e.g. overweight/obese, developmental coordination disorder), (ii) process (i.e. concerned with process or technique also known as qualitative) or product (i.e. concerned with outcome) assessment of at least two FMS (e.g. run, vertical jump, horizontal jump, hop, dodge, leap, gallop, side gallop, skip, roll, throw, stationary dribble, catch, kick, two-handed strike, static balance), (iii) summary/subtest measure of FMS competency (e.g. locomotor or object control summary score) was used in analyses, (iv) quantitative assessment of potential health benefit of FMS competency (i.e. psychological, physiological or behavioral), (v) quantitative analysis of the relationship between FMS and potential benefits in any of the above domains, (vi) cross-sectional, longitudinal or experimental/quasi-experimental study design, (vii) published in English. As this review focused on the potential benefits of FMS, which are gross motor skills [1], studies that used measurement batteries that included fine motor skills were excluded to preserve internal validity.

1.3 Criteria for assessment of study quality

Two authors (DRL and PJM) independently assessed the quality of the studies that met the inclusion criteria. The criteria for assessing the quality of the studies were adapted from the Strengthening the Reporting of Observational Studies in

Epidemiology (STROBE) statement [15] and the Consolidated Standards of Reporting Trials (CONSORT) statement [16]. A formal quality score for each study was completed on a 6-point scale by assigning a value of 0 (absent or inadequately described) or 1 (explicitly described and present) to each of the following questions listed: (i) Did the study describe the participant eligibility criteria? (ii) Were the participants randomly selected (or for experimental studies, was the process of randomization clearly described and adequately carried out?) (iii) Did the study report the sources and details of FMS assessment and did the instruments have acceptable reliability for the specific age group? (iv) Did the study report the sources and details of assessment of potential benefits and did all of the methods have acceptable reliability? (v) Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships? (vi) Did the study report the numbers of individuals who completed each of the different measures and did participants complete at least 80% of FMS and benefit measures? Studies that scored 0-2 were regarded as low quality studies, studies that scored 3-4 were classified as medium quality and those that scored 5-6 were classified as high quality. All studies were included in the review, however, an additional coding was applied to studies identified as high quality.

1.4 Categorization of variables and level of evidence

The benefits were categorized as follows: psychological (e.g. physical self-perception), physiological (e.g. fitness and healthy weight status) and behavioral (e.g. time spent in physical activity and sedentary behaviors). It must be noted that studies assessing the benefit of fitness in this review will be discussed in terms of whether they used product- or process-oriented motor skill assessments. This is because product-oriented motor skill assessments can view certain fitness constructs (such as strength and speed) as part of the motor skill assessment, unlike process-orientated assessments which are concerned with the quality or technique of the skill execution.

Results were coded using the methods first described by Sallis et al. [17] and more recently by Hinkley et al [18] and Van der Horst et al [19]. The relationship between FMS competency and each potential benefit was determined by examining the percentage of studies that reported a statistically significant relationship (i.e. between FMS competency and benefit) and is explained in Table I. If only 0-33% of the included studies reported a relationship between FMS competency and the benefit, the result was categorized as no association (0). If 34-59% of the studies reported statistically significant relationships between FMS competency and the benefit, the result was categorized as uncertain (?). If 60-100% of studies reported a positive relationship between FMS competency and the benefit, the result was coded as a positive association (+). The methods of Sallis et al. [17] were modified to address the issue of study quality and additional coding was conducted based on studies assessed as high quality. If 60-100% of high quality studies (≥ 4) found a positive relationship between FMS competency and the benefit, the result was coded as having strong evidence for a positive association (++).

2. Results

2.1 Overview of studies

A total of 1798 potentially relevant articles were identified using database searches (Figure 1). Following feedback from international experts and checking the reference lists of included studies, a total of 21 articles satisfied the inclusion criteria and were included in the review (Table II). The flow of studies through the review process and the reasons for exclusion are reported in Figure 1. Of the included articles, 15 reported on cross-sectional studies, four on longitudinal studies and two on experimental studies. Nine studies were conducted in Australia, eight in the United States, and one each in Canada, Scotland, Belgium and Germany. The number of study participants ranged from 29 [20] to 4363 [21].

