Review

Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review

Benjamin Holfelder*, Nadja Schott

University of Stuttgart, Department of Sport and Exercise Science, Allmandring 28, 70569 Stuttgart, Germany

Abstract

Objectives: This systematic review provides an overview of research elucidating the relationship between fundamental movement skills (FMS) and physical activity (PA) in children and adolescents.

Design: Systematic review.

Method: Prospective studies were identified from searches in Cochrane Library, BioMed Central, Education Resources Information Center (ERIC), PubMed, Scirus and SciVerse Science Direct from 2000 through 2013. We screened the titles and abstracts for eligibility, rated the methodological quality of the studies, and extracted data.

Results: We identified 23 studies meeting our relevancy criteria. The quality score of the studies ranged from 44% to 89%. Overall relationships between FMS and PA or relationships specific for gender and skill were identified in several studies. The variety of methods for assessing PA and FMS make the comparison of study results difficult. We found strong evidence from cross-sectional studies for a positive relationship between FMS and organized physical activities. Motor skill competency was only of low predictive value for the physical activity level in adults.

Conclusions: The results of this review suggest that a cause–effect relationship between FMS and PA is suspected but has not been demonstrated yet. The identification of a causal relationship appears very important to ensure feasibility of practical implementation. This could provide aids for decision making for teachers and coaches, but also for therapists’ decision guidance to create training, lessons and therapy adequate to the target group.

Introduction

Early and regular physical activity (PA) is associated with a number of positive effects on the respiratory, heart and circulatory systems (Sakuragi et al., 2009; Siegrist, Lammel, Haller, Christle, & Halle, 2013), positive psychological (Fedewa & Ahn, 2011; Lees & Hopkins, 2013) and cognitive effects (Fedewa & Ahn, 2011; Lees & Hopkins, 2013) and cognitive effects (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Hillman & Schott, 2013), as well as an active lifestyle (Stodden et al., 2008) in children and adolescents (i.e., 6–19 years of age). Nevertheless, current reviews show that many children and adolescents are not getting a sufficient level of physical activity (e.g. Hallal et al., 2012), which is reflected in the increasing number of overweight and obese children in the last few years (Sakuragi et al., 2009). Furthermore, the negative health effects associated with physical inactivity and obesity may result in insulin resistance and cardio-vascular disease (Froberg & Andersen, 2005). Therefore, the promotion of physical activity in children, as well as in adults, can be categorized as an important task for society as well as health policy. The exact reasons why some people are more physically active than others remain unclear (Stodden et al., 2008; Stodden & Holfelder, 2013).

The school routine and the club system shows that movement competence1 or mastery of fundamental movement skills (FMS) is assumed in children, adolescents and adults for them to be able to participate in organized and informal activities or even to be interested in taking part (Hardy, King, Farrell, Macniven, & Howlett, 2010; Livesey, Lum Mow, Toshack, & Zheng, 2011; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). From this point of view, the research question of to what extent the mastery of FMS influences the participation in organized and non-organized PA is derived.

* Corresponding author. Tel.: +49 711 68563167.
E-mail addresses: benjamin.holfelder@inspo.uni-stuttgart.de (B. Holfelder), nadja.schott@inspo.uni-stuttgart.de (N. Schott).

1 Motor competence can be defined as a person’s movement coordination quality when performing different motor skills, ranging on a continuum from gross to fine motor skills.
Furthermore, it is assumed that the mastery of FMS in infancy is not only directly associated with increased PA, but also positively influences the activity level in adulthood (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009a; Stodden et al., 2008). So far, there are only few studies examining the causal relationship between the quality of FMS and PA (Barnett, Morgan, van Beurden, Ball, & Lubans, 2011; Jaakkola & Washington, 2013), i.e. that having high fundamental movement skill level may increase options for participation in PA, as well as increased participation leading to further development of motor skills. However, a definite answer to this question cannot be given at this point. Some studies suggest a reciprocal relationship between PA and FMS (Barnett et al., 2011; Hume et al., 2008; Kambas et al., 2012; Stodden et al., 2008). For the present article physical activity is used as a generic term for every bodily movement produced by the skeletal muscles, that raises the energy consumption above the basal metabolism (Caspersen, Powell, & Christenson, 1985). Despite this simple definition, PA is a complex and multidimensional behavior, which includes qualitative aspects (e.g. way to school or sports) and quantitative aspects (e.g. frequency, duration, intensity). PA could be assessed using self-report (e.g. questionnaires and diaries) and objective measures (e.g. accelerometers, pedometers, heart rate monitoring) (Warren et al., 2010). A common method for calculating energy cost for different PA is applying the metabolic equivalent (MET), which seems to be valid for adults, but not for children (ibid.). For a detailed overview of instruments for assessing PA with all relevant advantages and disadvantages of each method, see the review of Warren et al. (2010).

Motor skills in general can be defined as the consistent production of goal-oriented movements, which are learned and specific to the task (McMorris, 2004), while motor abilities such as balance, flexibility, muscular strength and endurance are defined as "general traits or capacities of an individual that underlie the performance of a variety of movement skills" (Burton & Miller, 1998, p. 43; Burton & Rodgerston, 2001). Fundamental movement skills consist of locomotor skills that are used to propel a human body through space (e.g., running, jumping, hopping) and object control skills which include manipulating an object in action situations (e.g., throwing, catching, kicking; Cliff, Okely, Smith, & McKeen, 2009). These FMS are the building blocks for more complex and sport-specific skills (Robinson & Goodway, 2009), like "pitching" in baseball. Some research groups (e.g. Barnett et al., 2011; Cliff et al., 2009) summarize their results in form of sum scores across all individual test variables. Additionally, some authors (e.g. Gallahue & Ozmun, 2006; Jaakkola & Washington, 2013) classify balance and/or stability as a third dimension of FMS, which should be qualified according to the taxonomy of Fleishman (1962) and Burton and Rodgerston (2001) as a motor ability rather than a skill. The reason for this is, that the only way to assess balance is using FMS like walking or jumping.

