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REVIEW

Fundamental movement skills and weight status in children: A systematic review

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background Obesity has become a major health challenge in children. Fundamental movement skills (FMS) are suggested to have an important role for being physically active and decreasing the risk of obesity. This systematic review aimed to give an overview of studies providing evidence for a relationship between FMS and the weight status in children.

Material/Methods A systematic search of five electronic databases (MEDLINE (PubMed), SportDiscus, ERIC, PsycInfo and SCOPUS) was conducted in January 2015. Studies examining associations between FMS and weight status in children aged 3–12 years were included.

Results The final sample included 12 cross-sectional studies. Seven studies found statistically significant inverse association between FMS and body mass index (BMI). Three studies used waist circumference (WC), and significant inverse associations were found in two of these. Dual-energy X-ray absorptiometry (DXA) was used in one study and significant association was found between FMS and abdominal and total body fat percentage. One study, using skinfolds, found no association.

Conclusions Based on the findings of the 12 studies, the relationship between FMS and weight status in children aged 3–12 years remains unclear. Developing competency in FMS may have important health consequences, and more studies are needed in which body composition is objectively measured with DXA.

Key words BMI, fundamental movement skills, motor skills, obesity, overweight, weight status

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INTRODUCTION

Among children and adolescents, obesity has substantially increased worldwide. A recent systematic review indicated that between 1980 and 2013, the prevalence of overweight or obese children and adolescents (ages 2–19 years) increased by nearly 50%. In 2013, approximately 23% of girls and 24% of boys living in developed countries and 13% of girls and 8% of boys in developing countries were found to be overweight or obese [1]. Obesity is associated with multiple physical and psychological health problems already in childhood as well as with co-morbidities later in life [2]. Because of the established health risks and substantial increases in prevalence, obesity has become a major global health challenge [1].

The observed increase in the prevalence of childhood overweight and obesity is a likely consequence of a change in physical activity (PA) and nutrition patterns over time [3]. Adequate PA, together with healthy weight, is a protective factor against many health problems. PA has beneficial effects on adiposity, musculoskeletal health and fitness, and several components of cardiovascular health in children and adolescents [4]. Moreover, data from observational studies indicate dose-response relationships – the more PA, the greater the health benefits, and results from intervention trials show that even modest amounts of PA can have health benefits in obese youth [4].

Overall, low levels of PA are a potential cause and consequence of obesity, and it has been hypothesized that poor competence in fundamental movement skills (FMS) may be an important factor in this process. Low levels of PA lead to weight gain and a further reduction in PA because obesity may restrain the development of FMS and further decrease the motivation to participate in physical activities, which in turn increases weight gain [5–8].

FMS are an important part of human life, and they are interrelated with a child's physical, cognitive and social development [9]. FMS are considered to be the building blocks for movement and provide the foundation for specialized and sport-specific motor skills required for participation in a variety of physical activities. FMS are categorized as locomotor (e.g. run, hop, jump, leap), object-control (e.g. throw, catch, kick, strike), and stability (dynamic and static balance) skills [6]. Although motor development is a process continuing throughout life, early childhood is the optimal phase to learn and develop FMS [6]. This development is established through an interactive process of aspects related to the individual, the task and the environment. These aspects include biological and demographic factors, behavioral attributes and skills, cognitive, emotional and psychological factors, cultural and social factors and physical environmental factors [10].

Despite increasing interest in recent years in childhood overweight and obesity and their relationship to health-related fitness and motor competence, the association between weight status and FMS has not been comprehensively examined. Earlier reviews have examined associations of FMS competency with potential psychological, physiological and behavioral health benefits [11], between motor competence and health-related physical fitness [12], and motor competence and its effect on positive developmental trajectories of health [7]. In those reviews, assessments describing and defining motor skills varied and fitness components other than solely FMS were also measured.

The purpose of this systematic review was to give an overview of studies providing evidence for a relationship between FMS performance and weight status (healthy weight, overweight and obesity) in children.