2.2 Overview of study quality

There was 96% agreement between authors on the study assessment criteria and full consensus was achieved after discussion. Results from the study quality assessment are reported in Table III. Seven studies were identified as high quality [21-27], 13 studies were rated as medium quality [11, 20, 28-38] and one study was classified as low quality [39]. Most of the studies used valid and reliable measures of FMS assessment and also reported the reliability data from their potential benefits. None of the studies reported power calculations to determine if the studies were adequately powered to detect the hypothesized relationships.

2.3 Psychological benefits

A summary of the associations between FMS competency and potential benefits is reported in Table IV. Three studies examined the relationship between perceived physical competence and FMS competency [23, 25, 29]. Perceived competence was associated with at least one aspect of FMS competency in all three studies. Perceived competence refers to an individual's perception of their actual motor proficiency. In a 6-year longitudinal study, Barnett et al.[25] found that object control competency in childhood was associated with perceived physical competence in adolescence. Only one study assessed the association between FMS competency and global self-concept [28]. Martinek and colleagues [28] examined the impact of a motor skill intervention on FMS and self-concept in a sample of 344 children. Although

FMS and self-concept improved over the study period, the relationship between self-concept and FMS was non-significant at baseline and posttest [28].

2.4 Physiological benefits

Weight status was the most commonly assessed physiological benefit of FMS competency and was included in nine studies. Body composition was generally estimated using BMI z-score, however, skinfolds were used in one study [32]. Six of the nine studies found an inverse association between FMS competency and BMI z-score [11, 23, 32, 33, 37, 38, 40] and three studies found no association between FMS competency and weight status [27, 34, 35].

Four studies examined the relationship between FMS competency and CRF. All four found a positive relationship between skill ability and fitness level [20, 22, 26, 30]. Three of these studies used a process-oriented motor skill assessment [22, 26, 30] and one used a product assessment [20]. One study found positive associations between FMS competency, muscular fitness and flexibility [34]. Another study found a positive relationship between FMS competency and a composite physical fitness score (which included CRF, strength, endurance, flexibility and BMI) [11].

2.5 Behavioral benefits

Thirteen studies examined the relationship between FMS competency and participation in physical activity. Eight studies used self-report measures of physical activity, four studies used objective measures of physical activity (i.e. accelerometers) and one study used both self-report and pedometers. FMS competency was found to be associated with at least one component of physical activity (e.g. non-organized activity, organized activity, pedometer step counts) in 12 of the cross-sectional studies [11, 24, 25, 27, 31, 33-37, 39] and one of the longitudinal studies [36]. Longitudinally , McKenzie et al [32] found that FMS competency at ages 4 to 6 did not predict physical activity at age 12. Both studies that examined the association between sedentary behavior and FMS competency in children [33, 38] did not find a statistically significant relationship.

3. Discussion

3.1 Overview of findings

The aim of this systematic review was to identify the health benefits associated with FMS competency in children and adolescents. We found 21 articles that assessed eight potential benefits (i.e. self-concept, perceived physical competence, CRF, muscular fitness, weight status, flexibility, physical activity and sedentary behavior). We found strong evidence from cross-sectional studies for a positive association between FMS competency and physical activity in children and adolescents. There was also a positive association between FMS competency and CRF, and an inverse association between FMS competency and weight status. Due to an inadequate number of studies, the relationship between FMS competency and global self-concept, perceived physical competence, muscular fitness, flexibility and sedentary behavior were classified as uncertain.

