

Fundamental Movement Skills and Health-Related Outcomes: A Narrative Review of Longitudinal and Intervention Studies Targeting Typically Developing Children

Abstract: *Many children with typical development are highly sedentary, overweight/obese, and are deemed not ready for school at kindergarten entry. All of these concerns can be related to a lack of movement skill proficiency in this population. The purpose of this narrative review was to synthesize the literature examining the impact of movement skills on 5 areas of overall health: physical activity, physical fitness, body composition, self-beliefs, and executive functioning. To gain an understanding of these relationships, only studies employing an experimental or observational longitudinal design were reviewed. Although the results were limited in the number of studies available,*

there is evidence that movement skill may have a positive influence

Keywords: movement skill; children; intervention; primary prevention



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on these broad domains of health both naturally over the course of development and through intervention. We recommend that a universal approach to movement skill development is warranted, given the range of benefits that stem from developing proficiency in these skills.

Movement skills are an essential element of a child's overall development and play a significant role influencing physical, psychosocial, and mental health. Movement skills can be broadly classified into observable gross and fine skill domains such as those needed for

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running, catching, writing/printing, or dressing.^{1,2} More specifically, gross movement skills are those that require large muscle movements and coordination of the arms, legs, or whole body.^{3,4} Gross movement skills also include fundamental movement skills that are the basic movements such as jumping, catching, and throwing needed for participation in more complex physical activities.^{5,6} In comparison, fine movement skills require small muscle movements of the fingers, wrist, and hand and are involved in play-based participation, in everyday activities of daily living such as dressing and feeding oneself, and in the execution of tasks related to school-work such as printing and artwork.^{3,4} Movement skills must be taught and practiced in order to reach a level of mastery, known as one's movement proficiency.⁷ In contrast, motor development refers to the continuous, age-related changes in movement that occur across one's lifespan and the interacting individual, task, and environmental factors that underlie these changes.^{4,5} While motor coordination is the organization of one's body parts to create gross and fine movements.⁵ Because both fine and gross movement skills are used in virtually every aspect of an individual's daily activities, it is imperative to understand how these skills may affect other areas of functioning throughout the lifespan, starting in childhood. In particular, there is a growing body of work that explores the connections between early movement skill development and an array of health-related outcomes including social, cognitive, and emotional development.⁸⁻¹⁰ The results of this work suggest that motor development is directly linked to other aspects of development in early and middle childhood. It is to this issue that we direct our attention, focusing specifically on a number of health-related outcomes associated with fundamental movement skill.

There are a number of factors that may contribute to a child's overall health including their physical activity levels, body composition, self-beliefs, anxiety levels, and executive functioning, among others. Previous research has

demonstrated positive associations between gross and fine movement skills and areas of health including physical activity, fitness, healthy body composition, self-concept, and executive functioning.^{6,11} However, most of this research has been cross-sectional, meaning that it fails to demonstrate any long-term associations between movement skills and these health-related variables. In a recent systematic review of the literature, Lubans et al⁶ demonstrated the numerous health benefits of fundamental movement skill proficiency including increased physical activity and fitness, a lower body mass index (BMI), and improved mental health outcomes. However, the majority of the articles included in the review were cross-sectional⁶; thus, the causal relationship between these skills and health-related variables is not yet fully understood. As a result, we also do not have a thorough understanding of the impact of movement skill on children's overall health, through both naturally occurring development and in relation to interventions specifically targeted to improve movement skill.

It is also important to note that a significant number of studies on the relationships among fundamental movement skills and health-related outcomes have focused on children with specific clinical conditions such as developmental delay, motor disorders such as developmental coordination disorder and cerebral palsy, and other neurodevelopmental disorders (eg, attention deficit hyperactivity disorder, autism spectrum disorder).¹²⁻¹⁷ This is not surprising as these conditions are known to negatively affect movement skill development, and negative health sequela arising from disorders connected to motor impairment are well documented. Existing population prevalence estimates of these disorders in the general population, however, suggest that between 5% to 20% of children have one or more of these concerns^{18,19}; this means 80% or more of children are considered to be typically developing. A reasonable question to ask is does movement skill affect health and other

domains of development in typically developing children? Moreover, might children who are typically developing benefit from interventions designed to improve or optimize movement skill?

