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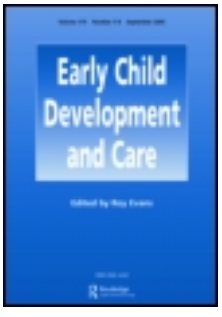


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Preschool children's fundamental motor skills: a review of significant determinants

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Fundamental motor skills (FMS) affect children's physical, social, and cognitive development. To plan successful interventions when promoting the development of children's FMS, the underlying positive determinants for the acquisition of FMS competence during preschool years need to be identified. The purpose of this systematic review was to identify positive determinants of FMS such as stability, locomotor, and manipulative movements in children between the ages of three and six. Five electronic databases (ERIC, PsycINFO, MEDLINE, SPORTDiscus, and Physical Education Index) were used for the systematic search and in our final analysis there were 29 articles. Four categories of determinants were identified: (1) individual characteristics (gender, ethnicity, age, physical activity, physical fitness, and playfulness), (2) education-related (programmes promoting physical activity and motor skill, attendance of physical education lessons, practice schedules), (3) social environments (parent- and family-related variables, older siblings, and sport club participation), and (4) physical environment (population density, size of preschool area, clothing). Age, gender, physical activity, and preschool-based programmes were positive determinants of FMS in preschool-aged children.

Keywords: fundamental motor skills; preschool children; positive determinants; review

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Introduction

It has been established that fundamental motor skills (FMS) affect children's physical, social, and cognitive development. These skills have also been associated with adopting a physically active lifestyle (Stodden et al., 2008). FMS may be viewed as correlates of physical activity (Cliff, Okely, Smith, & McKeen, 2009; Fisher et al., 2005; Williams et al., 2008) or adequate physical activity may be viewed as providing a basis for developing motor skills (Bürgi et al., 2011).

Young children are involved in the process of developing FMS in a variety of stability (i.e. gaining control over musculature in opposition to gravity), locomotor (i.e. moving through space), and manipulative (i.e. making controlled contact with objects in one's environment) movements. Stability movements consist of static and dynamic balance skills such as standing on one foot and walking on a straight line. Locomotor movements refer to skills such as running and hopping, and manipulative movements include skills such as throwing and kicking (Gallahue, Ozmun, & Goodway, 2011.) FMS develop nonlinearly and discontinuously in a highly individual

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manner (Kugler, Kelso, & Turvey, 1982; Newell, 1986). The developmental change in a child's motor skills is influenced by many critical determinants, which may be classified into the subsystems of requirements of the movement task (e.g. an obstacle's height or the size of a goal), the biology of the child (e.g. sex and heredity), and the environment (e.g. outdoor geography, educators' prompts to skill practicing, or socioeconomic background). These subsystems individually and mutually either encourage or discourage skill acquisition (Gallahue et al., 2011; Newell, 1986).

Preschool years are a critical period in terms of developing FMS. Therefore, it is eligible that early childhood education guidelines highlight that development and the promotion of motor skills should be an integral part of education programmes (Australian Government. Department of Health and Aging, 2011; Ministry of Social Affairs and Health, 2005). Although children may acquire rudimentary motor skills naturally through maturational processes (Malina, Bouchard, & Bar-Or, 2004), mature forms of the skills may only be achieved in a developmentally appropriate environment that provides encouragement, opportunities for skill-specific practice as well as inspiring and challenging physical environments to incorporate skills into different contexts (Gagen & Getchell, 2006; Gallahue & Cleland-Donnelly, 2003). In terms of promoting children's FMS development, educators should be aware of each child and his or her unique characteristics within a physical and social environment performing a task with specific goals, equipment, etc. (Gagen & Getchell, 2006).

Despite knowing that FMS play a crucial role in children's health and development, studies have indicated a secular decline in some of children's motor skills (Roth et al., 2010). Studies have also shown that children lack sufficient motor skills to maintain a favourable health (Castetbon, 2012). These alarming trends may reflect a change in children's behaviour activity in recent decades (Roth et al., 2010), and may reflect sedentary lifestyle (Hinkley, 2010) as well as low levels of physical activity (Trost, 2003). The rationale for the promotion of FMS development in preschool children relies on the scientific evidence of the public health (Lubans, Morgan, Cliff, Barnett, & Okely, 2010) and psychosocial (Bart, Hajami, & Bar-Haim, 2007) benefits related to the acquisition of motor skills. Recent studies have consistently reported the associations of childhood FMS with childhood or adolescent physical activity, cardiorespiratory fitness, and lower body weight (Lubans et al., 2010; Timmons et al., 2012). Further, there is evidence that childhood FMS relate to academic outcomes in later life, with children that have greater motor skill competency being more likely to adjust normal schooling (Bart et al., 2007). However, despite these multifaceted benefits associated with childhood FMS proficiency, the underlying positive determinants for the acquisition of FMS competence during preschool years have been less systematically evaluated. This would be critical in terms of identifying the determinants that should be paid attention to when promoting children's motor skill competence. The purpose of this systematic review was to identify potential positive determinants of FMS in preschool-aged (3–6) children and classify the determinants based on educational purposes.

Methods

Identification of studies and criteria for inclusion/exclusion

In September 2012 we conducted a systematic search of the literature to identify determinants that were associated with FMS in preschool children. The papers we reviewed were sourced from the following databases: ERIC (ProQuest), PsycINFO (1806–

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current [Ovid]), MEDLINE (Ovid), SPORTDiscus with Full Text (EBSCO), and Physical Education Index (ProQuest). In addition, the most influential papers examining preschool children's FMS from the authors' personal libraries were identified.