It has been suggested that proficiency in a range of FMS provides the foundation for an active lifestyle [1, 3]. The results from this review confirm the cross-sectional relationship between FMS competency and physical activity in children and adolescents. A number of large-scale cross-sectional studies [24, 31], some of which used objective measures of physical activity [24, 27], found positive associations between FMS competency and participation in physical activity. One longitudinal study found an association between childhood object control skill ability and adolescent physical activity [25, 36]. The other longitudinal study in this review found no association between FMS proficiency and physical activity [32]. This study examined early childhood (ages 4-6 years), three motor skills (lateral jumping, catching a ball, and balancing on one foot) and early adolescent (12 yrs) physical activity participation (measured via the seven day Physical Activity Recall questionnaire) [32]. However, the study was limited by the use of a physical activity self-report measure and the assessment of only three FMS. Furthermore, two of these skills included what the authors termed ‘a restricted range of measurement’; 0-2 for balancing and 0-6 for catching [32]. This notion that a more comprehensive skill battery might be needed to accurately test whether skill is associated with physical activity is substantiated by the positive associations found in this review; all the other studies that found positive associations between motor skill and physical activity assessed more than three motor skills.

The other factor that may have precluded the longitudinal study by McKenzie et al. finding no association, was that skills were measured before the children had been provided with an opportunity to participate in school physical education (PE) and in out-of-school PE and sport programs [32]. It has been proposed that the relationship between skill ability and physical activity may strengthen over time [41]. This theory may also be supported in this review, as the one cross-sectional study in which the relationship between physical activity and motor skill ability was most uncertain (both positive and negative associations) was in pre-school children [38]. Although, this study may simply be limited by a small sample size, as the other two studies in this age group did find positive associations (11,51).

We also found a positive association between FMS competency and CRF, and an inverse association between FMS competency and weight status. It has also been suggested that FMS competency might influence fitness levels, as activities that involve FMS also demand high levels of muscular and cardiorespiratory fitness [41].

More skillful children may increase their time in physical activity and persist with activities that require high levels of physical fitness [41], providing the opportunity for fitness adaptations through progressive overload. Increased time in higher intensity physical activity will contribute to higher levels of CRF and improvements in body composition [42].

3.2 Strengths and limitations

This is the first systematic review of studies examining the relationship between FMS competency and potential health benefits in children and adolescents. The QUOROM statement was consulted and provided the structure for this review which included an assessment of study quality using criteria adapted from the CONSORT and STROBE statements. However, there are a number of issues that should be noted. First, we did not include studies that combined gross motor skills and fine motor skills in the same composite score. For example, Wrotniak and colleagues [43] examined the relationship between motor competency and physical activity using the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP). While the BOTMP is an established measure of general motor ability, the current review was limited to FMS competency and therefore the inclusion of fine motor skills was beyond the scope of this review. It should also be noted that we excluded studies that did not provide a composite FMS score. A number of studies examined the relationship between individual FMS tests and potential benefits but did not provide a summary score [44-46]. Finally, due to the relatively small number of studies and the inclusion of longitudinal studies, the results for children and adolescents have been combined. As a result, this review could not assess whether the importance of FMS competency varies between childhood and adolescence [41], a hypothesis that requires further investigation.

4. Conclusions

Our review included only two longitudinal and two experimental studies. More longitudinal studies exploring the relationship between changes in FMS competency and potential benefits over time are needed to investigate the causal nature of such relationships. It has been hypothesized that children with high motor skill proficiency will have higher levels of fitness and perceived sports competence, which in turn predict greater participation in physical activity, and vice versa [41]. This proposed reciprocal relationship could also be investigated in future studies.

In the current review we did not include intervention studies that did not directly examine the relationship between FMS competency and potential benefits. For example, two previous high quality obesity prevention trials [47, 48] evaluated the impact of treatment on changes in FMS competency and BMI z-score in children, but did not report the relationship between such changes. Future physical activity and obesity prevention studies should conduct mediation analyses to identify if FMS competency mediates the impact of interventions on primary outcomes (e.g. BMI z-score, fitness). Few studies have conducted mediation analyses in physical activity interventions among youth [49] and the importance of FMS competency to future physical activity and other outcomes will be reinforced through this type of analysis. The one study reviewed that did conduct a mediation analysis [25], found that perceived sports competence acted as a mediator between skill ability and physical activity.