We believe in fact there is good reason to consider typically developing children in this regard. First, while the prevalence of specific neurodevelopmental disorders such as developmental coordination disorder and autism spectrum disorder are relatively low (between 1% and 5%),^{20,21} the estimates of children who experience delay in a specific domain of development are between 16% and 20%.^{18,19} These children, in other words, might show delay in one or more domains of development including motor, but do not necessarily go on to develop a neurodevelopmental disorder. Given that the population may still be at risk for future health concerns, it is clear that the targeting of movement skill to children in what we might call an "at-risk" population is warranted. Fundamental movement skills are essential for participation in physical activity,⁶ yet as much as 93% of children and youth are insufficiently active.²² This high rate of inactivity is one of the factors that contributes to approximately one third of children and youth being overweight/obese,²³ which is alarmingly high and yet again can be partially mediated through movement skills. In addition to issues with inactivity and overweight/obesity, nearly one third of children are deemed "not ready for school" at kindergarten entry for various delays including learning problems associated with gross movement skill.²⁴ When we consider the large numbers of children who may be at risk because they show signs of developmental delay, who are sedentary, and who are not ready for school, combined with children who have neurodevelopmental disorders that negatively affect movement, it is clear that a universal approach to movement skill development is warranted. The majority of children arguably show concerns related to movement skill, be it inactivity, overweight/obesity, or problems in learning, but are not diagnosed clinically.

At the very least, we cannot assume that a child who is typically developing will have the necessary fundamental movement skills necessary to achieve positive health-related outcomes. We propose then that movement skill may be a crucial target for public health initiatives given the broad impact of movement skills on optimal development. However, we first need to examine the longitudinal associations between movement skills and other aspects of health before universal public health initiatives can be created. Furthermore, while earlier review studies have demonstrated the effectiveness of fundamental movement skill interventions at improving movement skills in children with typical development,²⁵⁻²⁷ whether these improvements to movement skills result in positive changes to overall physical and mental health remains unclear.

Robinson and colleagues²⁸ recently synthesized the literature in regard to the effect of motor competence on developmental trajectories of health. In particular, they examined the impact on physical activity, fitness, perceived motor competence, and weight status in an attempt to support a model of engagement initially proposed by Stodden et al,²⁹ which proposed dynamic relationships between these variables in early childhood with the relationships strengthening over time.²⁹ The review of Robinson et al²⁸ supports the proposed model as evidence was found of positive associations between motor competence and perceived motor competence, physical activity, fitness, and a healthy weight status, which together support the core pathways identified in the model. However, the strength of these relationships over time have yet to be determined. While we acknowledge the positive contribution this model has made to the literature and our understanding of the dynamic interrelationships among motor competence, perceived competence, physical activity, fitness, and weight status throughout childhood, we propose that these are only a few of the potential benefits of gaining proficiency in one's

movements early on. Indeed, the Stodden model focuses specifically on healthy (and unhealthy) weight as the main outcome. As noted above, motor competence (ability) has been linked to a variety of our relevant developmental outcomes, including cognitive ability. Therefore, our review will touch on many of the aspects in Robinson and colleagues' recent review²⁸ but will aim to add to the literature in regard to the overall development of the child—not only relating motor competence to physical health but also aspects of cognitive development and mental health that we believe may have critical benefits for gaining movement proficiency.

In this narrative review, our aim is to synthesize current literature examining the impact of movement skills on the overall health of children with typical development. In the fall of 2014, we searched PubMed and Google Scholar using a combination of search terms relating to the population (ie, child, pediatric, youth, adolescent), independent variable (ie, motor or movement or coordination skills, competence, etc), and dependent variables (ie, health, development, physical activity, fitness, self-beliefs, executive functioning, behavior, etc) of interest. In order to gain a greater understanding of the potential relationships between movement skills and health, we focused only on studies employing an experimental or observational longitudinal design. Although a child's overall health can encompass a number of physical and mental health-related variables, this review will focus on the variables that have traditionally received the most, albeit still limited, attention: physical activity, physical fitness, body composition, self-beliefs, and executive functioning.

Physical Activity

Regular participation in physical activity is important for children to maintain low blood pressure, healthy weight, adequate bone mineral density levels, and reduce their risk of depression, among other

things³⁰; thus, it is important to understand which factors may promote regular physical activity engagement in children. Cross-sectional research has consistently demonstrated an association between fundamental movement skills and physical activity in children with typical development,⁶ where children with more proficient movement skills engage in higher levels of physical activity. However, as noted previously, most of this research is based on cross-sectional study designs. As such, the direction of causality is uncertain and it is not clear if movement skill earlier in life is associated with physical activity later in the life course. We were able to identify 5 studies that used prospective (longitudinal) observational designs. Of these, 4 studies showed a positive association between movement skill and later physical activity participation,³¹⁻³³ one did not.³⁴

Observational Studies

Four studies found that movement skill assessed at one point was associated with positive change in physical activity at follow-up. Barnett and colleagues³¹ followed a sample of 276 children over a 6-year period, beginning at 10 years of age. The authors found that object control skills (ie, catching, throwing, and kicking) in childhood (at age 10) were significantly and positively associated with self-reported participation in moderate-to-vigorous physical activity (MVPA) and organized activities 6 years later.³¹ Furthermore, they found that better object control skills in childhood resulted in a 10% to 20% chance of higher levels of participation in vigorous physical activities in adolescence.³¹ Lopes et al³² followed a group of 285 children between 6 and 10 years of age, assessing both their motor coordination and self-reported physical activity levels. For children with above-average levels of motor coordination, physical activity patterns remained stable over the duration of the study. However, children with average and low motor coordination both showed declines in physical activity, 2.47 and 2.58 units per year, respectively.³² The results suggest that

children with lower levels of motor coordination drop out of physical activities at an incrementally greater rate than their more proficient peers.