As Table 1 shows, we used a combination of search terms for preschool children and for FMS in the search strategy. Some of the search terms were followed by an asterisk, which meant that also the plural forms of certain words were searched for. If possible, related terms within the databases were searched for as well.

We based the search on inclusion and exclusion criteria. We included studies if they (1) assessed the outcome (product-oriented assessment) or technique (process-oriented assessment) of at least one gross motor stability, locomotor or manipulative skill, or overall gross motor coordination based on the FMS classification defined by Gallahue et al. (2011); (2) focused on an age range or mean age of the children from three to six years, or a wider age range that described the results for three- to six-year-old children separately; (3) assessed quantitatively a potential determinant of FMS (i.e. individual or environmental related); (4) analysed quantitatively the relationship between potential determinant and FMS; (5) had been published between 1 January 2000 and 30 August 2012 in an English-language peer reviewed journal; and (6) addressed typically developing, healthy children, that is, groups other than clinical or special populations.

In the first stage of research, the authors (S.I. and A.S.) independently checked the titles of the identified articles to arrive at the first selection of abstracts. In the second stage of research, the authors independently screened the remaining documents' abstracts and considered them for detailed full-text assessment. At this stage the following exclusion criteria were applied: (1) validity or reliability study; (2) focus on non-typically developed children/special population (e.g. obese children, low-income families); (3) focus on fine-motor skills (e.g. manual dexterity), perceptual-motor skills (e.g. eye-hand coordination), fitness constructs (such as strength and speed), or biomechanical determinants (e.g. joint motion or movement velocity) of motor skills; and (4) reviews. At the third stage of research the authors independently assessed the full-text articles for possible inclusion. To be included in the review, the full-text articles had to satisfy the following criteria: (1) participant eligibility; (2) description of the sources of measurements, their implementation, and acceptability of reliability for the specific age group; (3) reportage of the number of three- to six-year-old participants completing each of the gross motor skill measures; (4) description of the statistical methodology and calculations used for analysing the relationships between FMS and potential determinants; and (5) at least one statistically significant positive

Table 1. Search terms used in the search strategy.

Preschool children	FMS
Young children or	Motor skill[a] or
Preschool children or	Object manipulation or
Infant[a] or	Perceptual motor coordination or
Toddler[a] or	Psychomotor skill[a] or
Kindergarten or	Coordination or
Kindergarten children or	Motor ability[a] or
Preschooler[a] or	Perceptual motor learning or
Child care or	Motor performance or
Child care centre[a]	Movement skill[a]

[a]Truncation symbol used to search databases for plural words.

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relationship between the determinant variable and FMS outcome found. As this review focused on the FMS classification defined in the literature by Gallahue et al. (2011) and Gallahue and Cleland-Donnelly (2003), the articles that examined the divergent movement ability of individuals were also included. Divergent movement refers to the aspects of motor creativity, that is, motor fluency and motor flexibility when performing gross motor tasks. Motor fluency refers to a number of different movement responses and motor flexibility refers to a number of changes in the effort exerted in the spatial aspect or changing one's relation to another object (Gallahue & Cleland-Donnelly, 2003; Trevlas, Matsouka, & Zachopoulou, 2003; Zachopoulou & Makri, 2005). In the final stage of research we screened the reference lists of the retrieved full-text articles for possible inclusion. For reliability of our review process, we completed training in reviewing papers by selecting randomly some titles that were identified through database search and discussing whether a title should be accepted for an abstract assessment or not. We also calculated the number of abstracts (MEDLINE, PsycINFO, Physical Education Index) or full-texts (SportDiscuss) that we individually accepted, and then checked the differences between the accepted abstracts or full-texts by us. The number of abstracts or full-texts that we disagreed across the four databases ranged from zero to eight; hence the percentage of agreement between the two reviewers ranged from 79% to 100%. We resolved disagreements by consensus.

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Selection and categorisation of variables

A detailed summary table was created for describing the included studies to record results for three- to six-year-old children. Only the areas pertaining to the determinants that held positive relationship to children's FMS variables were extracted from the reviewed studies, despite many of them having other findings or wider focuses. It must be noted that an inverse relationship between a determinant and motor outcome reported in studies was interpreted as a positive relationship if the presence of a determinant meant improved motor skills. The summary table of the included studies' characteristics and determinants that related positively to children's FMS is presented in a supplemental file (Summary table of the included studies' characteristics and positive determinants of FMS). The positive determinants reported in the included articles were classified as individual characteristics (e.g. gender, age), education-related (e.g. intervention), social environment (e.g. parental physical activity), and physical environment (e.g. size of the preschool play area). The motor variables to which the determinants held positive relationships reported in the articles were classified as stability skills, locomotor skills, or manipulative skills based on the FMS classification established by Gallahue et al. (2011) and Gallahue and Cleland-Donnelly (2003). An additional class was made for composite score variables (e.g. total FMS score, gross motor quotient), and such variables that described overall gross motor coordination (e.g. motor fluency). This approach aims to identify which individual- and environment-related determinants have been mostly investigated across the dispersed literature and identified as being positively associated with the fundamental domains of gross motor skills.