MATERIAL AND METHODS

IDENTIFICATION OF STUDIES

A systematic search of five electronic databases (MEDLINE (PubMed), SportDiscus, ERIC, PsycInfo and SCOPUS) was conducted in January 2015 by an experienced informatician. Key words included motor skill, movement skill, fundamental movement skills, object control skill, locomotor skill, motor competence, motor proficiency, motor ability, obesity, overweight, weight status, body mass index, BMI, body composition, waist circumference, body fat, fatness, children, child, youth, kindergarten, and preschool children. The searches were conducted using single and combined terms. Only articles published in English in reviewed journals were considered for review.

CRITERIA FOR INCLUSION AND EXCLUSION

Titles and abstracts of the potentially relevant references were checked after removal of duplicates and then the full-text copies of potentially relevant citations were obtained. Then the two authors (SS and AS) independently reviewed the full-text articles and assessed the eligibility of the studies for inclusion (Figure 1). The inclusion criteria were the following: (a) participants were aged 3–12 years; (b) at least two FMS were assessed and the FMS measurement used was identified as a process- or product-oriented measurement; (c) a summary of FMS performance (reported as a total FMS score, object control score or locomotor score) was included in the analysis; (d) a quantitative analysis of the relationship between FMS and weight status were found; (e) only gross motor skills were assessed and a fine motor skills score was not included in analyses; and (f) the study was published in peer-reviewed journals in English. This review did not include studies with special populations or subjects with underweight, intervention studies or studies that evaluated only overweight/obese children/adolescents, fine motor skills, health-related fitness or motor abilities. If there was uncertainty about including an article, the article in question was reviewed again together by two of the authors (SS and AS) until a final decision was made. Ultimately, 14 unique citations met the eligibility criteria (Table 1).

Table 1. Summary of studies of the association between FMS competency and weight status

	Study Country	Sample Age/school grade	Analyses	FMS measure	Obesity measure	Results
1.	Franjko et al. 2013 (14) Croatia	73 children 8y	Pearson product-moment correlations	PROCESS: TGMD-2 PRODUCT:The FMS-POLYGON	BMI (?) Skinfolds (triceps and calf)	No statistically significant correlations between BMI and FMS in the total sample, nor in the separate sample of girls and boys. Significant relationships between BF and FMS were found in the total sample and in the sample of eight-year-old girls.
2.	D'Hondt et al. 2009 (23) Belgium	117 children 5-10 y	ANOVA, bivariate correlation	PRODUCT: MABC	BMI (IOTF)	FMS competency (ball skills and balance) was higher in normal and overweight compared with obese children