Previous systematic reviews/meta-analysis in this field analyzed the efficacy of interventions, which refers to organized physical activity, improving motor development in young typically (Logan, Robinson, Wilson, & Lucas, 2012; Morgan et al., 2013; Riethmuller, Jones, & Okely, 2009) and nontypically developing children (Logan et al., 2012). They concluded that the majority of studies are successful in significantly enhancing motor skill development and are therefore an important means to promote (lifelong) physical activity. For example Morgan et al. (2013) revealed large effect sizes in terms of standardized mean difference (SMD) for overall gross motor proficiency (SMD = 1.42, \( P < .0002 \)) and locomotor skill competency (SMD = 1.42, \( P < .001 \)), as well as a medium effect size for object control skill competency (SMD = .63, \( P < .0004 \)). However, it remains unclear from the studies which intervention strategy results in the most improvement in which FMS, and at which point a critical amount of instruction is reached (Logan et al., 2012; Morgan et al., 2013; Riethmuller et al., 2009). This might be due to the fact, that many studies did not describe their intervention strategy in sufficient detail (Logan et al., 2012; Morgan et al., 2013). Riethmuller et al. (2009) found that only 3 of the 17 studies involved had a high methodological quality, which highlights the demand on research, i.e. about the relationship between PA and FMS. Furthermore, Morgan et al. (2013) reported that many studies scored poorly for risk of bias items which could lead to an underestimation of the study quality. In a further review, Lubans et al. (2010) examined psychological, physiological and behavioral health benefits with FMS competency as well as the relationship between FMS and PA, but studies were excluded, which did not provide a composite score of FMS. Overall, they found a positive association between FMS and PA in children and adolescents, but did not make any statements about the postulated reciprocal relationship between PA and FMS (e.g. Barnett et al., 2011; Kambas et al., 2012).

The focus of these reviews (Logan et al., 2012; Lubans et al., 2010; Morgan et al., 2013; Riethmuller et al., 2009) was mainly on general associations without presenting and discussing results about relationships specific to skill and gender. Logan et al. (2012) and Morgan et al. (2013) differentiated only between locomotor and object control skills, but a skill-specific analysis that was mentioned by Lubans et al. (2010) as a future direction, was not conducted. This distinction seems to be essential, because current studies (e.g. Cliff et al., 2009; Jaakkola & Washington, 2013) reported gender and skill-specific differences, which could be important in giving appropriate instructions for planning sport lessons or designing interventions. Although, all reviews present the applied instruments assessing FMS and PA in their summary of the included studies, they hardly considered methodical influences and differences at this point, but point it out as a difficulty comparing studies (Morgan et al., 2013).

As far as we know, no systematic review with the exclusive focus on the relationship between PA and FMS has been performed. Therefore, in this article we are giving an update of published studies since the review of Lubans et al. (2010); 8 included studies were published since 2010 and later, c.f. Supplementary material 2) by presenting the results of a systematic review of the existing literature examining this relationship. We take into account the methodological quality of the studies, present and discuss the applied methods assessing FMS and PA. General relationships between PA and FMS will be discussed, but also relationships specific to skill and gender. Furthermore, we want to discuss briefly the understanding of FMS and the potential cause and effect relationship between PA and FMS. Based on previous studies (e.g. Cliff et al., 2009; Jaakkola & Washington, 2013) we hypothesize that there are skill- and gender-specific relationships between PA and FMS. In addition we assume that physical activity behavior in adolescents relies on the current or future benefits associated with the acquisition of FMS proficiency.

**Methods**

**Search strategy**

To identify all relevant studies, six electronic databases (Cochrane Library, BioMed Central, Education Resources Information Center (ERIC), PubMed, Scirus, and SciVerse Science Direct) were searched using the English search terms ‘physical activity’ and ‘children’ in combination with ‘motor skills’, ‘movement skills’ or ‘motor proficiency’ and the German search terms ‘koerperliche Aktivitaet’ and ‘Kinder’ in combination with ‘motorische Fertigkeiten’ or ‘motorische Grundfertigkeiten’. Studies were collected from 2000 up to June 2013. We restricted our search to studies...
published in the English or German languages and excluded studies with special populations like developmental coordination disorder (DCD) and cerebral palsy, reviews, and articles without peer-review procedure.

**Study selection**

The study selection was applied in accordance with other reviews in this field, such as Riethmuller et al. (2009) and Lubans et al. (2010), as well as general guidelines (Khan, Kunz, Kleijnen, & Antes, 2003; Wright, Brand, Dunn, & Spindler, 2007). Both authors independently performed an initial eligibility screen of all retrieved titles and abstracts (when available). Those studies reporting original data that specifically mentioned motor skill development and physical activity were selected for further review. Full-text review was independently performed by two reviewers (as above) for the following specific eligibility criteria: (1) only articles in journals or databases with peer-review procedure were included from January 1st 2000 up, and including, July 2013. Conference contributions or abstracts were not considered. (2) Studies with subjects aged 3–18 years were included. (3) Studies focusing exclusively on special populations like overweight children or children with developmental coordination disorder (DCD) were not included. (4) At least one gross motor skill had to be measured in regard to FMS. Instruments could have been process-oriented and/or product-oriented methods. (5) The relationship between motor skills and physical fitness or body composition were excluded from data selection. While a relationship with PA might exist, it is not necessarily given. Studies that explicitly used skills to examine abilities, for example static/dynamic balance skills for testing the balance ability were also not part of the investigation. (6) Intervention studies with an immediate pre-post-design were not considered for this review, because there are three different systematic reviews/meta-analysis which examined the effectiveness of motor skill interventions (Logan et al., 2012; Morgan et al., 2013; Riethmuller et al., 2009).