Results

Overview of studies

A total of 2484 potential titles were identified using database searches (Figure 1). Following the reviewing process and checking the reference lists of included studies, 29

articles satisfied the inclusion criteria and were included in the review. The flow of the articles through the review process and reasons for exclusion are reported in Figure 1. Details of the studies' characteristics (sample, design, determinants, FMS outcomes, and assessments as well as a description of main results) of their areas pertaining to the positive determinants of children's FMS are outlined in a supplemental file (Summary table of included studies' characteristics and positive determinants of FMS). Hence, the information included in the supplemental file is not repeated in the following subsections. Detailed results can be found in the articles (see reference list).

Of the 29 articles, 18 described cross-sectional studies, six reported on quasi-experimental studies, three on controlled trials, two on longitudinal design, and one on retrospective design. Studies included between 12 and 1228 participants, and they took place in 10 countries: Australia ($n = 5$), Belgium ($n = 2$), Finland ($n = 1$), Germany ($n = 2$), Greece ($n = 7$), Hong Kong ($n = 3$), Scotland ($n = 2$), Spain ($n = 1$), Switzerland ($n = 1$), and the United States ($n = 5$). The 29 articles reported on the usage of variable number of test items of test batteries, study specific tests, and combinations of test items of test batteries and study specific tests. Study specific tests refer to tests that were described in articles without citing previous literature. The reported test batteries included Movement ABC (Chow, Henderson, Sheila, &

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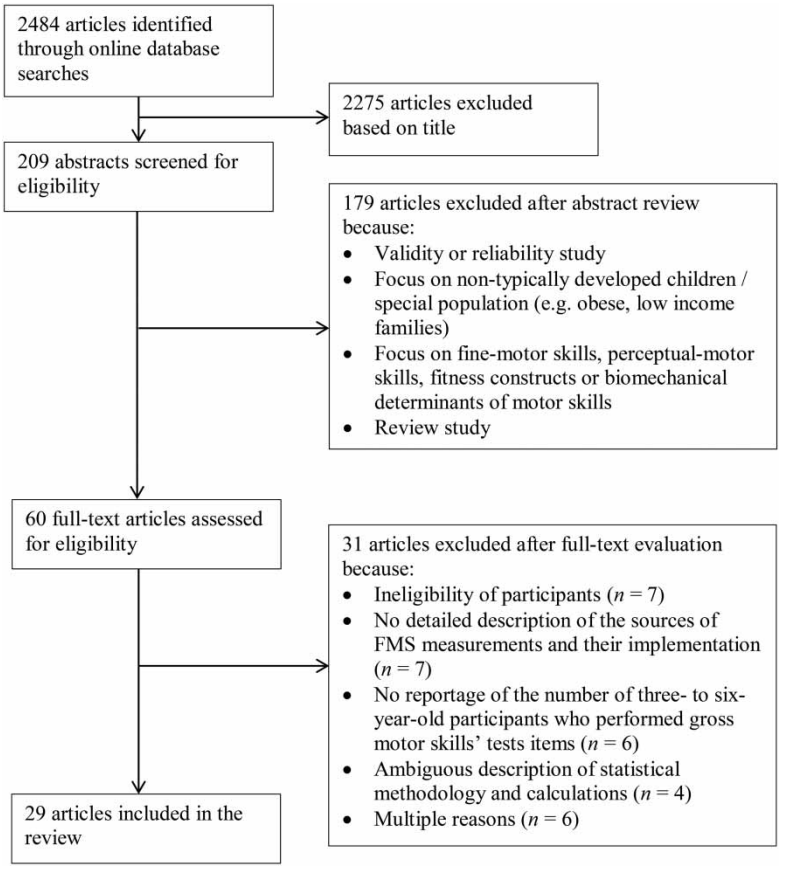


Figure 1. Search results and selection of articles.

Barnett, 2001), Test of Gross Motor Development (TGMD) (Ulrich, 1985)/Test of Gross Motor Development (second edition) (TGMD-2) (11 studies; Ulrich, 2000), Department of Education and Training planning guide for programming and teaching fundamental movement skills (Okely & Booth, 2004), Motoriketest für Vier- bis Sechsjährige Kinder (MOT 4–6) (Cools, De Martelaer, Samaey, & Andries, 2011; Roth et al., 2010; Vandaele, Cools, de Decker, & de Martelaer, 2011; Zachopoulou, Tsapakidou, & Derri, 2004), Body Coordination Test (Krombholz, 2006), Karlsruher Motorik-Secreening für Kindergartenkinder (Roth et al., 2010), Movement Assessment Battery (Fisher et al., 2005; Reilly et al., 2006), Divergent Movement Ability Test (Trevlas et al., 2003; Zachopoulou & Makri, 2005), Children Activity and Movement in preschool study motor skill protocol (Williams et al., 2008), APM Inventory Manual for assessing children's perceptual and FMS (Iivonen, Sääkslahti, & Nissinen, 2011), and Bruininks-Oseretsky Test of Motor Proficiency (Kambas et al., 2012; Venetsanou & Kambas, 2011). Three of the aforementioned test batteries assessed skill technique (process oriented), and the rest of the batteries assessed skill outcome (product oriented). The most frequently used battery, TGMD-2, assesses skill performance techniques in six locomotor and six object control tasks and quantifies the performances as composite scores (Ulrich, 2000).