	Study Country	Sample Age/school grade	Analyses	FMS measure	Obesity measure	Results
3.	Hume et al. 2008 (27) Australia	248 children 9-12 y	Linear regression, bivariate correlation	PROCESS: A Manual for Classroom Teachers. Object control and locomotor	BMI (IOTF)	BMI not associated with FMS in boys or girls. Compared with overweight or obese children, a higher proportion of children classified as non-overweight achieved mastery/near mastery in running.There were no differences in the other skills according to weight status or in the total FMS, object-control, or locomotor proficiency scores.
4.	Kemp & Pienaar 2013 (21) South Africa	816 children 6.84 (+0.39 SD)	Correlation coefficient?	PROCESS: TGMD-2 (only object control) PRODUCT: Bruininks Oseretsky test of Motor Proficiency-2	BMI (IOTF) values: normal weight, oveweight, obese) Skinfolds (subscapular, triceps, calf) Waist circumference	No significant correlations between obesity measures and object control skills. Small significant correlation between balance and BMI, running speed/ agility and BMI and body fat %.
5.	Khalaj & Amri 2014 (15) Iran	160 children 4-8 y	ANOVA	PROCESS: TGMD-2	BMI (IOTF)	Obese children had lower gross motor skill proficiency compared to their normal weight peers. 6-8 y obese children performed poorer gross motor skills compared to 4-6 y obese children
6.	Logan et al. 2011 (16) USA	38 children 4-6 y	Pearson product-moment correlations	PRODUCT: MABC-2	BMI (CDC)	No significant relationship existed between MABC-2 and BMI percentile ranks (r = -.237). Significant differences in MABC-2 percentile ranks existed between high and low (p = .042), and high and medium (p = .043) groups.
7.	Morano et al. 2011 (24) Italy	80 children 4.5±0.5 y	ANOVA Pearson's product-moment correlations	PROCESS: TGMD-2	BMI (IOTF) Overweight/non-oveweight	Relationships (p < 0.001) between BMI and locomotor and object-control skills, and between BMI and the Gross Motor Development Quotient. Overweight participants showed poorer performance on locomotor and object-control tasks than their non-overweight peers.
8.	Nervik et al. 2011 (25) USA	50 children 3-5 y	Pearson chi-square static test Pearson correlation coefficient test Stepwise hiearchical regression analysis	PRODUCT: PDMS-2	BMI percentiles / weight categories (CDC growth charts): 1)non-overweight or non-obese 2) overweight or obese	A significant correlation between BMI sets and gross motor quotients category (P=.002). BMI and the continuous measure of gross motor score not significant.
9.	Okely et al. 2004 (20) Australia	4363 children and adolescents 4, 6, 8, 10 grades	Logistic regression modelling, multiple linear regression	PROCESS: A Manual for Classroom Teachers	BMI (IOTF) Waist circumference	Overall FMS proficiency and locomotor skill proficiency were inversely associated with BMI and WC in children. No association between object control skill proficiency and BMI.
10.	Roberts et al. 2012 (17) USA	4650 children 4-6 y	ANOVA	PRODUCT (?): Combination of individual gross motor items from the Early Screening Inventory Revised, The Early Childhood Longitudinal Study Kindergarten Cohort of 1998-1999, The Bruininks-Oseretsky Test of Motor Proficeincy, and The MABC	BMI percentiles / weight categories (CDC growth charts):	Children with obesity had decreased motor abilities compared with children in other weight categories. There was no difference in skill level between weight categories for a manipulative task or involving body mass mobilization or management.
11.	Southall et al. 2004 (26) Australia	142 children 10.8 y	ANCOVA	PROCESS: TGMD-2	BMI (IOTF)	Overweight children had lower total FMS and locomotor FMS. No difference between overweight and normal weight children for object control skills.
12.	Spessato et al. 2012 (28) Brazil	178 children 4-7 y	ANOVA Pearson's correlations Regression analysis	PROCESS: TGMD-2	BMI percentiles / weight categories (CDC growth charts):	No differences in motor competence between obese and nonobese for the overall sample.
13.	Spessato, Gabbard &Valentini 2013 (29) Brazil	264 children 5-10 y	ANOVA Pearson's correlations Linear regression analysis	PROCESS: TGMD-2	BMI (CDC)	BMI was not significantly correlated with motor competence (overall, locomotor or object control). The linear regression model indicated that overall MC was a better predictor of PA than BMI.
14.	Slotte et al. 2015 (22) Finland	304 8 y	ANOVA	PROCESS: TGMD-2	Total body fat %, abdominal fat % (DXA) BMI (IOTF) Waist circumference	Significant inverse correlations between all the FMS categories (object control, locomotor and total FMS) and the different weight status variables (BF%, AF%, WC and BMI) measured.

CRITERIA FOR ASSESSMENT OF STUDY QUALITY

Two authors (KK-H and PR) independently assessed the quality of the 14 eligible studies (Table 2). The criteria for assessing the quality of the studies were adopted from Lubans et al. [11] based on the STROBE [13] and CONSORT [14] statements. A quality score for each study was completed on a six-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: (a) Did the study describe the participants' eligibility criteria? (b) Were the participants randomly selected? (c) Did the study report the details of FMS assessment and did the instruments have acceptable reliability for the specific age group? (d) Did all of the methods have acceptable reliability? (e) Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships? (f) Did the study report the numbers of individuals who completed each of the different measures and complete at least 80% of them? Studies that scored 0–2 were classified as low quality, 3–4 as medium quality and 5–6 as high quality.