Due to the limited number of studies it was not feasible to examine how the association between motor skill ability and potential benefits might differ according to gender. Gender differences in motor proficiency have been found, with males generally more proficient than females in object control skill performance [35, 50-52]. In locomotor skill performance, some studies report no gender differences [35, 52, 53], while others report males [54] or females [52] as more proficient. The potential impact of these differences is important to investigate.

Our findings suggest that FMS development should be included in school- and community-based interventions. Teaching children to become competent and confident performers of FMS may lead to a greater willingness to participate in physical activities that may also provide opportunities to improve fitness levels and reduce the risk of unhealthy weight gain. It is important that such skills are taught during preschool and elementary school years as children are at an optimal age in terms of motor skill learning [1] and motor skill proficiency tracks through childhood [55]. In addition, improving the FMS competency of girls should be a priority as many girls lack basic skill proficiency [10, 11]. Existing school physical education programs have been criticized for not providing a learning environment to develop FMS [56], so training and resources should be prioritized to ensure children receive quality instruction in FMS.

FMS have been hypothesized as important to children and adolescents' physical, social and psychological development [1, 2], and may be the foundation of an active lifestyle. This review has provided evidence supporting the positive association between FMS competency in children and adolescents and physical activity. Furthermore, the positive association between FMS competency and CRF and the inverse relationship between FMS proficiency and weight status suggest that developing competency in movement skills may have important health implications for young people.

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Table I: Rules for classifying the association between potential benefits and FMS competency

Studies supporting association (%)	Summary code	Explanation of code
0-33	0	No association
34-59	?	Inconsistent
60-100	-	Negative association
60-100	+	Positive association
60-100	++	Strong evidence for a positive association

Note. The relationship between benefit and FMS competency was considered uncertain if <4 studies examined the relationship; Strong evidence for a positive association is identified when >60% of high quality studies (≥4 studies) reported a positive association.

Table II: Summary of included studies

Study	Sample	Type of study	Analyses	FMS measure	Benefits assessed	Results
Martinek et al [28]	344 children Age 6 to10 years United States	Experimental	ANCOVA and bivariate correlation	PRODUCT: Körper Koordinations Test für Kinder (KTK) (balancing backwards, one-legged obstacle jumping, jumping from side to side as well as sideway movements	Global self-concept (Self Concept Scale for Children)	FMS and self-concept improved in the intervention group over the study period. However the relationship between self-concept and FMS was non-significant at baseline and posttest
Rudisill et al [29]	218 children Age 9 to 11 years Grades 3, 4 and 5 United States	Cross-sectional	Bivariate correlation	PRODUCT: Locomotor (standing long jump, 50-yard dash and shuttle run) and object control (two ball throws short and long distance)	Perceived physical competence (Motor Perceived Competence Scale)	Locomotor and object control proficiency associated with perceived competency
Marshall and Bouffard [30]	200 children Grades 1 and 4 Canada	Experimental	ANOVA and bivariate correlation	PROCESS: Test of Gross Motor Development (run, gallop, hop, leap, horizontal jump, slide, skip, striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll)- characterized into locomotor and object control subtests	CRF (multi-stage fitness test)	Object control and locomotor FMS competency associated with CRF
Reeves et al [20]	29 children Age 5 to 6 years Kindergarten United States	Cross-sectional	Bivariate correlation	PRODUCT: Bruininks Oseretsky Test of Motor Proficiency- a) running speed and agility b) balance c) bilateral coordination subtests	CRF (half mile walk/run)	CRF (half-mile walk run) was positively associated with balance and bilateral coordination
Okely et al [22]	2026 adolescents Age 13 to 16 years Grades 8 and 10 Australia	Cross-sectional	Bivariate correlations and linear regression	PROCESS: Fundamental Movement Skills: A Manual for Classroom Teachers: run, vertical jump, catch, overhand throw, kick, strike	CRF (multi-stage fitness test)	FMS competency associated with CRF controlling for gender and grade at school