Individual characteristics

Table 2 presents a summary of the determinants that were positively associated with children's performance of FMS such as stability, locomotor, manipulative skills, and total gross motor skill variables reported in the articles. Thirteen studies identified gender as a positive determinant of children's FMS. Male gender mostly associated with variables that described children's manipulative skills (seven studies) and female gender with variables that described locomotor (five studies) or balance (four studies) skills. Eight studies found a positive association between increasing or older age and children's FMS. Each of the eight studies used different instruments to assess motor skills. The mean ages or age groups of children also varied among the studies. Five of these studies reported older children as being more proficient in balance skills compared with their younger counterparts (Chow & Chan, 2011; Iivonen et al., 2011; Krombholz, 2006; McKenzie et al., 2002; Venetsanou & Kambas, 2011), and five studies reported positive relationships between increased age and manipulative skills (Chow & Chan, 2011; Iivonen et al., 2011; McKenzie et al., 2002; Williams et al., 2008; Wong & Cheung, 2006). Four studies indicated that age was positively associated with locomotor skills (Iivonen et al., 2011; Krombholz, 2006; Williams et al. 2008; Wong & Cheung, 2006). One of the seven studies investigated the effect of linear age on each FMS domain longitudinally (Iivonen et al., 2011), whereas the other six studies investigated cross-sectional relationships between age and skills in one to two FMS domains. Zachopoulou & Makri (2005) found that children in an older age group had higher scores on motor fluency compared with children in a younger age group.

Habitual physical activity was examined across six studies. Of these studies five were cross-sectional and one longitudinal. The number of participants across the studies ranged from 34 (Robinson, Wadsworth, & Peoples, 2012a) to 394 (Fisher et al., 2005). Three cross-sectional studies that used accelerometers to assess children's physical activity reported on total physical activity or time in moderate to vigorous physical activity being associated with children's total FMS scores (Bürgi et al.,

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Table 2. Summary of determinants that positively associated with fundamental motor skill variables in preschool-aged children reported in the included articles.

	FMS variables:			
Determinants	Stability First author (year)	Locomotor First author (year)	Manipulative First author (year)	Total FMS scores/agility/ gross motor creativity First author (year)
Individual characteristics				
Male gender	Venetsanou and Kambas (2011)	Chow and Chan (2011)	Chow et al. (2001), McKenzie et al. (2002), Okely and Booth (2004), Hardy et al. (2010a), Chow and Chan (2011), Vandaele et al. (2011), Robinson et al. (2012a)	Bürgi (2011)
Female gender	Chow et al. (2001), McKenzie et al. (2002), Krombholz (2006), Venetsanou and Kambas (2011)	Okely and Booth (2004), Pollatou, Karadimou, & Gerodimos (2005), Cliff et al. (2009), Hardy et al. (2010a), Vandaele et al. (2011)	Cliff et al. (2009)	Reilly (2006)
Increasing age or older age group	Chow et al. (2001), McKenzie et al. (2002), Krombholz (2006), Iivonen et al. (2011), Venetsanou & Kambas (2011)	Krombholz (2006), Wong & Cheung (2006), Williams et al. (2008), Iivonen et al. (2011)	Chow et al. (2001), McKenzie et al. (2002), Wong and Cheung (2006), Williams et al. (2008), Iivonen et al. (2011)	Zachopoulou and Makri (2005)
Ethnicity:				
Hong Kong	Chow et al. (2001)			
American			Chow et al. (2001)	

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Table 2. (Continued).

Determinants	FMS variables: Stability First author (year)	Locomotor First author (year)	Manipulative First author (year)	Total FMS scores/agility/ gross motor creativity First author (year)
Habitual physical activity:				
Total physical activity	Bürgi (2011)		Cliff et al. (2009)	Fisher et al. (2005), Cliff et al. (2009), Bürgi (2011)
Moderate to vigorous physical activity		Williams et al. (2008), Cliff et al. (2009)	Cliff et al. (2009)	Fisher et al. (2005), Williams et al. (2008), Cliff et al. (2009)
Number of steps/walking time	Kambas et al. (2012)	Kambas et al. (2012), Robinson et al. (2012a)	Kambas et al. (2012)	
Physical fitness	Krombholz (2006)	Krombholz (2006)		
Total playfulness				Trevlas et al. (2003)
Education-related				
Preschool/home-based physical activity and/or motor skill promoting programmes	Zachopoulou et al. (2004)	Zachopoulou et al. (2004), Deli et al. (2006), Hardy et al. (2010b), Iivonen et al. (2011), Jones et al. (2011), Robinson et al. (2012b),	Hardy (2010b)	Reilly (2006), Hardy et al. (2010b), Jones et al. (2011), Robinson et al. (2012b)
Scheduled random practice of motor skills			Vera & Montilla (2003)	
Attendance in physical education lessons at least once a week	Krombholz (2006)	Krombholz (2006)		
Social environment				
Family context:				
Higher parental education				Cools et al. (2011)
Parental behaviour (5 variables)				Cools et al. (2011)

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Table 2. (Continued).

	FMS variables:			
Determinants	Stability First author (year)	Locomotor First author (year)	Manipulative First author (year)	Total FMS scores/agility/ gross motor creativity First author (year)
Parental beliefs (7 variables)				Cools et al. (2011)
Having older siblings instead of being the only or first born child	Krombholz (2006)	Krombholz (2006)		
Sports club participation	Roth et al. (2010)	Roth et al. (2010)		Roth et al. (2010)
Middle/high socio economic status		Hardy et al. (2010a)		
Non-English speaking background		Hardy et al. (2010a)		
Physical environment				
Population density of living area				Cools et al. (2011)
Preschool play area:				
Smaller-sized			Chow & Chan (2011)	
Larger-sized		Chow and Chan (2011)		
Rural residential background				Roth et al. (2010)
Wearing athletic shoes instead of flip-flop sandals		Robinson et al. (2011)		

2011; Cliff et al., 2009; Fisher et al., 2005; Williams et al., 2008). One longitudinal study that also used accelerometers found that baseline physical activity predicted balance and agility at follow-up (Bürgi et al., 2011). One study reported on difference between genders in the relationships between physical activity and motor skills. Physical activity at different intensities related positively to locomotor and object control skills and gross motor quotients only in boys (Cliff et al., 2009). Two of the six studies used pedometers to assess physical activity. One study reported on mean steps per minute being associated with amount of variance in locomotor scores (Robinson et al., 2012a). Another study found positive relationships between daily

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steps or walking time and five different motor skills across the three FMS domains (Kambas et al., 2012).