**Assessment of methodological quality**

Both authors independently assessed each study by using a quality assessment form. The criteria for estimating the study quality were adapted from the Consolidated Standard of Reporting Trials (CONSORT) statement (Moher et al., 2010), the Transparent Reporting of Evaluation with Nonrandomized Design (TREND) statement (Des Jarlais, Lyles, Crepaz, & the TREND Group, 2004) and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (Von Elm et al., 2007). Each study was assessed using nine criteria (A-I), which are described in Supplementary material 1. The criteria answer format included positive (1) or negative (0). We gave a positive score if the publication provided an informative description of the criterion at issue and met the quality criterion. A negative score was given in case of an informative description but an inadequate performance. For each study, we calculated the percentage of items that a study scored positively on methodological quality. A study was considered to be of high methodological quality if the quality score was at least 75%. Scores from 45 to 75% were defined as medium quality, and a score less than 45% was defined as low quality.

**Data synthesis**

Given the considerable heterogeneity in the outcome measures used in studies meeting our inclusion criteria, we did not conduct any meta-analyses (Ioannidis, Patiopoulos, & Rothstein, 2008). We summarized the characteristics of the study populations and interventions, and used descriptive statistics to report the study outcomes.

**Results**

Fig. 1 outlines the flow of papers retrieved for the review. The search yielded 5120 potentially relevant articles for the time period after January 2000. After reviewing the titles and abstracts and removing duplicates, 23 articles were identified that met our relevancy criteria. Of the 23 studies included in this review, 15 studies were utilized cross-sectional study designs, and eight articles reported longitudinal designs. Ten studies were performed in Australia, five in the USA, three in Finland and one each in Greece, Belgium, Scotland, Portugal and Germany. Sample size varied from 34 participants (Robinson, Wadsworth, & Peoples, 2012) to 1844 participants (Okely, Booth, & Patterson, 2001), aged 3 to 18. The follow-up durations of longitudinal studies ranged from 3 years to more than 5 years.

**Supplementary material**

Supplementary material 2 provides an extensive description of the studies included in the present review on their main characteristics: study population, study design, measures of physical activity and motor skill, main results, and limitations.

**Methodological quality of studies**

The methodological scoring of the studies included, which ranged from 44% (Graf et al., 2004) to 89% (Barnett, Morgan, van Beurden, & Beard, 2008; Barnett et al., 2009a; Hands, Larkin, Parker, Straker, & Perry, 2009; Williams et al., 2008) is presented in Supplementary material 3. Nine studies had a score of at least 75% and thus were considered to be of high methodological quality. There was an 88% agreement for the 207 items (23 articles × 9 items) between the authors. Disagreements between reviewers were resolved by discussion and consensus.

Three out of nine criteria (C, D and E) were found in all studies included, whereas no a priori power calculations (item F) were conducted in any study to secure the calculated relationships. Eight studies (34%) didn’t report the results for gender or specific skills (when single skills were used) separately (item H), even though this is, according to current research (López-Moliner, Brenner, Louw, & Smeets, 2010; Moreno-Briseno, Díaz, Campos-Romo, & Fernandez-Ruiz, 2010), required. Although some studies report limitations (item I), three articles (Graf et al., 2004; Vandorpe et al., 2012; Ziviani, Poulsen, & Hansen, 2009) fail to mention and describe limitations adequately or discuss the limitations together with their results.

**Assessment of FMS**

**Process-oriented and product-oriented approach**

Process-oriented measures were used to assess motor skills in twelve studies. This perspective offers the option of rating the performance of FMS qualitatively on the basis of developmental sequences (Haywood & Getchell, 2009). A major limitation in some of these studies was the scoring system: For example, Fisher et al. (2005) based their evaluation of motor proficiency on the occurrence of developmental sequences of a skill (oriented on the performance of a proficient) (Yes vs. No); however, this classification does not take into account a developing continuum (Stodden et al., 2008). Ten studies used product-oriented methods with a quantitative approach such as, for example, running speed or throwing distance or the number of successful catch attempts in test batteries such as the Bruininks–Oseretsky Test of Motor Proficiency (BOTMP) (Wrotniak, Epstein, Dorn, Jones, & Kondills, 2006). Additionally, the motor skill development level can also be partially
explained by the amount of body mass involved in the action (Haywood & Getchell, 2009); for example, Bayios (1998) reported ball velocity to be positively correlated to body size and upper and lower extremities’ length. This product-orientation allows a direct comparison between different performances; however, no statements about the quality of the skills can be made (Stodden et al., 2008). Only one study chose a combination of process-oriented and product-oriented methods (Hands et al., 2009); thus, the advantages of the quantitative and qualitative measurements could be used. This is of importance, because in some studies the decision for one method is classified as a limitation (e.g. Fisher et al., 2005; Jaakkola et al. 2009; Wrotniak et al., 2006).

**Test batteries and single items**

Twelve of 23 studies utilized different test batteries to assess FMS. The process-oriented Movement Assessment Battery (MABC) was used in three studies (Fisher et al., 2005; Livesey et al., 2011; Ziviani et al., 2009). This battery is divided into four different age bands (4–12 years) measuring movement skills in three categories: manual dexterity skills, ball skills and balance skills. A weakness is the large age range, as well as the unfavorable proportion of test items (2–3) versus time (20–30 min) required for test administration (Cools, De Martelaer, Samey, & Andries, 2009). Only the subjects of Fisher et al. (2005) are in the critical age group of the MABC-1 (age band 1) with a mean age of 4.2 ± 5 years. The MABC-2, a revised version was identified by Smits-Engelsman, Niemeijer, and van Waalvelde (2011) as a reliable measuring instrument, for normally developed 3-year-old children as well.

