Title: Association between Fundamental Motor Skills and Physical Activity in the Early Years: A Systematic Review and Meta-Analysis

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Abstract

Background: Physical activity (PA) in the early years is associated with a range of positive health outcomes. Fundamental motor skill (FMS) competence is associated with PA and is theorised to be driven by PA in the early years and vice-versa in mid to late childhood. However, to date, no studies have meta-analysed the association between PA and FMS in the early years.

Methods: Six electronic databases were searched up to April 2019. Cross-sectional and longitudinal studies were included if they targeted children (age 3 to 6 years) as the population of the study and assessed the association between objectively measured PA and FMS. Fundamental motor skills (Total FMS), total physical activity (TPA) and moderate to vigorous physical activity (MVPA) data were meta-analysed using a random effects model.

Results: We identified 24 815 titles and abstracts. In total, 19 studies met the inclusion criteria; 14 cross-sectional, four longitudinal, and one study with cross-sectional and longitudinal analysis. There was a significant but small positive association between FMS and MVPA (r=0.20; 95% CI: 0.13-0.26) and TPA (r=0.20; 0.12-0.28). Findings from longitudinal studies revealed that PA drives FMS in early childhood. Mediation was explored in one study which found that perceived motor competence did not mediate the association between FMS and PA.

Conclusion: This study is the first to show a positive association between the early year's FMS and MVPA and TPA using a meta-analysis, suggesting that the association begins at an early age. Limited evidence from longitudinal studies support the theory that PA drives FMS in the early years. More evidence is needed from large studies to track PA and FMS until mid to late childhood and to explore the mediators of this association.

Key Words: Early Years, Fundamental Motor Skills, Physical Activity

1. Introduction

Engagement in physical activity (PA) in the early years brings a range of positive health outcomes, such as improvement in adiposity, cognitive development, bone and skeletal-, psychosocial-, and cardio metabolic health.[1] The United Kingdom physical activity guidelines recommend that preschool children should engage in at least 180 minutes of PA per day, with at least 60 minutes of this being MVPA.[2] Similar recommendations are provided in Canadian[3] and Australian[4] physical activity guidelines. However, compliance rates vary across the globe; studies have found that in Australia 93% of children meet the guidelines,[5] whereas in Canada only 62% meet the recommendations when physical activity is assessed using accelerometery.[6] A review of preschool physical activity levels found the proportion of children meeting the recommendations vary from 27%-100%.[7]

Understanding the mechanisms underlying participation in PA is important. Stodden et al., (2008)[8] describes a conceptual model in which a number of health-related factors might influence PA engagement. One of these factors is motor competence, which encapsulates fundamental motor skills (FMS). FMS have been described as the initial building blocks of more complex, coordinated movements.[9] Stodden et al., (2008)[8] suggested that PA and FMS have a reciprocal and dynamic relationship, where at a young age PA could drive development of FMS, which in turn drives engagement in PA at a later age. Establishing the relationship between PA and FMS in the early years, and seeing how this relationship changes over time, can help to test this premise.

Stodden et al., (2008)[8] also hypothesised that mediators such as perceived motor competence might influence this association. In early years when cognition is underdeveloped there is likely to be a small correlation between perceived motor competence and actual motor competence. This is valuable as children may persist in activities that they perceive themselves to be competent at, which can drive skill acquisition. However, in later childhood when children are more cognitively developed, the correlation between perceived and actual motor competence is stronger. Children who have low motor competence will have low perceived motor competence and engage in less PA. This in turns might affect the risk of conditions associated with physical inactivity such as obesity, which would ultimately feedback on their motor competence and subsequent PA levels. By examining what mediates the relationship between PA and FMS we can determine the underlying mechanism by which one influences the other and highlight potential targets for intervention.

The relationship between FMS and PA across different age groups has been narratively synthesised in several systematic reviews.[10-12] Logan et al., (2015)[10] reported a low to moderate association between FMS and PA in early childhood from four studies, low to high association in middle to late childhood from seven studies, and low to moderate association in adolescence from two studies. Lubans et al., (2010)[11] explored the association between FMS and PA in children and adolescents across 21 cross-sectional studies and found strong evidence of a positive association, this was similar to the findings of another review of cross-sectional studies from Holfelder and Schott (2014).[12] Finally, a narrative review found that eight of 11 studies in 3-5 year old children reported a significant relationship between motor skill competence and PA.[13] Given the growing evidence demonstrating the association between PA and health outcomes such as obesity[1], and cognitive outcomes which affect child development,[14] the establishment of the association between PA and FMS might have public health implications, which may lead to the further implementation of PA or FMS interventions in the early years.