One study (Chow & Chan, 2011) included a cross-cultural comparison of motor skill performances between Hong Kong Chinese and American children across three age groups. The study (Chow et al., 2001) found that Hong Kong Chinese children were better in balance skills, and American children were better in catching. One study (Krombholz, 2006) examined the relationship between physical fitness and gross motor coordination in a sample of more than 1000 preschoolers. The authors reported that three measures of fitness correlated positively with balancing and locomotor tasks in motor coordination tests (Krombholz, 2006).

Finally, Trevlas et al. (2003) reported on cross-sectional relationships between children's total playfulness and both aspects of divergent movement ability – motor fluency and motor flexibility. Total playfulness refers to physical, social, and cognitive spontaneity, manifest joy, and sense of humour (Trevlas et al., 2003).

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Education-related

Seven articles (representing eight programmes) reported positive associations between preschool- and nursery-based programmes and children's FMS. Fourteen (Robinson, Webster, Logan, Lucas, & Barber, 2012b) to 545 (Reilly et al., 2006) participants were involved in the studies, which implemented experimental designs with pre- and post-test comparisons ($n = 2$), experimental design with pre-, middle-, post-, and retention-test comparisons ($n = 1$), randomised controlled trials ($n = 3$), and longitudinal design with pre-test, post-test evaluation ($n = 1$). The six experimental studies that included intervention–control group comparisons reported control groups' continuing with their usual preschool curriculums ($n = 3$), receiving information on unrelated topics ($n = 1$), engaging free play ($n = 1$), or participating in a physical education programme ($n = 1$).

The durations of the programmes ranged from eight weeks (Deli, Bakle, & Zachopoulou, 2006) to eight months (Iivonen et al., 2011), and two to three 20- to 50-minute sessions were organised per week. Overall, the programmes' main aims related to the enhancement of children's motor skills and physical activity, but their constructs and outcomes were different: (1) a 24-week movement skill development physical activity programme including three times 20 minutes structured lessons per week plus professional development for staff improved the jumping and overall movement skill score of TGMD-2 (Jones et al., 2011), (2) a 24-week enhanced physical activity including three times 30 minutes lessons per week at nursery plus home-based health education to reduce children's body mass index improved scores for fundamental movement skills in the movement assessment battery (Reilly et al., 2006), (3) an eight-month physical education curriculum including two times 45 minutes lessons per week developed in an international project affected boys' running speed and girls' standing broad jump in the APM Inventory (Iivonen et al., 2011), (4) a sustainable, low-intensity, state-wide professional development programme aiming at healthy eating, physical activity, and movement skills improved points in the locomotor subtest, object control subtest, and FMS total score in the TGMD-2 (Hardy, King, Kelly, Farrell, & Howlett, 2010b), (5) an eight-week music and movement programme with rhythmic education including two times 35 minutes lessons per week implemented by physical educator affected jump and dynamic balance in MOT 4–6 (Deli et al., 2006; Zachopoulou

et al., 2004), and a similar kind of programme with a duration of 10 weeks affected locomotor skills of TGMD (Deli et al., 2006), and (7) an 11-week mastery climate programme including two times 30 minutes sessions per week implemented by early childhood education majors improved locomotor skills and total performance of TGMD-2 (Robinson et al., 2012b).

One Spanish study investigated the effectiveness of a variable random practice structure on children's skill learning and found that this type of contextual interference positively affected throwing skills in the acquisition, retention, and transfer phases (Vera & Montilla, 2003). Finally, Krombholz (2006) found that children who attended physical education lessons at least once a week outperformed their non-participating counterparts in balance and locomotor skills.

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Social environment

Four articles reported on positive associations between social environment variables and children's FMS outcomes. One cross-sectional study that was conducted in Belgium identified 13 family contextual variables as positive correlates of total FMS score of MOT 4–6 (Cools et al., 2011). Six parental variables describing physically active behaviour, motorised transporting, and high value placed on sport specific aspects of child's physical activity determined FMS in boys, whereas two parental variables (the frequency of providing equipment and a high value placed on sleep) determined FMS in girls. Higher parental education, transport to school by bicycle, and a high value placed on physical activity for parents' own children determined FMS competency in both genders (Cools et al., 2011). Another cross-sectional study that was conducted in Australia indicated that middle to high socioeconomic status and a non-English speaking background associated with higher scores in hop among boys (Hardy, King, Farrell, Macniven, & Howlett, 2010a). The part of the retrospective study that was conducted after 2000 in Germany indicated that sports clubs participation associated with higher scores for balancing, the standing long jump, and obstacle course (Roth et al., 2010).