Okely et al [31]	982 adolescents Age 13 to 16 years Grades 8 and 10 Australia	Cross-sectional	Linear regression analysis (controlling for gender, grade, SES, geographic location)	PROCESS: Fundamental Movement Skills: A Manual for Classroom Teachers: run, vertical jump, catch, overhand throw, kick, strike	PA (APARQ)	FMS associated with time in organized PA but not time in non-organized PA controlling for gender and school grade
McKenzie et al [32]	207 children Age 4 to 6 years United States	Longitudinal	Bivariate correlation and linear regression	PRODUCT: Lateral jump, catch, and one foot balance	PA (PAR 7-day recall questionnaire) and adiposity (skinfolds- triceps and subscapular)	Inverse association between adiposity and FMS in boys but not girls Jumping related to PA at age 12 for girls FMS at ages 4-6 did not predict PA at age 12
Okely et al [40]	4363 children and adolescents Grades 4, 6, 8 and 10 Australia	Cross-sectional	Logistic regression modeling and multiple linear regression	PROCESS: Fundamental Movement Skills: A Manual for Classroom Teachers: run, vertical jump, catch, overhand throw, kick, strike	BMI z-score and waist circumference	FMS (locomotor) inversely associated with BMI z-score in children and adolescents
Graf et al [33]	668 children Age 6.7 ± 0.4 years Germany	Cross-sectional	ANCOVA (adjusted for age and gender) and bivariate correlation	PRODUCT: Körper Koordinations Test für Kinder KTK (balancing backwards, one-legged obstacle jumping, jumping from side to side as well as sideway movements	BMI z-score, time spent in organised PA (parent questionnaire) and watching TV (child questionnaire)	Inverse association between BMI and FMS Positive association between FMS and PA Non significant association between FMS and TV watching
Southall et al [23]	142 children Age 10.8 years Grades 5 and 6 Australia	Cross-sectional	ANCOVA	PROCESS: Test of Gross Motor Development 2	BMI z-score, perceived physical competence (SPPC)	Overweight children had lower total FMS and locomotor FMS Overweight children had lower perceived physical competence scores No difference between overweight and normal weight children for object control skills

Fisher et al [24]	394 children Age 4.2 ± 0.5 years Scotland	Cross-sectional	Bivariate correlation	PROCESS: Movement Assessment Battery: 15 skills including jumps, balance, skips, ball exercises and throwing	PA (accelerometer)	FMS associated with total PA and MVPA
Hamstra-Wright et al [39]	36 children Age 8 to 9 years United States	Cross-sectional	Linear stepwise multiple regression (controlling for gender and age) and bivariate correlation	PROCESS: Test of Gross Motor Development 2 (run, gallop, hop, leap, horizontal jump, slide, striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll)- characterized into locomotor and object control subtests	PA (sport experience questionnaire)	Participation in organized and non-organized PA was associated with locomotor competency
Castelli et al [34]	230 children Age 9.5 ± 1.6 years United States	Cross-sectional	Bivariate correlation	PROCESS: South Carolina Physical Education Assessment Program (SCPEAP) scoring and protocols including: basketball dribble and pass, paddle bat hit and overhand ball throwing to provide a summative score for FMS competency	PA (parent and child 7 day questionnaire, pedometer), BM z-score, flexibility, CRF (PACER), muscular endurance (curl ups and push-ups) and flexibility (sit and reach)	FMS competency associated with CRF, muscular endurance, flexibility and PA No relationship between FMS and BMI z-score
Barnett et al [26]	928 children 244 adolescents (follow-up) Age 16.4 years Grades 10 and 11 Australia	Longitudinal (6 year follow up)	General linear regression model controlling for gender	PROCESS: Get Skilled, Get Active: object control (kick, catch, overhand throw) locomotor (hop, side gallop, vertical jump)	CRF (multi-stage fitness test)	Childhood object control proficiency associated with CRF in adolescence
Barnett et al [25]	928 children 250 adolescents (PA model) 227 adolescents (Fitness model) Age 16.4 years Australia	Longitudinal (6 year follow-up)	Bivariate correlation and structural equation modeling to test for mediators	PROCESS: Get Skilled, Get Active object control (kick, catch, overhand throw) locomotor (hop, side gallop, vertical jump)	APARQ, CRF (multi-stage fitness test) and perceived physical competence (PSPP)	Childhood object control was associated with adolescent perceived sports competence Childhood object control associated with adolescent PA Locomotor competency was associated with perceived