Table 2. Assessment of Study Quality of the 14 studies

	1. Did the study describe the participants' eligibility criteria?	2. Were the participants randomly selected?	3. Did the study report the details of FMS assessment and did the instruments have acceptable reliability for the specific age group?	4. Did all of the methods have acceptable reliability?	5. Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships?	6. Did the study report the numbers of indivi duals who completed each of the different measures and complete at least 80% of them?	Total quality score/ max 6
D'Hondt et al. 2009 (23)	0	0	1	1	0	1	3
Franjko et al. 2013 (14)	0	1	1	0	0	0	2
Hume et al. 2008 (27)	1	1	1	1	0	1	5
Kemp & Pienaar 2013 (21)	1	1	0	1	0	1	4
Khalaj & Amri 2014 (15)	0	0	1	1	0	0	2
Logan et al. 2011 (16)	1	0	0	1	0	1	3
Morano et al. 2011 (24)	0	0	1	1	0	1	3
Nervik et al. 2011 (25)	1	0	1	1	0	1	4
Okely et al. 2004 (20)	1	1	1	1	0	1	5
Roberts et al. 2012 (17)	1	1	0	1	0	1	4
Southall et al. 2004 (26)	1	1	1	1	0	1	5
Spessato et al. 2012 (28)	1	0	1	1	0	1	4
Spessato et al. 2013 (29)	1	0	1	1	0	1	4
Slotte et al. 2015 (22)	1	1	1	1	0	1	5

CATEGORIZATION OF VARIABLES AND LEVEL OF EVIDENCE

The relationship between FMS performance and weight status was determined by examining the percentage of studies that reported a statistically significant relationship (Table 3). Results were coded using the method earlier used by Lubans et al. [11] with the following criteria adopted: (a) Lack of scientific evidence if less than 33% of the studies indicated a significant association between variables or none of the studies deemed as low risk of bias found a significant association; (b) Uncertain evidence if 34–59% of the studies indicated a significant association between variables and at least one of them was deemed low risk of bias; (c) Positive evidence if 60–100% of the studies indicated a significant association between variables and 34–59% of the studies deemed low risk of bias found a significant association (in the same direction); (d) Strong evidence if 60–100% of the studies indicated a significant association between variables (in the same direction) and more than 59% of the studies deemed low risk of bias (score ≥5) found a significant association.

Table 3. Summary of studies examining the relationship between weight status and FMS

Weight status	Associated with FMS		Not associated		Summary coding (a) n/N for study		Association (b)	Level of evidence (c)
	testscore	references	testscore	references	(%)	high quality		
BMI	7	(17, 20, 22-26)	5	(16, 21, 27-29)	7/12 (58)	3/12	inverse	?
WC	2	(20, 22)	1	(21)	2/3 (67)	2/3	inverse	++
skinfolds			1	(21)	0/1 (0)	0/1	no	0
DXA	1	(22)			1/1 (100)	1/1	inverse	++
	Associated with product-oriented		Not associated					
BMI	3	(17, 23, 25)	1	(16)	3/4 (75)	0/4	inverse	0
WC								
skinfolds								
DXA								
	Associated with process-oriented		Not associated					
BMI	4	(20, 22, 24, 26)	4	(21, 27-29)	4/8 (50)	3/8	inverse	?
WC	2	(20, 22)	1	(21)	2/3 (67)	2/3	inverse	++
skinfolds					0/1 (0)	0/1	no	0
DXA	1	(22)	1	(21)	1/1 (100)	1/1	inverse	++
	Associated with locomotor skills		Not associated					
BMI	6	(17, 20-22, 24, 26)	2	(27, 29)	6/8 (75)	3/8	inverse	+
WC	2	(20, 22)			2/2 (100)	2/2	inverse	++
skinfolds								
DXA	1	(22)			1/1 (100)	1/1	inverse	++
	Associated with object control skills		Not associated					
BMI	3	(22-24)	5	(20, 21, 26, 27, 29)	3/8 (38)	1/8	inverse	?
WC	1	(22)	2	(20, 21)	1/3 (33)	1/3	inverse	0
skinfolds			1	(21)	0/1 (0)	0/1	no	0
DXA	1	(22)			1/1 (100)	1/1	inverse	++
	Associated with stability skills		Not associated					
BMI	2	(21, 23)	1	(17)				
WC					2/3 (67)	0/3	inverse	0
skinfolds								
DXA								