Physical environment

The two articles that reported associations between social environment and children's FMS also reported positive associations between neighbourhood characteristics and FMS outcomes. The Belgian study showed a trend for a significant relationship between population density of the children's living area and total FMS scores in boys (Cools et al., 2011), and the German study reported on children living in a rural neighbourhood being better in an obstacle course than children with an urban background (Roth et al., 2010). Cross-sectionally, one Hong Kong study indicated that children from preschool with a larger play area outperformed those from preschools with a smaller play area in locomotor skills of TGMD-2, while children from preschools with a smaller play area were better in object control skills (Chow & Chan, 2011). Finally, an experiment with a sample of only 12 children reported by Robinson et al. (2011) indicated that children scored significantly higher when wearing athletic shoes rather than flip-flops.

Discussion

The aim of this review was to identify and classify the determinants associated positively with preschool-aged (3–6 years) children's FMS competence divided into domains of stability, locomotor and manipulative movements, or overall gross motor coordination. Twenty-nine articles were included and 19 positive determinants were recognised that fell into categories of individual characteristics, education-related determinants, and social and physical environments. We found evidence from five to eight studies examining three- to six-year-old children and using nine different FMS testing instruments for a positive association between domains of FMS and gender, age, habitual physical activity, and preschool-based programmes. We found only singular studies that supported a positive association between children's different FMS domains and ethnicity, fitness, playfulness, participation in physical education lessons, social environment, and physical environment factors.

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Important age

This review gave support to the evidence documented in the pertinent literature suggesting that preschool age is the time increases in children's FMS competence to some point happens along with age through maturation processes (Gallahue et al., 2011; Malina et al., 2004). In our review, eight studies across five countries and using different instruments for assessing children's FMS supported this evidence. The studies indicated that improvements in motor skills of different domains followed an age trend or that older aged children demonstrated more competency in motor skills compared with their younger aged counterparts. However, no studies reported that the highest level of FMS competence was gained purely along with age, but all notified the importance of environmental opportunities provided from education and/or home and community life. A number of large-scale studies in this review reported that performance in balance improved as children aged (Chow & Chan, 2011; Krombholz, 2006; McKenzie et al., 2002; Venetsanou & Kambas, 2011). These results lend support to the assumption that preschool years are an important time for stability development (Gallahue et al., 2011; Venetsanou & Kambas, 2011). Stability is of great significance because it is an integral part of all movements and thus it is an underlying factor for the development of locomotor and manipulative skills (Gallahue et al., 2011). Unfortunately many studies in this age group focus on investigating locomotor and manipulative skills or on reporting composite scores that consist of a range of FMS, and thus provide limited information on development of this fundamental motor skill domain (Logan, Robinson, Wilson, & Lucas, 2011). We recommend that future studies should include assessment of balance skills.

Gender as inducement

Our review confirmed the gender-based differences in young children's FMS performances that were also reported in earlier reviews (Thomas & French, 1985; Toole & Kretzcschmar, 1993). Research has suggested that boys tend to have more developed manipulative skills than girls, whereas girls may be more competent in stability demanding tasks and locomotor skills than boys (Thomas & French, 1985; Toole & Kretzschmar, 1993). In this review, one longitudinal and six cross-sectional studies across four different counties and using five different instruments to assess FMS

indicated that boys performed better than girls in manipulative skills. Partly the same four to five studies indicated that girls performed better than boys in balancing and locomotor tasks. It has been suggested that gender differences in motor skills at a young age are likely to be influenced by environmental rather than biological factors (McKenzie et al., 2002). For example, boys may perform better in catching because it is reasonable to consider that they play more ball games, whereas girls may perform better in balancing and jumping because they play more games that involve these elements (McKenzie et al., 2002). We see that more important than underlining gender-based differences in children's FMS is to carefully consider possible differences when promoting children's FMS development. There is evidence that many girls do not develop manipulative skills or that girls may fall behind the development of mastery-level manipulative skills over time because they are less proficient in early childhood (Okely & Booth, 2004). However, it has also been suggested that if girls were provided with the similar opportunities to practise these skills the differences in skill proficiency between boys and girls could be reduced (Okely & Booth, 2004).

A recent follow-up study, where FMS intervention was delivered when the children were four years old and movement skills were assessed three years later at the age of eight years, confirmed that skill development during preschool years is important to subsequent motor skill competency, as children with better object control skills maintained their skill level in an adequate environment (Zask et al., 2012). It has also been suggested that locomotor skills do not explain subsequent skill proficiency as much as object control skills do. This difference illustrates that gaining good manipulative skills in preschool years is perhaps more critical to subsequent motor skill competence and physical activity than locomotor skills (Zask et al., 2012).

Physical activity participation

It has been indicated that proficiency in FMS is positively associated with physical activity participation in children and adolescents (Lubans et al., 2010). This review was able to confirm the relationship between FMS competency and habitual physical activity in preschool-aged children. A number of studies including five different test-batteries to assess motor skills, and all using objective measures of physical activity – some of which used accelerometers (Bürgi et al., 2011; Cliff et al., 2009; Fisher et al., 2005; Williams et al., 2008) and some of which used pedometers (Kambas et al., 2012; Robinson et al., 2012a) – found a positive relationship between children's FMS competence and physical activity. Cross-sectionally, four studies reported positive associations between children's physical activity and the sum of range of motor skills. Partly the same plus another two cross-sectional studies reported on positive associations between physical activity and scores for balance, locomotor and/or manipulative skills, which illustrates that physical activity relates to a comprehensive range of children's FMS. Only one study in this review was able to show the causality of the connection between physical activity and motor skills, specifically balance and agility (Bürgi et al., 2011).