						competence in girls only Locomotor competency was not associated with PA in either girls or boys Locomotor competency was associated with CRF in girls only
Erwin et al [11]	180 children Age 10.5 ± 0.8 years Grades 4 and 5 United States	Cross-sectional	Bivariate correlation	PROCESS: South Carolina Physical Education Assessment Program (SCPEAP) scoring and protocols including: basketball dribble and pass, overhand ball throwing and gymnastic movement and balance	PA (ACTIVITYGRAM questionnaire), physical fitness (CRF, strength, endurance, flexibility and BMI z-score)	FMS competency associated with PA and physical fitness
Hume et al [35]	248 children Age 9 to 12 years Australia	Cross-sectional	Linear regression and bivariate correlation	PROCESS: Fundamental Movement Skills: A Manual for Classroom Teachers: object control (overhand throw, two handed strike, kick) and locomotor (sprint run, dodge and vertical jump)	PA (accelerometer) and BMI z-scores	MPA, VPA and MVPA associated with FMS proficiency in boys VPA associated with FMS proficiency in girls BMI z-scores not associated with FMS in boys or girls
Williams et al [27]	198 children Age 3 to 4 years United States	Cross-sectional	Bivariate correlation	PROCESS: Children's Activity and Movement in Preschool Study Motor Skill Protocol: locomotor (run, jump, slide, gallop, leap and hop) and object control (throw, roll, kick, catch, strike and dribble)	BMI z-score and PA (accelerometry)	Object control and locomotor proficiency associated with PA in 4 year olds, but not 3 year olds BMI z-score not associated with object control or locomotor proficiency in 3 or 4 year olds
Barnett et al [36]	928 children 276 adolescents (follow-up) Age 16.4 years Australia	Longitudinal (6 year follow-up)	General linear model controlling for grade and gender, general linear model controlling for grade	PROCESS: Get Skilled, Get Active: object control (kick, catch, overhand throw) locomotor (hop, side gallop, vertical jump)	PA (APARQ)	Object control proficiency in childhood associated with time in MVPA and time in organized PA

			and logistic regression			Object control proficiency in childhood was associated with probability of participating in VPA but not associated with probability of participating in organized PA Locomotor proficiency did not predict time in or probability of participating in any form of adolescent PA
D'Hondt et al [57]	117 children Age 5 to 10 years Belgium	Cross-sectional	ANOVA and bivariate correlation	PROCESS: Movement Assessment Battery for Children: ball skills, static and dynamic balance	BMI z-score and PA (accelerometers)	FMS competency (ball skills and balance) was higher in normal and overweight compared to obese children FMS competency (ball skills and balance) associated with PA
Cliff et al [38]	46 children Age 4.3 ± 0.7 years Pre-school Australia	Cross-sectional	Bivariate correlation and linear regression	PROCESS: Test of Gross Motor Development 2- (run, gallop, hop, leap, horizontal jump, slide, striking a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll)- characterized into locomotor and object control subtests	PA and sedentary behavior (accelerometer)	Object control proficiency was associated with moderate PA in boys Locomotor proficiency was not significantly associated with PA in boys Locomotor proficiency and overall FMS proficiency were negatively associated with PA in girls Object control proficiency was not associated with PA in girls FMS not associated with sedentary behavior in boys or girls

Note. PROCESS = process assessment of FMS concerned with technique; PRODUCT = product assessment of FMS concerned with outcome, BMI = body mass index; CRF = cardio-respiratory fitness; PA = physical activity; PACER = Progressive Aerobic Cardiovascular Endurance Run; PRODUCT or PROCESS measure of FMS competency; APARQ = Adolescent Physical Activity Questionnaire; PSPP = Physical Self-Perception Profile; SPPC = Self-Perception Profile for Children