A meta-analysis in this area is important, as it tries to establish a statistical significance across studies in this area which would increase validity. This would provide public health and early years practitioners more reliable and valid information which could guide practice and policies in the area. Likewise, the mediators of the association between FMS and PA, which might have important implications for the design of PA or FMS interventions, have never been synthesised. Therefore, the aim of this study was to synthesise and meta-analyse the evidence from cross-sectional and longitudinal studies to examine the association between FMS and PA in 3-6-year-old children, and to investigate the potential mediators of this association. To our knowledge, this is the first meta-analysis of the association between FMS and PA in preschool aged children (3 to 6 years old).

2. Methods

This systematic review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.[15] The protocol for this systematic review has been registered at the International Prospective Register for Systematic Reviews (PROSPERO), registration number 2017: CRD42017062581.

2.1 Literature Search

In April 2017 we carried out an online search of six databases (MEDLINE, EMBASE, PsycINFO, SportsDiscuss, CINAHL and ERIC), this was repeated in April 2019 to update the review. The search strategy contained keywords for children, fundamental motor skills, physical activity, and association. These keywords were arranged using Boolean operators to provide a sensitive and specific search strategy, an example of search strategy (e.g. Medline) can be found in Supplementary File 1. No language or time barriers were placed on the search. Files were imported into Endnote version X7 reference management software and duplicates removed. The references of included articles identified in the search were hand searched for additional relevant publications.

2.2 Study Inclusion Criteria and Exclusion Criteria

Studies were included if they met the following inclusion criteria: 1) included children aged between 3-6 years at baseline, and up to 11 years (average age) at follow up; 2) were performed in normally developing children; 3) physical activity was measured objectively using an accelerometer or a pedometer; 4) reported a total or global score of FMS assessed using validated methods; 5) reported the correlation between FMS and PA; and 6) were cross-sectional or longitudinal studies. Studies were excluded if: 1) the average age of the participants at baseline or in a cross-sectional study was larger than six years old or had not reported subgroup data for this age group; and 2) were performed in children with developmental delay or physical impairment.

2.3 Study Selection and Data Extraction

The first author (DJ) screened all titles and abstracts identified through the search against the study selection criteria. A random sample of 20% of the excluded titles were reviewed by another researcher (LA). Those papers which met the inclusion criteria were reviewed in full and in duplicate by (DJ and LA, DJ and ELG, DJ and AI, and DJ and EvS). Backwards and forwards reference searching of the included studies was carried out in May 2019.

A standardised data extraction form was used to collect methodological and outcome variables from each included study. Data extracted included: study information (e.g. authors, publication year); population (e.g. age, sex, number of participants); measurement tools (e.g. FMS tool, PA tool,); outcome measures (baseline and follow-up (if longitudinal) of FMS and PA data), analysis (PA data processing and correlation values between FMS and PA). All of the data were extracted by DJ and validated by LA, ELG, AI and EvS.

2.4 Study Quality Assessment

All studies were assessed using the Evidence for Policy and Practice Information Centre (EPPI) for observational studies tool.[16] This tool has six items for assessing internal and external validity including: type of study, number of participants, representation of general population, adjustment of the analysis, and objective measure of the outcome and exposure. Studies were classified as low, intermediate, or high based on the number of criteria they met: 1) low <2; 2) intermediate 3-5, and 3) high: >5. Quality assessment was performed by two reviewers independently (DJ and LA), any disagreements were decided on by a third reviewer (AI).

2.5 Data synthesis and Meta-analysis

Cross-sectional studies were meta-analysed. Papers that reported TPA using different units (e.g. minutes of physical activity per hour, counts per minute, total number of steps per day) were grouped in the same analysis. Papers that reported MVPA were grouped in a separate analysis, this included percent of MVPA per day or minutes of MVPA per day, these were grouped regardless of the cut-points used.

Authors were contacted if they had measured the association between FMS and PA using regression analyses but had not reported the Pearson correlation (r) values. Eight of the authors contacted[17-24] provided the information required. One author could not be contacted and was excluded from the analysis.