Jaakkola and colleagues³⁵ recently examined the association between fundamental movement skills (balance, leaping, and dribbling; measured at age 12) and self-reported physical activity 6 years later in a sample of 224 children. They found that baseline fundamental movement skill predicted light, moderate, and vigorous physical activity at follow-up. Furthermore, when controlling for baseline activity, sex, and BMI, there was still a moderate effect of fundamental movement skills on physical activity at the 6-year follow-up. Finally, another smaller longitudinal study with 17 participants found that directly measured fundamental movement skills at 6 years of age were positively associated with self-reported leisure time physical activity at 26 years of age in females and participants with high levels of movement skill proficiency in childhood.³³ Together, these studies suggest that a high level of movement skill proficiency in early childhood may result in higher levels of physical activity in later childhood, possibly through to adulthood.

In contrast to these findings, McKenzie and colleagues³⁴ examined the relationship between 3 fundamental movement skills (jumping, catching, and balancing) at 4 to 6 years of age and self-reported habitual physical activity at 12 years of age in a group of 207 children. Results indicated that the children's early movement skills were not related to physical activity at age 12. It is possible that this finding could be attributed to only measuring 3 skills and the inclusion of younger children who may have greater difficulties in skill comprehension and attention, both of which may influence test results.

Overall, the studies on longitudinal associations between movement skills and physical activity demonstrate promising results. While all 5 of the studies are limited by their use of self-reported measures of physical activity, that 4 of the studies found

positive relationships between childhood movement skills and later physical activity points us in favor of an association. Since all studies measured different movement skills, it is unclear whether certain individual or groups of skills (ie, object control vs locomotor) are more important in early childhood for later physical activity. It is recommended that future studies continue to examine the longitudinal associations between these variables with particular emphasis placed on whether early movement skills are related to later participation in physical activity, as well as whether individual skills may be more or less important for both males and females, individually and as a whole.

Experimental/ Intervention Studies

The previous section identified studies of naturally occurring fundamental movement skills and physical activity using observational methods. Yet, if fundamental movement skills are causally linked to physical activity, then we would expect that interventions that manipulate fundamental movement skills should lead to changes in physical activity behavior. We could locate 7 studies that have intervened on movement skills and measured the ensuing impact on physical activity levels in children with typical development. As with the longitudinal observational studies, the results are mixed with 4 studies showing no effect³⁶⁻³⁹ and 3 studies showing a positive effect of intervention.⁴⁰⁻⁴²

Barnett et al³⁸ conducted a 6-year follow-up of their "Move It, Groove It" intervention aimed at improving fundamental movement skills and physical activity levels of elementary school children 10 years of age. The intervention took place over a 1-year period during scheduled physical education classes. There were no differences in MVPA between the participants in the intervention and control groups at the 6-year follow-up, as measured by self-reported questionnaire.³⁸ Similar results were evident following a pilot randomized

controlled study that compared a movement skill-based physical activity program (run 3 times per week for 20 weeks) to usual care in 3- to 5-year-old children within supervised child care centers.³⁶ Physical activity was assessed pre- and postintervention by accelerometers worn by the participants while at the child care center, and results indicated that there were no differences in physical activity levels between the intervention and usual care groups at the posttest.³⁶

Cliff et al³⁹ conducted a randomized controlled trial to examine the effect of a child-centered physical activity/skill development program (n = 63), parent-centered dietary modification program (n = 42), or a combination of both programs (n = 60) on the physical activity (measured via accelerometer) levels of 5- to 9-year-old overweight and obese children. The 6-month intervention period consisted of a 10-week program (2 hours per week) and a 3-month maintenance period. The skill development group focused on teaching 12 fundamental movement skills over the course of the 10 sessions. The dietary modification program consisted of parents-only educational sessions, and the combined program consisted of both skill development and dietary modification being taught concurrently. The authors found no time or group by time differences in physical activity either immediately following the intervention or 6 months later.³⁹ Last, Barnett and colleagues³⁷ conducted a 3-year follow-up of their Tooty Fruity Veggie movement skill intervention for preschool aged children. The intervention took place over a 10-month period and participants (n = 111) were followed up on their physical activity levels via accelerometer at 8 years of age. Results indicated that the average time spent in daily MVPA at follow-up was 93.0 minutes; however, participation in the intervention, fundamental movement skills, and anthropometric measures were not significant predictors of MVPA, indicating that the intervention did not have an impact on later physical activity.³⁷