In contrast to what had been previously hypothesised, Bürgi et al. (2011) showed that the relationship between children's physical activity and motor skills was dominated by the impact of physical activity on motor skills. This finding lends support to the role that motor skill competence plays in physical activity proposed by Stodden et al. (2008), who have suggested that physical activity might drive young children's motor skill development and that during early childhood the connection between

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these two is still weak but will strengthen over the time. More longitudinal studies are warranted to confirm this issue. In addition, we suggest that more research is important to understand what types and contexts of physical activity provide optimal support to motor skill development in young children, because the aforementioned studies used objective measures of physical activity that are unable to provide this sort of information. For example, it has been suggested that play is a type of physical activity that allows children to use an ample scope of motor repertoire according to their psychological and cognitive constructs (Trevlas et al., 2003). While engaging in physically active play, children may express themselves creatively through performance of FMS and produce different motor patterns for movement problems and tasks, and thus learn FMS (Gallahue & Cleland-Donnelly, 2003). Because we found only singular studies that indicated a positive relationship between different FMS domains and specific ethnicity, physical fitness, and playfulness as an internal personality characteristic in preschool-aged children, these individual characteristics' significance in gaining FMS competence must be confirmed in future studies.

Educational context as important environment

The majority of children under seven years of age are enrolled in a preschool or day care centre (Logan et al., 2011; OECD Family Database, 2008). Therefore these educational contexts provide an important environment in which to promote children's FMS through structured programmes. Recently, a number of preschool-based programmes have been conducted in order to prevent physical inactivity and support motor skill development in young children (Logan et al., 2011). The majority of the programmes have targeted children that were classified as developmentally delayed or at risk of delay in FMS competence because of environmental and biological factors (Logan et al., 2011). This review identified eight programmes that were relatively different from each other and were targeted at typically developing children in early education context. Five of the programmes focused on motor skill development (Deli et al., 2006; Jones et al., 2011; Robinson et al., 2012b; Zachopoulou et al., 2004), and three had more profound aims with respect to children's health (Hardyet al., 2010b; Reilly et al., 2006) or physical education curriculum development (Iivonen et al., 2011). Seven of the programmes included a number of structured lessons implemented by preschool staff (Iivonen et al, 2011; Jones et al., 2011; Reilly et al., 2006), physical educator (Deli et al, 2006; Zachopoulou et al., 2004), or students (Robinson, 2012b). One programme did not include any compulsory structured lessons, but provided education and material for setting staff to promote children's FMS (Hardyet al., 2010b). Regardless of the durations of the programmes, frequency of structured lessons, or detailed contents of the structured activities, the programmes succeeded in improving children's FMS. The most gains were achieved in locomotor skill development.

Based on these findings it may be suggested that several types of preschool-based programmes that include an aim to develop motor skills, last eight or more weeks and implement at least two structured sessions per week can improve children's FMS, and may particularly support locomotor skill development. More research is needed to understand the optimal characteristics of effective programmes to support different gross motor skill domains of typically developing children who are not at risk of developmental delay (Logan et al., 2011). Future studies should also assess who implemented the interventions, as this variable may have an impact on outcomes.

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In addition, studies should implement a follow-up or retention assessment in order to determine if achievements in motor skills in childhood are sustained (Zask et al., 2012). We found only two studies with substantially different settings that indicated education-based contexts other than preschool-based programmes to be positively associated with gross motor skills (Krombholz, 2006; Vera & Montilla, 2003). This may suggest that different types of education arrangements outside preschool may be also important means of children's FMS promotion. It has been suggested that, with respect to seeing greater improvements in children's FMS proficiency, directed activities may be more important than opportunities to practise during free play (Gagen & Getschell, 2006).

Social and physical environments

Due to the limited number of studies, we found little evidence for positive association between children's FMS competence and social and physical environment determinants. Five relatively large-scale studies in different geographic locations and using different FMS test batteries found five different social environment determinants to be positively associated with children's balance and/or locomotor skills (Hardy et al., 2010a; Krombholz, 2006; Roth et al., 2010) and/or total FMS scores (Cools et al., 2011; Roth et al., 2010). The same two studies (Cools et al., 2011; Roth et al., 2010), one large-scale study (Chow & Chan, 2011), and one experimental study with a limited number of participants (Robinson et al., 2011) found together four physical environment determinants to be positively associated with children's locomotor (Chow & Chan, 2011; Robinson et al., 2011) and/or manipulative skills (Chow & Chan, 2011) or total FMS scores (Cools et al., 2011; Roth et al., 2010).

Due to differences between the social and physical environment determinants found by the studies, we were unable to provide consistent answers to the question of what kind of social and physical environments, besides education-related contexts, optimally promote different motor skill domains in preschool-aged children. It is possible that many of the positive associations between children's FMS and environment-related determinants found by the studies (Chow & Chan, 2011; Hardyet al., 2010a; Robinson et al., 2011; Roth et al., 2010) were realised in the specific setting or population and thus limit our ability to draw generalised conclusions. However, many of the positive associations between environmental determinants and motor skill outcomes were reported only in boys (Cools et al., 2011; Hardyet al., 2010a).

Some explanations can be provided. Interactions among young girls tend to be conducted in a cooperative and caring way while interactions among boys are marked by competitiveness and individualism (Hardy et al., 2010a). These interactions may reflect the differences in activities between boys and girls and limited skill practice could contribute to the development of some of the motor skills in girls (Hardy et al., 2010a). In addition, the role interaction with parents may be different for the genders (Cools et al., 2011). Parents may show gender-typed behaviours more strongly towards boys than girls (Sääkslahti et al., 1999).