Three studies (Graf et al., 2004; Lopes, Rodrigues, Maia, & Malina, 2011; Vandorpe et al., 2012) used the product-oriented Koerperkoordinationstest fuer Kinder (KTK). The KTK, with four items, is considered a highly reliable and easily set up instrument to assess the gross motor coordination (Vandorpe et al., 2010). Limitations of the KTK are: the relatively old normative data, the non-optimum assessment for preschool children and the focus only on dynamic balance skills, object control and locomotion functioning are not integrated in the test on locomotion skills (Cools et al., 2009). Dynamic balance skills are often used to measure balance ability, which should not be equated with locomotion skills (Burton & Rodgerson, 2001; Fleishman, 1962). In two studies (Kambas et al., 2012; Wrotniak et al., 2006) the Bruininks–Oseretsky Test of Motor Proficiency Short Form (BOTMP-SF) was used, which is suitable for children aged 4–21 (Venetsanou, Kambas, Aggeloussis, Fatouros, & Taxildaris, 2009). The validity of the short version of the BOTMP is poor for children at the age of 4–6 (Venetsanou et al., 2009). Therefore, it is possible that low mean values represent a high percentage of children with zero scores (Kambas et al., 2012). Two studies (Cliff et al., 2009; Robinson et al., 2012) used the Test of Gross Motor Development II (TGMD-2). Hands et al. (2009) chose the process-oriented and product-oriented McCarron Assessment of Neuromuscular (MAND) test battery, which involves five gross motor and five fine motor tasks. However, the results of these tasks are summarized in only one motor competence score. Williams et al. (2008) utilized the process-oriented CHAMPS Motor Skill Protocol (CMSP), which assess for the two dimensions of object control and locomotor skills, with six skills each.

Eleven investigators chose a combination of single skills to assess motor skill competency. For example, in the study of Reed, Metzker, and Phillips (2004), three items were accomplished (passing, balance, and agility), from which only the AAHPERD Passing Test is to be classified as a motor skill test. As a limitation, the authors stated that the applied tests are possibly not appropriate for the age group.

Okely et al. (2001) and McKenzie et al. (2002) classify the number of tested skills as a limitation, whereby McKenzie et al. (2002) also estimate the restricted range of measures of two skills as a limitation. All other studies with single items examined a maximum of six different skills, as in the study of Okely et al. (2001). In three studies (Jaakkola et al., 2009; Jaakkola & Washington, 2013; Kalaja, Jaakkola, Liukkonen, & Watt, 2010), country-specific single items were used (e.g. Finland). According to these authors, the tests are reliable. However, the authors refer to publications in their national language; a test classification as well as a comparison with other study results is limited.

**Assessment of PA**

Physical activity was measured using various instruments, most commonly questionnaires that relied on participants' recall (n = 13 of the reviewed studies). Ten studies utilized direct measurements of physical activity including the use of accelerometers (Cliff et al., 2009; Fisher et al., 2005; Hume et al., 2008; Williams et al., 2008; Wrotniak et al., 2006) and pedometers (Hands et al., 2009;
Kambas et al., 2012; Reed et al., 2004; Robinson et al., 2012; Ziviani et al., 2009).

Direct measurements

Five research groups (Cliff et al., 2009; Fisher et al., 2005; Hume et al., 2008; Williams et al., 2008; Wrotniak et al., 2006) used accelerometers, which can objectively capture body movement and provide information on the total amount, intensity, duration and frequency of physical activities performed. Accelerometers are called the “Gold-Standard” for the objective measurement of duration and intensity of PA, which are also a reliable and valid measuring instrument for preschool children (Bornstein et al., 2011).

In these studies, different sampling frequencies (15 s – 1 min) were used (Cliff et al., 2009; Fisher et al., 2005; Williams et al., 2008) or not given at all (Hume et al., 2008; Wrotniak et al., 2006). The choice of sampling frequencies and the age-dependent classification of the intensity steps (cut points) influence the classification of PA (Ojiambo et al., 2011), which complicates the comparison of study results. Additionally, the measuring interval effects vary between children and adults, especially in the identification of moderate to vigorous PA (MVPA) (Edwardson & Gorely, 2010). Few studies (Hands et al., 2009; Kambas et al., 2012; Reed et al., 2004; Robinson et al., 2012; Ziviani et al., 2009) used pedometers, which measure PA with the help of the number of steps. In contrast to the accelerometer, pedometers are substantially cheaper: nevertheless, no intensity differences can be measured (Le Masurier & Tudor-Locke, 2003). Pagels, Boldemann, and Raustorp (2011) calculated a relationship between an accelerometer and a pedometer of \( r = .67 \) for the assessment of PA in 3 to 5-year-old children. McNamara, Hudson, and Taylor (2010) identified a correlation between pedometer and accelerometer of \( r = .47 – .99 \) in their review, depending on the kind of PA and environment. However, a higher validity is still ascribed to the accelerometer (Mitre, Lanningham-Foster, Foster, & Levine, 2009). Like accelerometers, pedometers are not able to register activities like swimming or riding a bike. This is especially relevant in the seasonal context. Both direct measures seem to be altogether suitable for children; however, indirect measures as questionnaires are difficult, due to the fact that age has as strong an influence when measuring physical activity as it does for the accuracy of the information provided (Allor & Pivarnik, 2001).