Conversely, 3 studies have found positive increases in physical activity levels following school-based fundamental movement skill interventions.^{40,41,43} The first school-based intervention included 10-year-old children who were randomized within their classrooms to a fundamental movement skill intervention (n = 74), behavioral modification intervention (n = 66), combined behavioral modification and fundamental movement skill intervention (n = 93), or to a control group (n = 62). The interventions involved 19 sessions (40-50 minutes each) spread over the course of one school year.⁴⁰ Following the intervention, the fundamental movement skill group had higher levels of directly measured (via accelerometry) physical activity, as well as greater enjoyment of physical activity, in comparison to the control group, and these differences were maintained at 6- and 12-month follow-up assessments.⁴⁰ The second school-based intervention included 11-year-old children randomized to either the intervention (n = 97) or waitlist control group (n = 71).⁴¹ The intervention was delivered in-class over a 7-week period and used a mastery motivational climate and games-centered approach to teach fundamental movement skills. Following the intervention, the participants in the intervention group had a significant increase in their directly measured in-class physical activity (via pedometry) in comparison to the waitlist control group.

Most recently, Cohen and colleagues⁴³ examined the effect of their Supporting Children's Outcomes using Rewards, Exercise, and Skills (SCORES) intervention, a comprehensive school-based 12-month physical activity and fundamental movement skill intervention for 7- to 10-year-old children (n = 199 intervention group, n = 261 control group), on physical activity levels at midintervention and the end of the program. No significant group by time interactions were present for physical activity between the intervention and control groups at midprogram.⁴³ Significant group by time interactions were present at the posttest, with the intervention group engaging in 13 more

minutes of MVPA per day than the control group. The intervention group also engaged in significantly more daily after school MVPA and daily weekend MVPA.⁴³ Further analysis revealed that overall fundamental movement skills significantly mediated the intervention effect on MVPA.⁴²

There are a limited number of movement skill interventions that report the impact on physical activity levels, and their results are divided with only 50% demonstrating positive results. A number of reasons may account for these differences. For example, Jones et al's³⁶ study included a younger age group of children and focused more on teaching the individual components of the fundamental movement skills. This means that the children may not have been as active during the actual sessions as a lot of direct skill instruction is more sedentary in nature. Furthermore, since physical activity was only assessed in the child care setting, the children in the experimental group likely did not have many more opportunities to be physically active than the usual care group, given the space and scheduling constraints of most child care centers. Two of the studies demonstrating increases in physical activity indicated that they used games-centered approaches to teach fundamental movement skills, with an emphasis on fun and maximum participation.^{40,41} It appears that this approach resulted in the participants engaging in more physical activity during the actual intervention, and increasing their enjoyment of physical activity,⁴⁰ which ultimately may be one of the mediating factors needed to increase activity levels through movement skill interventions. There is, however, still a critical need to conduct further, well-controlled, intervention studies to better understand if physical activity levels can be increased through movement skill interventions in children with typical development. Intervention programs should focus on targeting a broad range of movement skills, making the activities enjoyable for all children, and emphasizing maximum participation.

There is some evidence that school-based physical activity interventions can have a sustained (>6 months) impact on activity levels postintervention⁴⁴; however, this effect needs to be further explored in community settings and using movement skill-based intervention programs. Intervention studies should also include direct measures of how active the children are during the actual sessions, at program completion, and at longitudinal follow-ups to assess the true impact of movement skill interventions at increasing physical activity in the short and long terms.

Physical Fitness

Another important element of children's overall health is their physical fitness. Physical fitness is a measure of the bodily functions needed to perform daily physical activity and exercise, and it is currently considered one of the most important health markers.⁴⁵ Physical fitness comprises a number of different components, with the main health-related components being cardiorespiratory and muscular fitness.⁴⁵ Improved cardiorespiratory fitness may reduce total and abdominal adiposity, and both cardiorespiratory and muscular fitness may reduce cardiovascular disease risk factors, depression, and anxiety, as well as improve one's self-esteem.⁴⁵ Given the numerous health benefits associated with physical fitness, it is imperative that children have the necessary skills, movement or otherwise, to be physically fit. In typically developing children, there is very limited research on this outcome.