Based on the studies reporting positive relationships between children's FMS and environmental determinants we can provide some suggestions to be considered when designing FMS promotion strategies in preschool-aged children: (1) information on gender differences in FMS can help educators and parents identify which skills should be reinforced so that both genders are given the opportunity to learn fundamental skills (Hardy et al., 2010a), (2) making parents aware of the importance of organised

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physical activity for their child's beneficial development may support children's FMS development (Cools et al., 2011), (3) facilitation of access to facilities such as sport clubs (Roth et al., 2010) and equipment may support children's skill acquisition (Cools et al., 2011), (4) socioeconomically lower class children may benefit from the efforts of sport clubs and organisations to enhance their accessibility by lowering socio-economic barriers to participation (Cools et al., 2011), and (5) a larger play area may provide children more opportunities to practise and learn locomotor skills such as running and leaping, which require a spacious area, contrary to manipulative skills, which can be reinforced in smaller sized areas (Chow & Chan, 2011).

Strengths and limitations of the study

To our knowledge this was the first review that aimed to identify positive determinants of gross motor skills across the domains of fundamental stability, locomotor and manipulative movements in typically developing preschool-aged children. The earlier reviews about the current topic combined preschool-aged and older children into the same analysis, included children that were classified as developmentally delayed or at risk of delay and used some other inclusion criteria, especially concerning the FMS measures that differed from this review (Logan et al., 2011; Lubans et al., 2010).

Due to the short but growing history of research interest about FMS development in this population as well as the various research practices, we faced a number of challenges when reviewing the papers. When establishing the aim of this review as extensively as possible, we included several study designs that utilised variable-sized samples, varied in their characteristics (e.g. ethnic background and location) and used various process- or product-oriented FMS assessment instruments. In order to locate the pertinent and comprehensive literature, we sourced five databases that covered different disciplines: sport sciences, education, psychology, medicine, and health. We did not apply existing statements for criteria for assessing the quality of studies or code the results following a particular model. To be included in this review, the study had to satisfy each of the five quality criteria determined by the authors. Furthermore, we compounded the structure for this review from careful examination of the included papers in order to provide a practical point of view that best guides educators and researchers in finding those determinants that can increase the level of child's motor competence.

When reviewing the included studies, we faced the challenge of structuring the reported motor skill outcome variables according to the three FMS domains (Gallahue, et al. 2011; Gallahue & Cleland-Donnelly, 2003). In order to avoid incorrect interpretations of outcome variables reported by studies, we created a category for those variables that described overall gross motor coordination consisting of a set of different gross motor skills (e.g. the obstacle course reported by Bürgi et al. (2011)) or computational variables of the number of motor skill scores (e.g. the total score of TGMD 2).

The second major challenge we faced when reviewing the papers was the failure, in some studies, to report detailed sample characteristics or clearly report whether a study was targeted at children that were classified as developmentally delayed or at risk of delay in FMS competence because of environmental and biological factors. These limitations hampered our attempts to interpret which studies to exclude because of an examination of children with non-typical development. These points are a reflection of the scarcity of published studies about preschool-aged children and their FMS development. To gain a comprehensive understanding of the complex, multidimensional

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relationships that exist between preschool-aged children's FMS competence and its determinants, future studies should simultaneously examine multiple variables across different FMS domains. The use of larger samples may allow for the identification of weak yet significant relationships previously concealed. Longitudinal designs may assist in the detection of the persistence of these relationships. To obtain a comprehensive picture of preschool-aged children's FMS competence, it is imperative to collect FMS data from more diverse and typically developing children across a range of locations and contexts using instruments that encompass different FMS domains and that are validated in the preschool population.

Conclusions

Despite these limitations of our review, the findings of the included studies let us postulate some key messages that are important to consider when promoting preschooler's FMS development:

- Improvements in motor skills of different domains to some point follow an age trend at preschool age (e.g. Chow et al., 2001; Iivonen et al., 2011; McKenzie et al., 2002).
- Gender differences in FMS competence may exist: boys are better in manipulative skills, and girls may be better in balance and locomotor skills (e.g. Chow et al., 2001; Hardy et al., 2010a; McKenzie et al., 2002; Okely & Booth, 2004; Vandaele, et al., 2011). There may be a need to encourage girls to practise more manipulative skills (Okely & Booth, 2004).
- An individual's biological and behavioural characteristics need to be considered when supporting children's FMS competence.
- Habitual physical activity is an important correlate of FMS (e.g. Bürgi et al., 2011; Cliff et al., 2009; Fisher et al., 2005; Williams et al., 2008).
- Due to the limited amount of scientific evidence, the significance of social and physical environments in promoting children's FMS is still uncertain. Family, residential, and schooling conditions may play a positive role in children's FMS competence (Chow & Chan, 2011; Cools et al., 2011; Hardy et al., 2010a; Krombholz, 2006; Roth et al., 2010).
- From a research standpoint, it is imperative to continue to determine the optimal conditions for childhood FMS development.

Summary

This review found evidence from a number of studies for a positive association between domains of preschool-aged children's FMS and gender, age, habitual physical activity, and preschool-based programmes. As only singular studies supported a positive association between different FMS domains and ethnicity, fitness, playfulness, participation in physical education lessons, and social and physical environment factors, the positive relationship between children's FMS competence and these determinants remains uncertain.

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