Indirect measurements

Four of the 13 studies which used subjective methods (Barnett et al., 2008, 2009a, 2009b, 2011) utilized the Adolescent Physical Activity Recall Questionnaire (APARQ). The APARQ asks subjects to think about a normal week during summer school and winter school terms and report separately time spent in organized and non-organized physical activities. Subjects report the activity, the duration and frequency for each activity reported. The APARQ has an acceptable-to-good validity and test–retest reliability for adolescents and adults (Booth, Okely, Chey, & Bauman, 2002). In these four studies, the average age of the sample was 16.4 years. Therefore, the application of the APARQ can be classified as an instrument appropriate for age. A positive aspect is the seasonal differentiation, because seasonal sports like swimming are considered separately. One study (Mckenzie et al., 2002) used the Physical Activity Recall (PAR) in which the energy expenditure is estimated from activity time spent in moderate, hard and very hard PA. The data is given by the children and converted into kcal (Mckenzie et al., 2002). Sallis, Buono, Roby, Micale, and Nelson (1993) value the PAR for children in the 5th grade as a reliable and valid instrument. It is also classified as appropriate for the 12-year-olds in the study of McKenzie et al. (2002). The PAR shows a test–retest reliability from \( r = .77 – .93 \) and a validity of \( .44 \) and \( .53 \) between VPA and heart rate (Sallis et al., 1993). However, Allor and Pivarnik (2001) consider that it is difficult for children to remember the time spent and intensity of PA exactly. Furthermore, it is to be supposed that intensity data and the connection between load and subjective demand vary individually, which is why a conversion into kcal seems too vague. This could explain the moderate validity of the PAR.

Lopes et al. (2011) used the Godin–Shephard Questionnaire (GSQ), which assess children’s time spent in PA (> 15 min) classified as mild (factor 3), moderate (factor 5) and strenuous (factor 9). The time spent in the different activity steps are multiplied by the weighting factor and added to a total score (Lopes et al., 2011). Sallis et al. (1993) report a moderate validity (.32 – .42). A limitation of this approach is that children between the ages of 6 and 10 (Lopes et al., 2011) are presumably less able to give accurate information about the real time spent in PA (Allor & Pivarnik, 2001). Furthermore, only activities which last longer than 15 min are assessed, which is a disadvantage compared to the objective methods. Activities such as walking to the bus station or to school are possibly not considered; however these are to be valued positively. The seven other studies of this review (Graf et al., 2004; Jaakkola et al., 2009; Jaakkola & Washington, 2013; Kalaja et al., 2010; Livesey et al., 2011; Okely et al., 2001; Vandorpe et al., 2012) used not otherwise specified subjective methods to assess the PA.

In summary: just nine studies make a distinction between an organized and a non-organized form in the assessment of PA (Barnett et al., 2008, 2009a, 2009b, 2011; Graf et al., 2004; Jaakkola et al., 2009; Livesey et al., 2011; Okely et al., 2001; Vandorpe et al., 2012). However, this appears important, which is supported by the results of Logan et al. (2012), Morgan et al. (2013) and Riemthmueller et al. (2009).

Relationship between physical activity and fundamental movement skills

Overall relationship between physical activity and fundamental movement skills

Twelve of the 23 studies of this review showed a relationship between PA and motor skills, regardless of gender and skill. Okely et al. (2001) reported a correlation between motor skills and the time spent in organized PA, although only a common variance of 3% is given (\( r^2 = .03 \)). The low association is due to the self-reported PA and the limited number of motor skills tested (Okely et al., 2001; Rivilis et al., 2011). Five other studies (Fisher et al., 2005; Graf et al., 2004; Kambas et al., 2012; Williams et al., 2008; Wrotniak et al., 2006) demonstrated positive relationships (\( r = .18 – .47 \)) between different types of PA (activity steps) and motor skills. In the study of Graf et al. (2004), the children with the greatest extent of exercise reached the highest values in the KTK (\( p = .035 \)). Nevertheless, these results did not take gender or the differentiation between organized and non-organized PA into account.

The study results of Livesey et al. (2011) show that a diminished skill level goes hand in hand with decreased PA (\( r = -.21 \) to -.30) and leads to a lower peer-acceptance. In three studies (Hands et al., 2009; Kalaja et al., 2010; Ziviani et al., 2009), no significant relationship between PA and motor skills was found. Interestingly, Kalaja et al. (2010) observed that a group with good skills showed only a low level of PA as well, which is why additional factors of influence are relevant. This is also supported by other research groups (Fisher et al., 2005; Okely et al., 2001; Vandorpe et al., 2012; Ziviani et al., 2009). Jaakkola and Washington (2013) reported a relationship between PA and FMS in grade 9 (\( r = -.17 \)), for boys and girls.

Object control

In six of 23 studies (Barnett et al., 2009a, 2011; Reed et al., 2004; Williams et al., 2008), positive relationships were...
calculated between object control and PA \( (r = .19 \ldots .35 \text{ or } R^2 = .18) \). In addition, Kambas et al. (2012) determined an association between aerobic steps per day and catching \((r = .32)\) as well as throwing a ball at a target \((r = .30)\). Robinson et al. (2012) also reported a correlation of \( r = .44 \) between medium PA in three days and object control raw scores.

**Locomotion.** Wrotniak et al. (2006) showed negative associations between different activity counts and running speed \((r = -.25 \text{ to } -.37)\) and positive relationships with the broad results for jumping \((r = .30 \ldots .40)\). Williams et al. (2008) and Barnett et al. (2011) observed similar correlations \((r = .14 \ldots .21)\) between locomotion and PA. Kambas et al. (2012) ascertained a connection between aerobic steps per day and running speed and agility \((r = .32)\). In the study of Robinson et al. (2012), a correlation is given between the average PA of 3 days and locomotor raw scores \((r = .46)\). Furthermore, the achieved locomotor raw scores could be identified as a predictor for PA \((R = .46, R^2 = .21)\).