Table III: FMS study quality checklist with quality scores assigned

Studies	(i) Did the study describe the participant eligibility criteria?	(ii) Were the participants randomly selected? [a]	(iii) Did the study report the sources and details of FMS assessment and did the instruments have acceptable reliability for the specific age group?	(iv) Did the study report the sources and details of assessment of potential benefits and did the all of the methods have acceptable reliability for the specific age group?	(v) Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships?	(vi) Did the study report the numbers of individuals who completed each of the different measures and did participants complete at least 80% of FMS and benefit measures?	Quality score total /6
Martinek et al [28]	1	0	1	1	0	0	3
Rudisill et al [29]	1	0	0	1	0	1	3
Marshall and Bouffard [30]	1	0	1	1	0	1	4
Reeves et al [20]	1	0	1	1	0	1	4
Okely et al [22]	1	1	1	1	0	1	5
Okely et al [31]	1	1	1	0	0	0	3
McKenzie et al [32]	1	0	1	0	0	1	3
Okely et al [40]	1	1	1	1	0	1	5
Graf et al [33]	1	1	1	0	0	0	3
Southall et al [23]	1	1	1	1	0	1	5
Fisher et al [24]	1	1	1	1	0	1	5
Hamstra-Wright et al [39]	0	0	1	0	0	0	1
Castelli et al [34]	1	0	1	1	0	0	3
Barnett et al [26]	1	1	1	1	0	1	5
Barnett et al [25]	1	1	1	1	0	1	5
Erwin et al [11]	1	0	1	0	0	1	3
Hume et al [35]	1	0	1	1	0	1	4
Williams et al [27]	1	1	1	1	0	1	5
Barnett et al [36]	1	1	1	1	0	0	4
D'Hondt et al [57]	1	0	1	1	0	1	4
Cliff et al [38]	1	1	1	1	0	0	4

[a]For intervention studies the criterion was as follows: were participants randomly allocated and was the process of randomization clearly described and adequately carried out (envelope or algorithm)?

Table IV: Summary of studies examining the relationship between potential benefits and fundamental movement skill competency in youth

Benefits	Associated with FMS		Not associated with FMS	Summary coding[a]	
	Reference no.	Assoc. (-/+)[b]	Reference no.	*n*/N for benefit (%)[c]	Assoc. (-/+)[b]
Psychological benefits					
Global self-concept			[28]	1/1 (100)	?
Perceived physical competence	[25]f, [29], [23]	+		3/3 (100)	?
Physiological benefits					
Weight status (BMI z-score, BMI, skinfolds)	[37], [23], [33], [40], [32]d	-	[34], [35], [27]	5/8 (63%)	-
Cardio-respiratory fitness (CRF)	[26]g, [30], [20], [22]	+		4/4 (100%)	+
Muscular fitness	[34]	+		1/1 (100%)	?
Flexibility	[34]	+		1/1 (100%)	?
Physical fitness[i]	[11]	+		1/1 (100%)	?
Behavioral benefits					
Physical activity	[31], [33], [24], [39], [34], [11], [35], [27], [36], [38]d, [37], [25] h	+			
	[38]e	-	[32]j	11/13 (85%)	++
Sedentary behavior			[33], [38]	2/2 (100%)	?

NB. A positive or negative association was noted if at least one component of FMS competency was associated with the hypothesized benefit
[a]Summary code provides an overall summary of the findings for each benefit
[b]Association shows the direction of the individual and summary association
[c]N = number of studies that examined and reported possible associations between FMS competency and potential benefit, *n* = number of studies that report support for relationship
[d]Association for boys only
[e]Association for girls only
[f]Childhood FMS competency associated with adolescent perceived competence
[g] Childhood FMS competency associated with CRF in adolescence
[h]Childhood FMS competency associated with PA in adolescence
[i]Composite physical fitness score including CRF, flexibility, strength, muscular fitness and BMI
[j]FMS competency at ages 4 to 6 did not predict PA at age 12