Observational Studies

Only 3 studies could be located that examined the association between movement skill and physical fitness over time.⁴⁶⁻⁴⁸ Barnett and colleagues⁴⁶ examined the relationship between childhood fundamental movement skill proficiency at 10 years of age and physical fitness 6 years later in adolescence in a group of 244 participants. They found that object control skills in childhood were

significantly and positively associated with cardiorespiratory fitness at the 6-year follow-up.⁴⁶ Another study measured the cardiovascular endurance of 5- to 7-year-old children ($n = 38$) once a year for 5 consecutive years and found that, on average, the fitness of all participants improved over the 5 years but that the participants with low levels of movement skill proficiency were consistently outperformed by their higher proficiency peers.⁴⁷ Lastly, Vlahov and colleagues⁴⁸ examined the relationship between fundamental movement skills in preschool and physical fitness (cardiorespiratory fitness, muscular strength, and flexibility) 11 years later ($n = 140$). They found that both object control and locomotor skill proficiency in preschool significantly predicted all aspects of fitness 11 years later in adolescence, while object control skills were a better predictor.⁴⁸

Together, these findings suggest that childhood movement skill proficiency may be related to later fitness levels. However, the literature is still quite limited. For example, only one type of fitness, cardiorespiratory fitness, was examined in 2 of the 3 studies. Although aerobic fitness is important, physical activity in childhood is better described as frequent, short bursts of activity rather than sustained endurance over time.⁴⁹ Therefore, anaerobic fitness may be a more relevant marker of fitness levels, yet no research we could locate examined short-burst muscle power in children and youth.

Experimental/ Intervention Studies

We could only locate 2 intervention studies that examined the impact of a movement-based intervention on fitness. Matvienko and Ahrabi-Fard⁵⁰ examined the impact of a 4-week afterschool program on the physical fitness of kindergarten and first-grade students assigned to an intervention ($n = 42$) or control ($n = 28$) group. The daily (Monday-Friday) intervention consisted of a 15-minute morning walk and 90-minute afterschool program that included 20 minutes of motor

coordination instruction (throwing for distance, kicking for accuracy, and jump rope). The remainder of the program included classroom instruction, fitness activities (10 minutes), and free play. Immediately following the intervention the authors found that the intervention group significantly outperformed the control group on the number of push-ups they could complete (muscular endurance) and their long-jump distance (muscular power). At a 4-month follow-up, significant differences between the groups were apparent in pull-ups (muscular endurance) and shuttle run scores (aerobic fitness), with the intervention group outperforming the control group. The impact of Cohen and colleagues⁴³ SCORES intervention on physical fitness was examined with the 20-meter multistage fitness test. Results indicated that participants in the intervention group significantly improved their fitness (completed 5 additional laps) following the intervention in comparison to the control group. It was further identified that both locomotor and overall fundamental movement skills significantly mediated the intervention effect on physical fitness.⁴²

More research is necessary to better understand the longitudinal relationship between childhood movement skills and later physical fitness, as well as whether intervening on movement skills will result in subsequent improvements to fitness levels. It is also important to understand the relative role that physical activity may play in moderating a relationship between movement skill proficiency and physical fitness, as well as whether any particular movement (ie, locomotor, object control, sport-specific) skills are more or less important to develop during early childhood for improved fitness later in life.

Body Composition

Maintenance of a healthy weight and body composition is important to reduce the risk of type 2 diabetes, cardiovascular disease, and a number of other chronic conditions later in life.⁵¹⁻⁵⁴ Previous research has established the benefits of

regular engagement in physical activity in order to maintain a healthy body composition,³⁰ and cross-sectional research has established an inverse relationship between fundamental movement skills and BMI in children.^{6,55} Yet only 3 studies have looked at the long-term associations between movement skills and body composition, while 3 studies of movement skill interventions have reported the impact of the intervention on body composition.

Observational Studies

Lopes and colleagues⁵⁶ measured the motor coordination and the triceps and subscapular skinfolds of 285 children annually from 6 to 10 years of age. They found that motor coordination had a significant effect on overall skinfold, with each unit of improvement in motor coordination being associated with a decline of 0.06 mm in total skinfolds,⁵⁶ indicating a decline in subcutaneous adiposity with improved motor coordination. Similarly, Vlahov et al⁴⁸ found that movement skill proficiency in preschool was a significant predictor of body fat percentage (measured via triceps skinfolds) 11 years later in adolescence. It is unclear, however, how much of these associations can be directly attributed to movement skills or if the relationship is mediated through physical activity.

Last, D'Hondt and colleagues⁵⁷ measured the motor coordination and BMI of a group of 754 children once between the ages of 5 and 13 years and again 2 years later. Results indicated a significant inverse relationship between motor coordination at baseline and BMI 2 years later. The authors also ruled out physical activity as mediating this relationship as it was not related to either motor coordination or BMI at baseline.⁵⁷