**Gender-specific aspects**

In the study of Okely et al. (2001), the relationship between FMS and time in organized physical activity was stronger for girls than for boys. With the exception of the very low quintile for movement skills, girls spent significantly more time in organized physical activity than the boys. An explanation could be the presumably higher social acceptance of boys for participating in organized PA; motor skills proficiency is perceived as a less important part of participation (Okely et al., 2001). However, boys clearly spent more time in non-organized PAs, whereby FMS can probably also be improved. Positive relationships existed for both genders between different levels of physical activity and overall FMS, whereby for girls only the correlation with vigorous PA (VPA) \((r = .21)\) is worth mentioning (Hume et al., 2008). Cliff et al. (2009) argued that the relationship between FMS and physical activity in preschool children may differ by gender, by the movement skill subdomain, and by physical activity intensity. While the correlations for boys are positive for all physical activity levels \((r = .32 \ldots .46)\), the girls show similarly strong but negative correlations. This was explained by a higher Gross Motor Quotient (GMQ) and, at the same time, lower PA levels. Similar results were reported by Williams et al. (2008). They found significantly less time spent in PAs for 4-year-old girls with good motor skills in comparison to boys in the same age group. However, no information was given about gender-specific differences with regard to FMS, although other studies confirmed gender differences (Moreno-Briseño et al., 2010). Lopes et al. (2011) reported better performances in motor coordination and clearly higher PA levels for boys for all the age groups examined (6–10 years) in comparison to girls of the same age. In this, the authors observed a tendency toward a decrease of PA with, at the same, time stable results for motor skills for both genders with increasing age. In the study of Jaakkola and Washington (2013), PA in grade 7 predicted FMS in grade 6 \((r = .24)\) and FMS in grade 7 predicted PA in grade 9 \((r = .20)\), only in boys.

**Object control.** Reed et al. (2004) observed similar results in the AAHPERD Passing test for girls and boys, although the PA of boys is substantially higher. Boys in the 6th/7th and 8th grades showed positive relationships between the AAHPERD Passing Test and daily pedometer steps as well as for the steps during physical education for boys in the 8th grade \((r = .92)\). For girls in the 6th and 7th grades, the negative correlations between steps in physical education and AAHPERD Passing Test are remarkable. These observations strengthen the gender-specific results of Cliff et al. (2009), where girls, in spite of lower PA, show good results in motor skills. However, there is a positive relationship between steps in physical education and the AAPHERD passing test for older girls in the 8th grade \((r = .56)\) (Reed et al., 2004). The authors affiliate the higher correlations of the students in 8th grade to the low sample size \((n = 14 \text{ & } n = 10)\). In the studies of Hume et al. (2008) and Cliff et al. (2009), positive correlations were found between MPA and MVPA for boys, but Cliff et al. (2009) reported stronger relationships.

**Locomotion.** The McKenzie et al. (2002) study indicated a positive relationship between jumping and overall PA for 12-year-old girls and not VPA. Hume et al. (2008) calculated a positive connection between locomotion and VPA for both genders. In the study of Cliff et al. (2009), positive correlations were found between different activity steps and locomotion for boys \((r = .30 \ldots .34)\). Altogether, the girls are less physically active and show stronger negative relationships for locomotion and PA. Jaakkola et al. (2009) identified relationships between organized PA and the results of the Leaping Test with higher correlations for girls \((r = .55)\).

**Association between FMS and PA**

The association between FMS and PA should be explored using longitudinal investigations (Barnett et al., 2008, 2009a, 2009b, 2011; Lopes et al., 2011; McKenzie et al., 2002; Vandorpe et al., 2012). Barnett et al. (2008, 2009a) ascertained a connection between object control in infancy and PA in adulthood. For this, Barnett et al. (2008) calculated a variance of \(8\% \ (r = .28, R^2 = .08)\) with a larger relationship for boys \((r = .22)\) than for girls \((r = .11)\). Although boys achieved better performances in object control and PA, gender could not be identified as a moderating factor of influence on the correlation between both variables. Barnett and colleagues (2009a) calculated a variance of \(12.7\% \ (r^2 = .13)\) for this: In this study the effect was also larger for boys than for girls. The adolescents in 10th grade were more active than in 11th grade; in each grade boys more so than girls. The authors argued that children with a good object control have, in comparison to children with a poor object control, a 10–20\% higher likelihood of participating in vigorous physical activities. A good level of motor control in infancy raises the participation rate in adulthood in MVPA, but not in organized sport. However, it is only assumed that there is a relationship between object control in infancy and PA in adulthood in this context (Barnett et al., 2009a). Lopes et al. (2011) believe that the level of FMS greatly influence the PA of children at the age between 6 and 10. Children with good motor skill showed a constant level of PA, whereas the level of PA of children with poor motor skills decreased most strongly with increasing age. In the study of Barnett et al. (2009b), the intervention group achieved a better performance in four out of six motor skills after 6 years of follow-up. However, no significant differences were found for the participation in MVPA in adulthood, which is why other factors of influence should also be considered. Initially, Barnett et al. (2011) examined the supposed reciprocal relationship between PA and FMS in a study with adolescents. In this study, significant correlations \((r = .35)\) between PA and object control could be observed; vice versa, the time spent in MVPAs explained only \(12\% \ (R^2 = .12)\) in object control. Nevertheless, the authors still assume a reciprocal relationship between object control and PA (Kambas et al., 2012; Stodden et al., 2008). No such relationship was found for locomotion (Barnett et al., 2011). According to the authors, the case for the mastery of object control skills can be seen as offering more possibilities to participate in sports than locomotion does. Vandorpe et al. (2012) divided the children of their study into three groups of sports participation: no participation, partial participation and consistent participation, which means at least 1 h/week between year 1 and year 3. The MQKTK at the first time of assessment could be identified as a strong predictor for the participation in organized sport at the third time of assessment. All
three groups improved their performance between consecutive measurements, whereby the group which was consistently engaged in organized PA across three years achieved the best values in the KTK. It was suggested that the improvements of the children who didn’t participate in organized sport reflected systematic practice effects caused by test replication. This confirms the importance of organized PA or specific programs as described in different reviews (Logan et al., 2012; Morgan et al., 2013; Riethmüller et al., 2009). However, McKenzie et al. (2002) were not able to determine an influence of FMS in infancy (4–6 years of age) on PA for youths (12 years of age). Although boys from the ages of 4 and 6 to 12 spent altogether more, and more often, time in MVPA than girls, boys only show better results between the ages of 4 and 6, and only for catching.