Meta-analyses were carried out for total FMS and MVPA, and total FMS and TPA. Analyses were performed using the statistical software Comprehensive Meta-Analysis version 3 (Biostat, Englewood, NJ, USA). If studies only reported correlation data separately for boys and girls, they were entered separately into the meta-analysis. In studies in which both univariate and multivariate correlations were available, only the univariate were included in the meta-analysis, as not all papers had included the same characteristics in the multivariate analysis. Correlation values (r) were pooled and entered into the software along with the sample size of the study. Correlation coefficients were transformed to Fisher z and then weighted and averaged, and transformed back to a pooled r. Heterogeneity amongst the studies was measured using the tau statistic (τ); a standard deviation representing the typical variability of the mean between studies.[25] Pooled correlation values (r) with 95% confidence intervals were calculated for all studies included in the meta-analysis. A random effects model was used to derive a pooled estimate of the correlation values.[26] To interpret the strength of correlation we used Cohen's cut-off points of 0.10, 0.30 and 0.50 as cut-off r <0.30 as small, r = 0.30 to <0.50 as medium and r ≥ 0.50 as large.[27] A funnel plot was used to investigate publication bias.

Sensitivity analyses were performed, to investigate the effect of combining studies reporting MVPA with studies reporting TPA since these variables are highly correlated.[28] The first sensitivity analysis incorporated all studies that reported MVPA, with studies that only reported TPA. The second sensitivity analysis incorporated all studies that reported TPA, with studies that only reported MVPA. Sensitivity analyses exploring studies in which the same or similar motor skills tests (i.e.TGMD2, TGMD3 and CMSP) were applied. CMSP and TGMD2 were combined in the analysis since the test procedures are identical. This analysis was performed for TPA and MVPA. A sensitivity analysis was performed in studies that had only used accelerometers to measure PA. Further sensitivity analyses were conducted to investigate the effect of using the adjusted models for each paper on the association between FMS with TPA and MVPA.

Included longitudinal studies presented a wide disparity in data collection methods and analysis, for example, some studies measured PA at baseline and FMS at follow up, or vice versa; furthermore, not all studies reported the change in PA or FMS over time. Therefore, a meta-analysis was deemed inappropriate and these studies were synthesised narratively.

3. Results

3.1 Study Selection

The two searches yielded a total of 37 094 citations, however, 12 279 of these were duplicate citations and were therefore removed, leaving 24 815 papers in total. Nineteen papers[17-24, 28-38] met the inclusion criteria and were included in the review. Fourteen cross-sectional studies[18-24, 28-34] were included in the meta-analyses while four longitudinal studies[35-38] were included in the narrative synthesis. One study[17] presented both cross-sectional and longitudinal data, the cross-sectional data were included in the meta-analysis, and the longitudinal data were included in the narrative analysis. Fig.1 shows the PRISMA flowchart.

Figure 1 – PRISMA Flowchart

Please insert Fig.1 in here

3.2 Study Characteristics

Table 1 summarises the 19 studies included in the review. All studies were published in English, between 2004 and 2018, and were conducted in eight countries: United Kingdom (n= 4)[20, 23, 28, 32], United States (n= 5)[24, 29, 33, 36, 37], Switzerland (n= 3),[22, 35, 38] Greece (n= 1),[31] Finland (n= 2),[19, 21] Australia (n= 2),[17, 30] South Africa (n=1)[34] and Denmark (n= 1).[18] No studies were conducted in the continents of South America or Asia. Seventeen studies were conducted in preschool settings,[18-22, 24, 28-38] one in a primary school setting[23] and one study did not state where the data collection was carried out.[17] Overall the cross-sectional studies included 2616 participants, and the longitudinal studies included 1239 participants. Hall et al., (2018)[28] and Hall et al., (2019)[23] were both cross sectional studies based on the same original population, measured at different time points. Schmutz et al., (2018)[35] was the follow up, longitudinal paper of Schmutz et al., (2017).[22]