(a) An overall summary of the findings. n = number of studies that report support for relationship, N = number of studies that examined and reported possible associations between FMS and weight status.
(b) The direction of the association.
(c) 0 = Lack of scientific evidence, ? = Uncertain evidence, + = Positive evidence, ++ = Strong evidence

RESULTS

LITERATURE SEARCH

A total of 783 references were identified from five electronic databases. Initial screening of titles and abstracts produced 40 (SS) and 64 (AS) potentially relevant references after removal of duplicates. These references were further screened for their full text and 14 studies met the inclusion criteria (Figure 1).

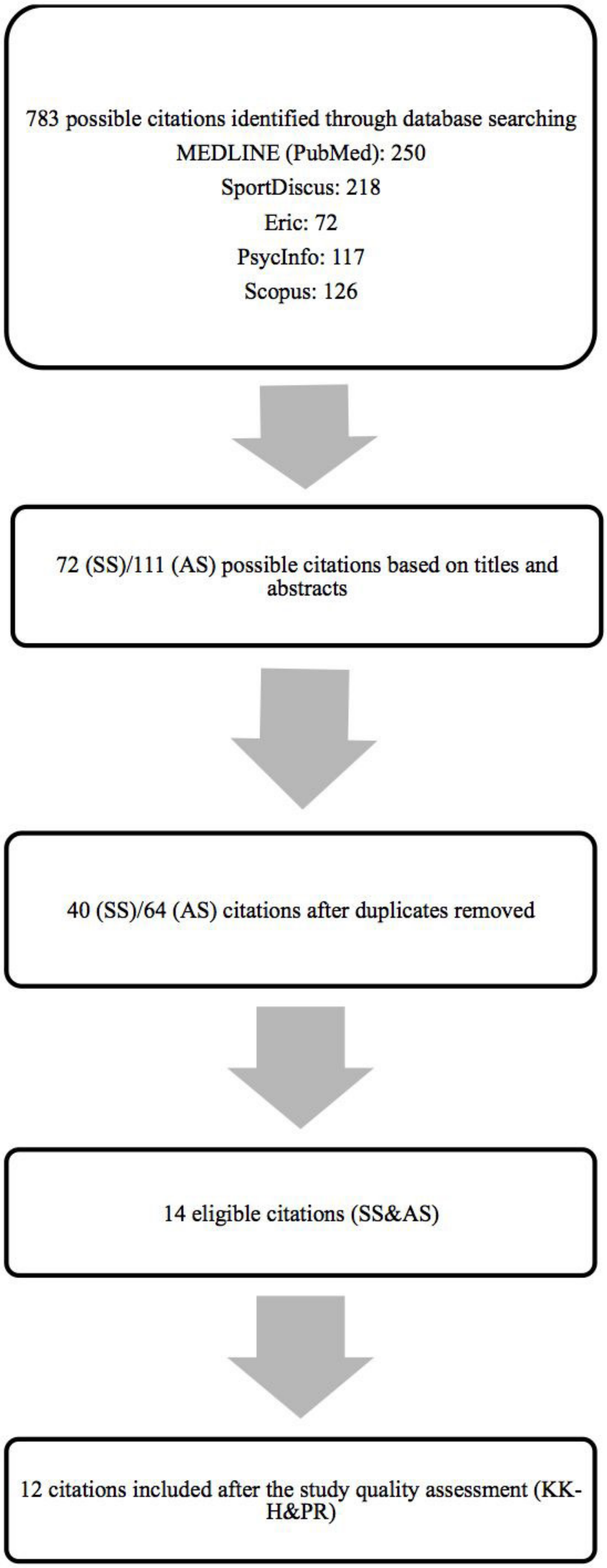

Fig. 1. Flow of studies through the systematic review process

STUDY QUALITY

Results from the assessment of study quality are reported in Table 2. Four of the studies were classified as high [21, 23, 27, 28], eight as medium [17, 18, 22, 24–26, 29, 30] and two of low quality [15, 16]. The low quality studies [15, 16] were excluded from analyses, and the final sample in this review included 12 studies.

OVERVIEW OF INCLUDED STUDIES

All the included studies were cross sectional and published between 2004 and 2014. Three of the studies were from Australia [21, 27, 28], three from Europe [23–25] (Belgium, Finland and Italy), three from the USA [17, 18, 26], two from South America [29, 30] (Brazil) and one from Africa [22] (South Africa). The number of study participants ranged from 38 [17] to 4650 [18]. All the studies examined associations between FMS and weight status using correlation and/or regression analyses.

WEIGHT STATUS

In all the studies weight status was established using the body mass index (BMI) calculated from weight and height. Seven studies (58%) used IOTF/Cole et al. [19] sex- and age-specific BMI cutoff values based on six internationally representative data sets. The US growth-curves from the Centre for Disease Control and Prevention (CDC) [20] were used in five studies (42%). In addition waist circumference (WC) was measured in three studies [22–24], skinfold thickness in one study [22] and dual energy X-ray absorptiometry (DXA) was used in one study to measure abdominal fat percentage and total body fat percentage [23].