Discussion

The general aim of this systematic review was to describe the relationship between physical activity and FMS competency in children and adolescents. We found 23 articles that assessed product-oriented as well as process-oriented motor skills, and direct, as well as indirect, measures of physical activity. We found strong evidence from cross-sectional studies for a positive relationship between FMS and organized physical activities. However, motor skill competency was only of low predictive value for the physical activity level as adults. Indeed, some publications point out that the relationship between FMS and PA has not yet been sufficiently clarified. Bürgi et al. (2011) assume that the influence of PA dominates the development of FMS. It could be suspected that people who are more physical active tend to develop and perform FMS more easily, especially if the children participate in structured PAs. On the other hand, Cliff et al. (2009) have advocated the approach that, with a high performance level in FMS, an increasing level of PA could be observed, which is confirmed by the studies with a longitudinal design (Jaakkola & Washington, 2013). The direction could also be influenced by age. In early childhood, when the developed motor skills could be classified more as motor milestones/unspecific motor skills, physical activity is necessary to develop sport-specific movement skills, whereas in middle and late childhood, when the differences of FMS proficiency between children is higher and the children become able to compare their skill level with the motor proficiency of their peers, the activity level could be influenced by perceived motor competence (Fisher et al., 2005; Williams et al., 2008). On the basis of the data presented, a cause–effect relationship between FMS and PA is suspected, but has not been demonstrated yet (Barnett et al., 2011; Kambas et al., 2012; Okely et al., 2001; Stodden et al., 2008). So far, the postulated reciprocal relationship has been examined only in two longitudinal studies (Barnett et al., 2011; Jaakkola & Washington, 2013) as demanded in the review of Lubans et al. (2010). These studies do not allow a final statement about a cause and effect relationship, because both studies report results which are predictive in both directions. The identification of a causal relationship appears very important to ensure feasibility of practical implementation. This could provide aids for decision making for teachers and coaches, but also for therapists in decision guidance to create training, lessons, and therapy adequate to the target group. Regarding the influence of gender, Jaakkola and Washington (2013) reported stable correlations for FMS over time for boys and girls, but only partially existing relationships between PA and FMS within a grade and over time and for PA over time. Overall, there is no clear pattern for a gender effect: while some studies report results in favor of boys, other studies have not been able to confirm such a difference. Nevertheless, studies need to focus on gender-specific questions (Cliff et al., 2009; Lubans et al., 2010), because it appears that girls achieve better results in locomotion skills, whereas boys produce better results in object control skills (McKenzie et al., 2002).

An essential problem is the comparability of study results, due to the method variety in assessing physical activity (objectively vs. subjectively; measuring duration) and FMS competency (qualitatively vs. quantitatively; single items vs. test battery). Even if similar FMS were tested in many studies, results should be discussed carefully, due to several constraints: for example, catching strongly depends on the size (Savelbergh, Whiting, & Bootsma, 1991), the speed (Mazyn, Savelbergh, Montagne, & Lenoir, 2007) and the trajectory of the object (McLeod, Reed, & Dienes, 2006). However, this information is described only insufficiently if at all (cf. Supplementary material 1). Furthermore, catching, in contrast to throwing, requires the ability to anticipate the trajectory of the object and a higher capacity to process visual information (López-Moliner et al., 2010). Nevertheless, in some studies (e.g. Barnett et al., 2009a, 2011; Williams et al., 2008), both skills are summarized as object control and presented as common results. This might have affected the developmental-specific and gender-specific differences within single motor skills (Moreno-Briseno et al., 2010); therefore, the results cannot be presented with sufficient certainty.

It can be assumed that the relationship between PA and quantitative-assessed FMS such as jumping distance or throwing velocity is larger compared to the relationship between PA and qualitative measurements, because of the combined positive effects of practice and maturation in childhood. The existing results certainly don’t confirm this speculation. In some studies, the applied test batteries (e.g. BOTMP in Wrotniak et al., 2006 or MAND in Hands et al., 2009) assessed fine as well as gross motor skills; in spite of this, these authors summarized their results in just one score, naming it motor competence or motor proficiency. However, this generates the problem that it is impossible to parcel out the influence of gross or fine motor skills on PA or vice versa. Furthermore, the existing literature gives the impression that there is, in some aspects, no common understanding of FMS (Burton & Rodgerson, 2001). Some studies (e.g. Jaakkola et al., 2009; Jaakkola & Washington, 2013; Kalaja et al., 2010) classify apparent fitness tests (e.g. shuttle running test, figure 8 dribbling test) or balance/stability tests (e.g. Flamingo Standing Test) as FMS. As described above, balance is an important basic motor ability (Burton & Rodgerson, 2001; Fleishman, 1962), which could only be assessed with a FMS, but it’s not a FMS itself. The same problem is evident in some test batteries such as the KTK, in which motor abilities and FMS are tested and summarized as a motor quotient and described as motor abilities (Graf et al., 2004) or motor coordination (Vandorpe et al., 2012). In the BOTMP, the broad jump and running speed are used to assess strength (Wrotniak et al., 2006), which could also be classified as product-oriented tests of loco-motor skills. In summary, it is not easy to comprehend at a glance whether FMS, motor abilities, fitness or a combination of these factors are assessed.