Please insert Table 1 in here

Fifteen cross sectional studies were identified, of which 14 studies used accelerometers to measure PA,[17-24, 28-30, 32-34] while one used a pedometer.[31] Thirteen studies used an ActiGraph model (7164 n=3, GT1M n=4, GT3X n=6, CSA n=1) (ActiGraph, Pensacola, FL, USA).[17-20, 22, 24, 29, 30, 32-35, 38] One study used an X6-1a accelerometer (Gulf Coast Data Concepts Inc, Waveland, MS, USA),[21] two studies used a GENEActiv accelerometer (GeneActiv Activeinsights, Cambridge, UK),[23, 28] two studies used Actical accelerometers (Mini-Mitter Co., Inc., Bend, OR),[36, 37] and one study used Omron Pedometers.[31]

Measurement tools used to asses FMS varied widely, ten different measurement tools were used, they included the CHAMPS motor skills protocol (CMSP) (n=2),[29, 33] which is based on the Test of Gross Motor Development-2 (TGMD-2) (n=6)[17, 20, 23, 28, 30, 34] and Test of Gross Motor Development-3 (n=1),[24] the Körperkoordinations Test für Kinder (KTK) (n=2),[18, 21] Bruininks-Oseretsky Test of Motor Proficiency – Short Form (BOTMP-SF) (n=1),[31] APM Inventory (n=1),[19] Movement Assessment Battery (MAB) (n=1),[32] the Zurich Neuromotor Assessment (ZNA) (n=2),[22, 35] PE Metrics (n=2)[36, 37] and Balance and Agility Tests (n=1).[38] Accelerometer cut-points also vary among studies, the range used to define MVPA between studies was 1680 counts per minute[20, 22, 24, 33-35, 38] to 3564 counts per minute,[30] of the studies that reported cut-points, seven different values were used to define MVPA. The most frequently used cut-points for MVPA was 1680 counts per minute.

3.3 Quality Assessment

Study quality ranged from intermediate to high. All of the longitudinal studies, [35-38] one cross sectional study[22] and the study including both cross-sectional and longitudinal data[17] were deemed to be of high quality. Three studies did not analyse more than 50 participants.[19, 23, 30] It was unclear for ten of the included studies[18, 20, 28, 29, 32-34, 36-38] whether the author deemed the study sample to be representative of the general population, 15 of the included studies used adjusted or multivariate analysis,[17-20, 22-24, 29, 30, 33-38] as part of the inclusion criteria all of the studies used objective measures of PA and a validated measure of FMS. A summary of all included papers quality assessment score can be found in Supplementary File 2.

3.4 Meta-Analyses

The correlation values for either (or both) Total FMS and TPA, or Total FMS and MVPA, were extracted (or provided by the author from the 12 cross-sectional studies) and included in the meta-analyses. The meta-analysis for total FMS and TPA included twelve studies.[19-24, 28-32, 34] Fig.2 shows that the pooled correlation between total FMS and TPA was statistically significant but small, r= 0.20 (95% confidence interval [CI] = 0.12 to 0.28). Heterogeneity was present in this analysis, with a τ value of ± 0.113.

Figure 2 – Total FMS and TPA Meta-Analysis

Please insert Fig.2 in here.

A meta-analysis of association between MVPA and FMS is presented in Fig.3. Twelve studies[17-20, 22-24, 28, 30, 32-34] were entered into this meta-analysis. There was a significant, but small pooled correlation of r = 0.20 (95% CI=0.13 to 0.26). Heterogeneity was present in this analysis with τ value of ± 0.089.

Figure 3 – Total FMS and MVPA Meta-Analysis

Please insert Fig.3 in here

TPA and MVPA were combined in two separate meta-analyses. Firstly, papers that reported TPA were pooled together with papers that only reported MVPA. The pool of 15 studies presented a significant but small correlation of r= 0.20 (95% CI = 0.14 to 0.26, τ ± 0.091). Secondly, papers that reported MVPA were pooled together with papers reporting TPA only (n= 15). A similar and significant correlation was observed r = 0.21 (95% CI = 0.15 to 0.27, τ ± 0.092).

Sensitivity analyses were carried out looking at studies which used the same FMS measurement tool (n=9), the TGMD-2 and CMSP and TPA and MVPA (TPA as preference). The correlation remained significant and positive (r=0.18, 95% CI=0.09 to 0.26 τ ± 0.096) but weaker compared with the analysis using all FMS measurement tools as reported earlier (r =0.20 (95% CI = 0.14 to 0.26, τ ± 0.091).