FMS ASSESSMENT

In seven studies FMS performance was defined using process-oriented tests (i.e. qualitative movement patterns): the Test of Gross Motor Development-2 in five studies [23, 25, 26, 29, 30] and items from the Fundamental Motor Skills: A Classroom Manual for Teachers in two studies [21, 28]. In four studies FMS competency was defined using product-oriented tests (i.e. outcomes): the Movement Assessment Battery for Children in two studies [17, 24], the Peabody Developmental Motor Scales (second edition) in one study [26] and a combination of individual test items from the Early Screening Inventory Revised, the Early Childhood Longitudinal Study Kindergarten Cohort of 1998–1999, the Bruininks–Oseretsky Test of Motor Proficiency, and the Movement Assessment Battery for Children in one study [18]. In one study FMS competency was defined using a combination of both process-oriented and product-oriented tests [22]: the Test of Gross Motor Development-2 and the Bruininks–Oseretsky Test of Motor Proficiency.

ASSOCIATION BETWEEN FMS AND WEIGHT STATUS

Seven (58%) studies found statistically significant inverse association between FMS total score and BMI [18, 21, 23–27]. Three of these were classified as high quality [21, 23, 27]. Five (42%) studies did not demonstrate statistically significant associations between FMS score and BMI [17, 22, 28–30], and one of these was classified as high quality [28]. Three studies used WC [21–23] and significant inverse associations were found in two of these studies [21, 23], classified as high quality. One study [22], which used skinfolds, found no statistically significant association. In one study DXA was used and a significant association was found between FMS and abdominal fat percentage and total body fat percentage [23].

ASSOCIATION BETWEEN TOTAL SCORES OF PRODUCT- AND PROCESS-ORIENTED TESTS AND WEIGHT STATUS

Four studies used a product-oriented test for assessing FMS performance [17, 18, 24, 26] and in three of them FMS were significantly inversely associated with weight status estimated using BMI [18, 24, 26]. None of these were classified as high quality.