Experimental/ Intervention Studies

We located 4 studies that examined the impact of movement skill interventions on body composition in typically developing children. A cluster randomized nursery school-based movement skill intervention for 545

children 4 years of age was conducted and BMI assessed as an outcome.⁵⁸ The intervention comprised 30-minute sessions, administered 3 times a week, for 24 weeks; however, there were no differences in BMI between the experimental and control groups following the intervention or at the 6- and 12-month follow-up assessments.⁵⁸ Similarly, Matvienko and Ahrabi-Fard⁵⁰ examined changes in BMI and waist circumference following their 4-week afterschool program for kindergarten and first-grade students. They found no differences between the experimental and control groups on either variable immediately following the intervention or at the 4-month follow-up. These findings suggest that movement skill-based interventions may not have an impact on the BMI of young children. Yet the relative contribution of other variables (eg, physical activity, maturation) is not always accounted for. One study by Barnett's group did take into account physical activity levels when examining the impact of a movement skill intervention on BMI 3 years postintervention.³⁷ It was, however, found that the intervention, movement skill proficiency, MVPA, age, and sex, were not significant predictors of the change in BMI or waist circumference from baseline to the 3-year follow-up; however, it is important to note that locomotor skill proficiency was significantly positively associated with the change in waist circumference.³⁷

In contrast to the previous finding, Salmon and colleagues⁴⁰ found that their movement skill-based intervention did have an impact on the BMI of the 10-year-old participants in their "Switch-Play" program. The authors found a significant intervention effect from baseline to postintervention on the BMI of the participants in the behavioral modification/fundamental movement skill group in comparison to controls, and this was maintained at the 6- and 12-month follow-ups.⁴⁰ Furthermore, participants in the behavioral modification/fundamental movement skill group were less likely to be overweight or obese, in comparison to

the participants in the control group, from baseline to postintervention and this difference was maintained at the 12-month follow-up.⁴⁰

While the 4 movement skill interventions for children with typical development that report BMI outcomes have contradictory results, the findings may be due in part to the age of the participants. For example, the 3 studies that did not report changes in body composition^{50,58} included younger children (4-8 years of age) who may be less likely to have a change in BMI status as the diets and activity patterns of young children are primarily determined by their parents and caregivers, possibly negating any direct intervention effects. Another factor that could account for these differences is that Salmon and colleagues⁴⁰ found increases in physical activity levels and enjoyment of physical activity, along with changes in body composition, following their intervention, which are 2 factors that could mediate the intervention effect. It is recommended that future movement skill-based interventions report anthropometric outcomes such as BMI, waist circumference, and skinfolds. It may also be beneficial to evaluate whether the participants' response to treatment varies by age, intervention content, and intervention duration. Furthermore, for studies targeting younger children it may be necessary to include parental education as a target of the intervention in order to help shape the behavioral patterns of the entire family.

Self-Beliefs

Self-beliefs include one's self-concept, self-esteem, and self-efficacy and are all generally used to describe an individual's opinion of themselves, including their perceived ability to successfully complete tasks.⁵⁹ Both self-concept and self-esteem are an integral part of a child's overall development as they can act as a protective factor for both mental and physical health.⁵⁹ Low levels of self-esteem, however, can lead to depression, anxiety, and high-risk behaviors.⁵⁹

Previous research has suggested correlations between various domains of self-perception. For example, Harter's Self Perception Profile for Children has demonstrated relationships between scholastic competence and behavioral conduct, as well as between perceived physical appearance, athletic competence, and social acceptance. Focusing more specifically on the motor domain, relationships have been suggested between perceived movement competence, actual movement competence, physical activity levels, and physical fitness in children and youth.^{29,60} Few studies, however, have examined the longitudinal associations between movement skills and self-beliefs, particularly in regard to perceived movement competence, nor have they looked at the impact of movement skill interventions on these areas.

Observational Studies

We were able to locate 3 longitudinal studies that examined the relationship between movement skills and self-beliefs over time. Barnett and colleagues⁶¹ measured the perceived sports competence of 256 adolescents who had previously participated in their fundamental movement skill intervention 6 years earlier at the age of 10. Results indicated that with the groups and genders combined, perceived sports competence in adolescence was significantly and positively associated with childhood object control skills.⁶¹ Additionally, adolescent females', but not males', perceived sports competence was significantly and positively related to childhood locomotor skills.⁶¹ Lloyd et al³³ observed the relationship between directly measured fundamental movement skills at 6 years of age and self-reported perceived movement skill competence at 16 and 26 years of age as part of a small longitudinal study. They found positive associations between childhood fundamental movement skill proficiency (age 6) and perceived movement competence at age 16, as well as tracking of perceived competence from 16 to 26 years of age.³³ These results suggest that the higher a child's

actual movement skill proficiency, the more highly they may perceive their own competence in adolescence through to adulthood, which may have implications on their greater self-concept, mental health, and activity levels.

Another aspect of children's self-beliefs may be linked to their social status with their peers. For example, it is possible that if one perceives himself or herself to have a high social standing he or she may be more confident in his or her self and abilities, resulting in higher self-beliefs. Ommundsen and colleagues⁶² followed 80 children from first through fourth grades on measures of motor coordination and social status as measured by peers wanting to participate in classroom and play scenarios. The results indicated that the participants' level of motor coordination in first grade was positively and significantly correlated with their social status in fourth grade.⁶² It is possible that better motor coordination in early childhood results in one's peers viewing them as more skilled, resulting in greater social acceptance.