For studies with the same FMS measurement tools and reported associations of TPA and MVPA (MVPA as preference) the correlation also remained significantly positive (r=0.18, 95% CI=0.08 to 0.28, τ ± 0.121) but weaker when compared with all FMS tools together (r=0.21 (95% CI = 0.15 to 0.27, τ ± 0.092).

Sensitivity analyses looking only at studies using accelerometers to measure MVPA or TPA (Kambas et al., 2012[31] removed from analyses because of pedometer use), found that the heterogeneity of the analysis decreased for all effected analyses and pooled correlation remained significant: 1) TPA and MVPA (TPA as preference) (r=0.18, 95% CI=0.13 to 0.24, τ ± 0.073); and 2) TPA and MVPA (MVPA as preference) (r=0.20, 95% CI=0.14 to 0.26, τ ± 0.080). A final sensitivity analysis investigated the effect on the association between FMS and MVPA and TPA for studies which used an adjusted statistical model as part of their analysis. For both MVPA and TPA, the strength of the association decreased slightly (TPA - r=0.19 and MVPA - r=0.18) but remained significant.

3.5 Longitudinal Studies

A total of five longitudinal studies were included in the review. Two of these studies were conducted by the same research team[36, 37] with different populations of children. They measured FMS using PE Metrics in American kindergarteners during autumn, PA was measured using Actical accelerometers the following spring. An Australian study[17] measured children's MVPA using ActiGraph GT1M accelerometers at 19 months, 3.5 years and 5 years, and children's FMS skills using TGMD-2 at age 5. Burgi et al., (2011)[38] measured agility and dynamic balance as motor skills and the PA of Swiss children (mean age 5.2 years) using ActiGraph GT1M accelerometers at baseline and 9 months later. Another Swiss study[28] assessed FMS using the ZNA and PA using an ActiGraph wGT3X-BT accelerometer at baseline, and one year later.

FMS as a predictor of PA

Findings from longitudinal studies revealed that FMS can act as a predictor of PA for some FMS domains, in particular object control and locomotor skills. Gu (2016)[36] found a positive and significant association between total FMS (r=0.26), object control skills (r=0.21) and locomotor skills (r=0.21) with MVPA at follow-up. The authors also found that locomotor skills, not object control skills explained significant variance in MVPA, after controlling for BMI.

Gu et al., (2018)[37] found a positive and significant association between total FMS (r=0.28), object control skills (r=0.24) and locomotor skills (r=0.24) and MVPA at follow-up. Similarly, Schmutz et al., (2018)[35] identified gross motor skills at baseline as a determinant of TPA (p=0.048) and MVPA (p=0.023) at follow-up. However, despite the increase in PA over the period of the study, gross motor skill at baseline were not significantly associated with change in either TPA or MVPA from baseline to follow-up.

Burgi et al., (2011)[38] also found that changes in agility ($p \geq 0.14$) and balance ($p \geq 0.14$) from baseline to follow-up did not significantly predict PA at follow-up.

PA as a predictor of FMS

Only two studies explored the longitudinal association of PA as a predictor of FMS, showing a positive association of PA for predicting some FMS domains (e.g. balance, locomotor skills), but no association or negative association for others (e.g. agility and object control). Burgi et al., (2011)[38] found that baseline TPA was negatively associated with change in agility (p=0.005) and positively associated with change in balance (p=0.02) over 9 months. Barnett et al., (2016)[17] however, found that MVPA from children at 3.5 years approached significance in positively predicting total skill score (p=0.059) and positively predicting locomotor skill at age 5 (p=0.033). However, MVPA at any age did not significantly predict object control skills at age 5.

3.6 Mediators

Only one study included in this review investigated the mediators of the relationship between FMS and TPA. Hall et al., (2019)[23] found that in the early years, neither TPA nor MVPA were positively associated with an increase in motor competence as mediated by perceived motor competence.

4. Discussion

The aim of this review was to synthesise the evidence on the relationship between FMS and PA in the early years both cross-sectionally and longitudinally, while the secondary aim was to explore the mediators of this relationship. This review is the first to meta-analyse the cross-sectional association between the early years FMS and PA and found that total FMS was positively associated with TPA (r=0.20, CI=0.12 to 0.28), and MVPA (r=0.20, CI=0.13 to 0.27), suggesting that the association between FMS and PA occurs at an early age.