Eight studies used a process-oriented test for assessing FMS performance [21–23, 25, 27–30]. All used BMI and significant inverse associations were found in four studies [21, 23, 25, 27] and three of them were classified as high quality [21, 23, 27]. Four studies did not find associations between FMS and BMI [22, 28-30], and one of these was classified as high quality [28]. Three studies also used WC [21–23] and a significant inverse association was found in two of these, both high-quality studies [21, 23]. In one study, classified as high quality, DXA was used and a significant association was found [23]. One study [22] which used skinfolds, found no association between FMS and weight status.

ASSOCIATION BETWEEN LOCOMOTOR SKILLS AND WEIGHT STATUS

Inverse association between locomotor skills and weight status was found in six studies [18, 21–23, 25, 27]: Kemp and Pienaar (product: running speed/agility), Morano et al. (process: composite score of seven locomotor test tasks), Okely et al. (process: composite score of two locomotor test tasks), Roberts et al. (product: hop and jump), Southall et al. (process: composite score of six locomotor test tasks), Slotte et al. (process: composite score of three locomotor test tasks). Of these studies three were classified as high quality [21, 23, 27]. Two studies found no significant association between locomotor skills and weight status [28, 30]: Hume (process: composite score of two locomotor test tasks), and Spessato, Gabbard and Valentini (process: composite score of seven locomotor test tasks).

ASSOCIATION BETWEEN OBJECT-CONTROL SKILLS AND WEIGHT STATUS

Inverse association between object-control skills and weight status was found in three studies [23–25]: D'Hondt (product: ball skills), Morano (process: composite score of five object-control test tasks) and Slotte (process: composite score of two object-control test tasks), and one of these was classified as high quality [23]. In five studies there was no significant association between object-control skills and weight status [21, 22, 27, 28, 30] and three of these were classified as high quality [21, 27, 28].

ASSOCIATION BETWEEN STABILITY SKILLS AND WEIGHT STATUS

Inverse association between stability skills and weight status was found in two studies [22, 24] and in one study [18] the association was not significant. None of these were classified as high-quality studies.

DISCUSSION

FMS are natural part of human life and important for a child's physical, cognitive and social development. In addition, experiences support learning and development of FMS and the foundations of these skills are created in early childhood. It has been hypothesized that better FMS performance is essential to encourage a physically active lifestyle, which for its part leads to healthy weight status [5–8].

The purpose of this systematic review was to examine the relationship between FMS performance and weight status (healthy weight, overweight and obesity) in children aged 3–12 years. Overall there was an inverse but weak association between FMS and weight status. Seven (58%) of the studies found a statistically significant inverse association between FMS total score and BMI, and five (42%) studies found no association. In those studies using WC for establishing weight status, an inverse association was found in two of the three studies (67%) and in the one study, which used skinfolds, found no significant association. In one study DXA was used and a statistically significant inverse association was found between FMS performance and weight status.

Eight studies used process-oriented tests and four studies used product-oriented tests for assessing FMS. Half of the studies, which used process oriented tests and three of four studies which used product-oriented tests, found significant inverse association between FMS and weight status (BMI). Product-oriented (quantitative) assessment techniques evaluate the outcome of the movement skills and are based on the time, distance or number of successful attempts resulting from the performance of the skill but process-oriented (qualitative) assessment techniques evaluate the form of the movement skills [31]. Process-oriented assessments may be more suitable when assessing overweight and obese children because they more accurately identify specific characteristics of the movement, reflecting the developmental skill level instead of maturational levels and physical growth of children.

In those studies where FMS was partitioned into locomotor skills, object-control skills or stability, inverse associations between FMS proficiency and weight status were mostly found in locomotor skills rather than object-control skills or stability. It has been suggested that biomechanical factors associated with high body mass, such as lower limb problems, may be one reason that overweight and obese children have greater difficulty in performing locomotor skills [32, 33].