Experimental/ Intervention Studies

Two experimental studies have examined the impact of movement skill interventions on self-beliefs; one found positive results³⁹ and the other did not.⁴¹ Cliff and colleagues³⁹ randomized controlled trial sought to examine differences in the participants' perceived athletic competence following their 6-month intervention program that consisted of either child skill development, parental dietary modification, or both. Significant improvements in perceived athletic competence were made in both the skill development and skill development/dietary modification groups at the posttest, and again at the 6-month follow-up by the skill development/dietary modification group; there were not statistical differences between the 2 groups.³⁹

In contrast, Miller and colleagues⁴¹ examined the differences in perceived sports competence of the participants in their PLUNGE movement skill

intervention and those in the waitlist control group. They found that there were no intervention effects on perceived competence following the 7-week program.

The emergent relationship between actual childhood movement skill proficiency and later perceived competence may be viewed through the skill-learning gap hypothesis where those children with more proficient movement skills continue to engage in play and physical activities that require further practice and reinforcement of the skills throughout their adolescence. In contrast, those children with low levels of movement skill proficiency in childhood may withdraw from activities requiring skill proficiency, thus limiting further opportunities for skill development and resulting in a negative spiral where they constantly perceive their skills as being below the level of their peers (whether or not they are actually proficient in the skills). Future longitudinal and experimental research should continue to explore the impact of movement skills (both gross and fine) on one's self-beliefs, as well as other areas of mental health including social acceptance, anxiety, and depression in order to better inform future public health initiatives and programming aimed at improving children's overall mental health.

Executive Functioning

Executive functioning is an umbrella term used to describe a number of neuropsychological control functions that are needed for physical, cognitive, and emotional self-control.^{63,64} The 3 core executive functions are inhibition, working memory, and cognitive flexibility, which are the foundation for higher order functions such as planning and problem solving.⁶³ In young children, executive functioning is particularly important for learning and school readiness^{63,65-67} and, as such, is a vital component of a child's development and well-being. Previous research has demonstrated positive relationships between children's engagement in

physical activity and aspects of executive functioning^{63,68,69}; however, few studies have examined the unique or specific role of movement skills on executive functioning.

Observational Studies

Four observational studies were located that examined the relationship between movement skills and executive functioning. Piek and colleagues⁹ examined this relationship in a longitudinal sample of 33 children between the ages of 6 and 11 years who had previously been assessed with the Ages and Stages Questionnaire between 4 months and 4 years of age. The authors found that the participants' gross motor trajectory in early childhood accounted for a significant proportion of the variance in their current cognitive performance, after controlling for socioeconomic status.⁹ Furthermore, they found a significant predictive relationship between gross motor trajectory in early childhood and current working memory and processing speed,⁹ indicating that gross motor proficiency in early childhood may have an impact on cognitive abilities in middle childhood.

In another study, Cameron and colleagues⁷⁰ tested 213 children who were 4 to 5 years of age on their fine movement skills, executive functioning, and academic achievement at kindergarten entry and again in the spring of their kindergarten year. They found that independent from the broader classification of executive functioning, fine movement scores were positively correlated with academic achievement at kindergarten entry in all areas except applied problems.⁷⁰ Furthermore, children with better fine movement scores at kindergarten entry had a greater improvement in their reading composite scores, passage comprehension, sound awareness, and letter-word identification in the spring.⁷¹ Similarly, a large study of 2714 children found that fine movement skills in kindergarten predicted later achievement in reading and math, while controlling for family and child characteristics.⁷¹ These results suggest

that children with better gross and fine movement skills at a young age may have better executive functioning and academic achievement later in childhood.

It is possible that executive control may lie on a causal pathway connecting movement skill to outcomes such as intelligence and school achievement. Roebbers et al⁷² recently followed 169 children 5 to 6 years of age for 2 consecutive years and conducted yearly assessments of fine movement skills, intelligence, executive functioning, and early school achievement. The authors found that proficient fine movement skills at baseline had a significant effect on intelligence after the first year, as well as on academic achievement after the first and second years; however, the impact of fine movement skills was no longer significant when executive functioning was added to the model.⁷² This finding suggests that specific aspects of executive functioning mediate the relationship between fine movement skills and areas of cognitive function. There is a critical need for more research in this area, particularly in regard to the longitudinal relationships between gross movement skills and executive functioning.