This review also reports mixed findings from longitudinal studies. Four out of five studies looked at FMS as a predictor of PA. In two studies[36, 37] domains of FMS (i.e. object control and locomotor skills) predicted MVPA at follow-up. In another study[35] gross motor skills were identified as a determinant of PA at follow up, but these were not associated with changes in PA from baseline to follow-up. Finally, one study[38] found that agility and balance at baseline did not predict PA at follow-up. Similar to our findings, studies with older children have found that FMS skills can predict PA at a later age for some of the FMS domains. Barnett et al., (2009)[39] found that object control skills at mean age of 10 years predict PA levels in adolescence. This finding was echoed by Lopes et al., (2011)[40] who found that motor competence was an important predictor of PA between the ages of 6 and 10 years.

Conversely, two studies explored the opposite, examining whether PA predicted FMS. One study[38] found that changes in TPA were significantly associated with changes in agility and balance nine months later, while another[17] found that MVPA at age 3.5 years approached significance for predicting FMS at age 5. The disparity between the data collection time points, and the short follow up period prevents firm conclusions being drawn on the direction of the relationship between FMS and PA. However, the findings from this review for FMS as a predictor of PA indicates that FMS does not drive changes in PA over a short time period in the early years. Although changes in PA might predict changes in FMS in the early years.

The limited findings from longitudinal studies in our review cannot support or refute the theory developed by Stodden et al., (2008)[8] that PA drives FMS in early childhood. It is important to test conceptual models to see if they work in reality. Therefore, further studies should be conducted to explore the association, in which PA and FMS data collection are performed in the early years and continues at regular follow-up intervals through mid to late childhood, adolescence and potentially adulthood. This would help to strengthen the evidence and clarify the direction of association and enable skill and age specific interventions to be developed.

Demonstrating the association between FMS and PA is important, as it suggests that interventions in the early years could be of benefit for increasing FMS and PA in both the short and long term. Several interventions have been designed to improve FMS in the early years, however, there is limited evidence from systematic reviews on the effect of FMS interventions to increase PA. Van Capelle et al., (2017)[41] found that FMS interventions do not significantly increase PA levels, attributing this to the discrepancies between studies in measuring PA. However, in a recent systematic review Engel et al., (2018)[42] found that teacher led FMS interventions delivered at least three times a week can improve FMS proficiency, increase PA intensity and reduce sedentary behaviour in preschool children, suggesting that school-based interventions may be effective for increasing children's PA levels. Children may acquire rudimentary levels of some FMS through exploration, but to reach advanced levels of FMS children requires instruction.[43] This is evident from a number of early childhood interventions[44-46] which have shown that by only providing children with free play time, they will not significantly improve their FMS, and it is only when instructed by trained specialists that significant improvements are made. These findings were confirmed in narrative systematic review which supported the use of FMS interventions to improve children's FMS beyond free play.[47] Concerning the effect of PA interventions on FMS, a systematic review which examined the effect of PA interventions in the early years found that 80% of the included RCTs studies showed an improvement in motor skills.[48] The authors concluded that PA interventions may be better at increasing the early years PA and FMS as opposed to FMS interventions, a reason for this may be that PA may drive FMS in the early years, however this review did not find evidence to support or refute that theory. The authors also explored the association of physical activity and cognitive development and found a positive association for measures of academic achievement, learning, working memory and language in four out of five studies.[48] This might have public health and educational implications, as increasing the early years PA could lead to better motor skills, health outcomes and academic achievement. Given that motor competence and physical development are essential criteria for a child to be ‘school ready’ in the early years,[49] the dissemination of this evidence could be used to encourage schools and parents to increase the opportunity for children to engage in PA in the early years.