Based on this systematic review, the relationship between FMS and weight status in children is still unclear. This is contrary to the conclusions of the two earlier reviews [11, 12]. The explanation may be that assessment methods describing and defining motor skills varied and also components of health-related fitness (e.g. cardiorespiratory and muscular fitness) and motor ability (e.g. speed, power, explosive strength) were measured in those reviews. Motor skills are sometimes confused with fitness abilities but are different. In our review we wanted to restrict to FMS, which are the foundation movements for more complex and specialized skills required in various physical activities and everyday life from childhood years to later in life.

In all the studies body weight status was established using BMI. In addition, skinfold thickness was measured in one study [22], WC in three studies [22–24] and only in one study [23] DXA was used to measure abdominal fat percentage and total body fat percentage. As body fatness and specifically abdominal fatness are associated with less favorable cardiovascular risk factor status in children and adolescents [34], it is important to assess weight status using more accurate methods than only BMI in order to obtain more precise evidence for a relationship between FMS performance and weight status in children. BMI is based on weight and does not differentiate between fat mass (adipose tissue) and lean mass (mostly muscle tissue) and, therefore, it is an imperfect measure of either fatness or thinness. In children BMI correlates with fat mass more strongly among heavy (where fat mass makes up a larger proportion of weight) than among thin children [35]. So in thin children BMI is a better predictor of lean mass than fat mass. Both BMI and WC are proxy measures and should not be considered as accurate measures of total body or abdominal fat [36] comparable with the measurement of body composition by more sophisticated methods such as DXA. DXA can be used to evaluate childhood obesity and determine fat mass [37], and it has increasingly been suggested and used as a criterion or a reference method for comparing other measurements of body composition [38]. In most of the studies included, obese or overweight children were compared to those with healthy weight, while potential differences between healthy weight and underweight were not taken into consideration. There is lack of studies in underweight children and adolescents, and incomplete understanding of health consequences of underweight [39] and, therefore, a need for studies where underweight is included.

LIMITATIONS

This review has limitations. Longitudinal and intervention studies were not included in this review. The limitations of cross-sectional study designs prevent making definitive conclusions regarding causality relating to the development of FMS and weight status. The use of BMI as a measure of body weight status in all the studies in this review limits our understanding of the contributory effects of overall increased mass (i.e. body fat mass and lean mass) to FMS. One limitation is the fact that there were only 12 eligible studies on which our results are based on and the quality of the studies varied. Comparisons between studies were partly difficult due to the methodological heterogeneity and different methods used for assessing FMS performance and weight status. Our goal was to restrict the studies included to those, which clearly measured FMS, but some product-oriented tests likely evaluated motor abilities more than they did FMS.

CONCLUSIONS

The results of this systematic review indicate that the relationship between overall FMS proficiency and weight status in children aged 3–12 years is still unclear. However, the significant inverse relationship found between FMS proficiency and WC and especially with objectively measured abdominal fat percentage and overall body fat percentage, suggest that competency in FMS may have important health consequences.

There is a need for studies where body composition is more accurately measured with, for example, DXA. The use of BMI as an only measure of weight status limits the understanding of the contributory effects of overall increased mass (i.e. lean mass and body fat mass) to FMS. In addition, FMS should be assessed with qualitative tests, which focus on the technique of the movement. Also measurement of FMS needs more standardized and global methods. Research on FMS development and performance in developing children is scarce and rather dispersed and there is a shortage of updated information on movement skill development and performance especially in European children [40]. There are very few longitudinal studies in the area of childhood FMS, weight status and physical activity [41, 42] and longitudinal and long-term intervention studies from early childhood years would also better clarify the influence of FMS development on weight status. This kind of knowledge would help health care personnel and kindergarten and school physical education teachers to prevent development of overweight, and when needed, tailor intervention for individual needs.

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