According to the results of previous reviews (Logan et al., 2012; Morgan et al., 2013; Riethmüller et al., 2009), most of the intervention studies achieved significant improvements at follow-up, confirming the efficacy of motor development interventions in young children. Therefore, an organizational framework promotes the improvement of FMS by which presumably also the relationship between PA and motor skill competency is strengthened. Hence, studies examining this relationship should make a distinction between PA in organized and non-organized activities. This distinction is only made for studies with subjective or self-reporting of PAs; all studies but Graf et al. (2004) and Vandorpe et al. (2012) reported this as a limitation. Although nine studies used methods which would allow this differentiation, only four
studies computed the results separately (Jaakkola et al., 2009; Okely et al., 2001; Reed et al., 2004; Vandorpe et al., 2012). The importance of drawing a clear distinction between organized and non-organized PA can be explained by the performance-orientation of organized sport; the training is typically offered by experienced, qualified coaches. Children and adolescents are supported according to their individual capabilities following technique models, while the assessment of FMS are based on these technique models. This is often connected with the improvement of quantitative aspects (e.g. throwing distance), because a good technique allows also the optimal use of their physical capabilities. Additionally, frequency and time spent for each object control and locomotion skill should be recorded separately. This appears to be necessary, as different forms of PA, such as swimming, may result in an improvement of quantitative aspects of an object control skill such as throwing velocity, by improving the strength, but appears highly unlikely in qualitative aspects. This argument might help to explain the weak relationships between PA and FMS, which were reported in some studies (e.g. Fisher et al., 2005; Kalaja et al., 2010; Okely et al., 2001). In addition, this suggests that the exclusive use of accelerometers as the “Gold-Standard” doesn’t provide enough information to make substantiated statements about the relationship between PA and FMS. While the longitudinal data of Jaakkola and Washington (2013) confirms that physical activity has only moderate tracking coefficients from childhood to adolescence, no sport-specific assessment of PA was conducted. Altogether, the factor PA seems to be more variable over time and influenced by, for example, the seasonal context (Booth et al., 2002; Jaakkola & Washington, 2013). A proficient thrower, who spends a lot of time on the basketball court or playing handball in summer, will still be a proficient thrower in winter, even if very little time was spent for PA. Thirteen studies that used subjective methods highlight the problem of a comparative assessment of the construct PA (Rivilis et al., 2011). It is generally debatable whether the different instruments are age-appropriate (Kalaja et al., 2010); information about reliability or validity are not included (Graf et al., 2004; Okely et al., 2001).

Strengths and limitations

To our knowledge, this is the first systematic review which examines the relationship between FMS and PA under consideration of applied methods. The methodological quality was assessed with nine criteria adapted from the CONSORT, TREND and STROBE statements. Moreover, not only were general relationships illustrated, but skill-specific (locomotion, object control/manipulation) and gender-specific results were also shown, as well as the distinction between organized and non-organized PA, as far as the selected studies allowed this. Lastly, we tried to show the influence of FMS acquired during childhood on physical activity in adolescence and adulthood to establish the sustainability of FMS. However, only eight studies with a longitudinal design could be identified for this essential research question for this review. Another limitation of this review is the exclusive consideration of the relationship between PA and FMS. In addition, many other factors apart from age and gender play a role, such as motivation, socio-demographic and socioeconomic factors or the influence of self-perception. Only a small number of studies have solely examined special populations such as obese children or children with DCD who possibly report stronger connections.

Conclusions

The results of this indicative review show, despite the low relationships/variances that studies examining the relationship between FMS and PA represent, they are a valuable approach to understanding the positive effects of an active lifestyle. However, the study results confirm our opinion that other factors such as the perceived skill-proficiency (Barnett et al., 2011) or the family socio-economic status and the provision of motor affordances in the home (Freitas, Gabbard, Caçola, Montebelo, & Santos, 2013) should be considered in future studies; a cause and effect relationship had not been established yet (Kambas et al., 2012). Nevertheless, the studies included in this review altogether confirm that a high level of FMS competency is certainly related to an increase of PA, and vice versa.

Ideally, future studies should incorporate a combination of subjective and objective methods to assess PA, which report on all PAs representing a ‘normal’ week and make a distinction between organized and non-organized activities, as well as between time spent for object control skills and locomotion skills separately for girls and boys. Based on rational considerations and the partially weak relationships reported in the studies, it cannot be expected that unspecified PA will lead to an improvement of specific FMS. As an applied result, it seems reasonable to consider the idea of specific training contents for planning interventions or sport lessons. The assessment of FMS would benefit from methods which are process-oriented, as well as product-oriented, since this would allow the identification of developmental qualitative and quantitative motor differences. Furthermore, fundamental motor skills are a product of the interactions between growth, maturation, development and the environment.

In order to allow meaningful comparisons, longitudinal studies with detailed description of the sample as well as the assessment methods and the intervention protocols are necessary. The application of statistical methods like SEM, which was used in two studies (Barnett et al., 2011; Jaakkola & Washington, 2013), are needed to clarify speculations about the cause and effect relationship between PA and FMS. It would, of course, be desirable to examine the interaction of all possible factors influencing the relationship between PA and FMS competency. At present, this approach seems difficult to achieve, given the multifactorial complexity which stems from the interdisciplinary nature of this area. Nevertheless, this underlines the need of further studies, especially with a longitudinal design.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.psychsport.2014.03.005.

References