An important aspect of this study was the analysis of mediators of the association which might support the design of an intervention. Stodden et al., (2008)[8] theorised that perceived competence and physical fitness could mediate the relationship between PA and FMS, but it is likely to occur in middle childhood, when children have a better understanding of their competence, and their physical fitness is more important for engagement with PA and sport. The only study included in this review that explored mediators,[23] found that perceived motor competence did not mediate the relationship between motor competence and MVPA and TPA. This is similar to other research in preschool children, Crane et al., (2015)[50] examined the individual domains of FMS, but not total FMS and found that perceived motor competence did not mediate the relationship between object control skill and MVPA in a small sample of preschool children. Although there is no evidence of mediation of motor competence and MVPA and TPA in the early years, two studies conducted in older children support the Stodden et al., (2008)[8] theory, as they demonstrate that perceived motor competence[51, 52] and physical fitness[53, 54] can mediate the association between motor competence and PA. However, there are no studies which explored physical fitness as a mediator in the early years. This is possibly due to the difficulty of measuring this outcome in the early years. Therefore, Stodden et al’s., (2008)[8] may be accurate; the mediation effect of perceived competence and physical fitness on FMS and PA might only be apparent during middle childhood. However, more studies exploring mediators in early childhood with larger sample sizes are needed, since current studies Hall et al., (2019)[23] (n=38) and Crane et al., (2015)[50] (n=116) were conducted with a small number of participants.

This systematic review has not explored the individual domains of motor skills, (object control skills, locomotor skills and balance) for cross sectional studies. However, there is evidence to suggest that individual FMS domains might predict PA in the early years. Robinson et al., (2012)[55] found that locomotor skill was a significant predictor of PA, but object control skill was not. However, two studies[50, 56] found that object control skill, but not locomotor skill were significantly associated with PA. Further research is needed to explore if these individual domains of motor skills develop naturally, or as a result of structured practice or training, and the rate at which these skills develop.

4.1 Strengths and Limitations

This systematic review has some strengths including a rigorous search and sifting methodology and the use of a meta-analysis. However, it is important to acknowledge the limitations of the current review. In this study, only 20% of the excluded titles and abstracts were screened. Although, this procedure has been used in many other systematic reviews[57-59] in the field, future studies should consider double screening as according to a recent methodological systematic review this could be a limitation.[60] Another limitation is the inclusion of studies with varying methodologies used to assess motor skills, although the skills measured were similar, the measurement tools or procedures were different. For example, Movement Assessment Battery Checklist (MABC) includes a measure of fine motor skills, whereas TGMD-2 does not. Other tools measure all aspects of FMS, while the KTK does not assess object control skill. However, the heterogeneity among the studies was not substantial, and previous meta-analyses have also pooled studies with different FMS assessment tools.[61] Furthermore, sensitivity analyses revealed that the small positive association persisted, and heterogeneity was maintained when studies using the same assessment method were pooled. Due to the large magnitude of research into motor skills, we believe it is necessary to standardize a tool to be used to measure motor skills across research internationally. This would increase the generalisability of studies as well as increase the likelihood of the study results being replicated. Another limitation to the meta-analysis is the varying cut-points and data processing methods used to define objectively measured MVPA and TPA. Although these different methodological procedures can be considered a limitation, in this study we investigated the correlation between the two variables (FMS and MVPA/TPA), therefore having minimum effect on our findings and it repeats the procedures that have been conducted in another meta-analyses.[62] Nonetheless, the use of the same cut-points for MVPA would be useful for comparison across studies in the same age group. Likewise, all but one[31] of the studies included in this review used accelerometers to assess PA. Recent evidence has suggested that accelerometery may not be the gold standard for measuring PA, and it may underestimate PA intensity in object projection skill performance.[63] Therefore, the association between FMS and MVPA may be underestimated. Furthermore, many of the participants in these studies were required to remove the accelerometers for water-based activities, meaning that not all PA was captured.

5. Conclusion

In conclusion this study is the first to meta-analyse the association between FMS and PA in the early years. A significant, but small positive association was found, which is consistent with narrative systematic reviews and studies in older children. The limited longitudinal findings cannot support or refute Stodden et al's., (2008)[8] theory that PA drives FMS in early childhood. Further longitudinal evidence is required to explore if the association tracks into later life, or if FMS begins to drive PA. Finally, one study with a small sample (n=38) examined a mediator of the relationship between FMS and PA, finding that perceived motor competence did not mediate the relationship. More research is needed on this topic, as mediators could potentially inform intervention components.

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Authors Contribution

DJ was involved in the conception of the study, the structured search, the sifting of search results, data extraction, quality assessment, analysis and writing of the manuscript. AI, ELG and LA were involved in the conception of the study, sifting of search results, data extraction, quality assessment and commenting on and editing of the manuscript.

All authors have read and approved the final version of the manuscript and agree with the order of the presentation of the authors.

Conflict of Interest

The authors declare they have no competing interests.

Supplementary information is available at The Journal of Sport and Health Science website.

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