Experimental/ Intervention Studies

Only 3 movement skill interventions have reported outcomes in executive functioning; however, their results are encouraging. In one early elementary school-based intervention, the experimental classrooms ($n = 152$) received physical education and movement skill-specific lessons 5 days per week during the school year, while the control classrooms ($n = 99$) received their usual 2 days of physical education per week.⁷³ The results indicated that the students in the experimental classrooms had better reading, writing, and math scores 1 year later in comparison to the students in the control classes.⁷³ Another intervention study randomly assigned 7- to 9-year-old children to a physical activity-based afterschool program that included 40 minutes of movement skill focused activities daily for 9 months, or

to a waitlist control group, and measured the ensuing impact on working memory.⁷⁴ The authors found that there was an increase in response accuracy at the posttest for the intervention group but not for the control group. Furthermore, the intervention group had larger improvements in the cognitive control of their working memory, relative to the control group.⁷⁴

More recently, Palmer and colleagues⁷⁵ compared the effects of a single 30-minute bout of movement skill training to 30 minutes of sedentary behavior on the attention and response inhibition of 16 preschool-aged children. They found that the children had significantly better attention following the movement skill training in comparison to the sedentary condition. Furthermore, the children had better response inhibition scores following the movement skill session, although they did not statistically differ from the scores following the sedentary condition.

The results of these studies suggest that gross movement skill-based interventions have a positive impact on aspects of executive functioning. However, much more research is needed in this area, particularly in regard to the intervention content, duration, and age ranges that may elicit the best outcomes, as they relate to executive functioning throughout childhood.

Discussion

It is evident that developing proficient movement skills is an important aspect of the physical and mental health of children with typical development; yet there is still much to be learned in this regard. It is imperative that as researchers, clinicians, policy makers, and parents we understand the relationships between movement skills and health-related outcomes in order to provide children with the best opportunity for healthy development. Given the high rates of inactivity, overweight/obesity, and issues with school readiness, that many children experience, we propose that intervening on movement skills may be one

universal way in which to enhance the development of all children, not just those with clinical delays or disorders.

Despite what we know of the importance of early childhood movement skills, there are still critical gaps in the literature regarding their impact on later health and development. Researchers should aim to conduct longitudinal studies of the relationships between early movement skills and areas of health including, but not limited to, physical activity, fitness, body composition, self-beliefs, depression, anxiety, and executive functioning. In addition to prospectively examining these relationships throughout childhood, it may be just as important to begin intervening on movement skills, in all children, at an early age. Early movement-based interventions should target gross and fine movement skills and outcome measures should include aspects of physical and mental health, in addition to changes in movement skill proficiency. Doing so will help us to better understand the relationships between these variables, in addition to understanding whether we can improve aspects of children's overall health by intervening on movement skills. Furthermore, if early movement skill proficiency is truly associated with later outcomes such as physical activity, fitness, and self-beliefs, among others, then intervening at an early age for all children is the most proactive way in which to minimize future negative health consequences associated with not developing proficiency in these skills.

Another essential component to consider when examining the relationship between movement skills and health-related variables is the presence of any mediating variables that may affect the relationships. For example, given the positive relationships between movement skills and physical activity,⁶ and between physical activity and a healthy body composition,³⁰ it is likely that physical activity mediates the relationship between movement skills and body composition. However, the relative contribution of physical activity, or movement skills, to this relationship is

yet to be determined. We recommend that future movement skill interventions include direct measures of activity levels and intensity (ie, via accelerometry, pedometry, heart rate monitors) during the actual intervention sessions. This will help us better understand the role of activity versus skill instruction when assessing our outcome variables. Furthermore, it is important that potential confounding factors (eg, socioeconomic status) are controlled for when examining the relationship between movement skills and health-related variables in order to better understand which factors, movement skills or otherwise, make the greatest contribution to a child's overall health.

Based on our current review and the previous review by Robinson et al,²⁸ it is becoming increasingly clear that movement skill proficiency is essential for engagement in physical activity, physical fitness, and a healthy body composition. This review, however, has added to our understanding of the role of movement proficiency on one's self-beliefs, beyond just perceived motor skills, as well as the relationship between movement proficiency and executive functioning. Furthermore, we believe there is an additional element that is essential to continued participation in physical activity and movement-based activities: Enjoyment. Any apparent associations between movement skills, physical activity, fitness, body composition, self-beliefs, and executive functioning cannot be realized without a certain level of enjoyment of the activity. Meaning that children will not be able to become proficient if they do not practice, and practicing these skills must be enjoyable for the children. We propose that enjoyment of movement skills and physical activities may play a central role in one's proficiency during early childhood when children will continue to attempt a skill, thus gaining practice, as long as they are enjoying it. However, this relationship may be reversed in later childhood where proficiency plays a much more central role to enjoyment. Therefore, it is vital that early movement opportunities are made enjoyable for

young children so that they can develop early proficiency and be set on a path of lifelong participation in physical activity, reaping the developmental benefits that go along with such participation.

Last, it is imperative that researchers use consistent terminology when investigating movement skill-based lines of inquiry because terms such as motor development, movement skills, movement proficiency, and motor coordination are often used interchangeably; however, they have unique meanings and should be used accordingly. While the majority of the included studies have accurately used these terms, we have found some discrepancies. Mainly, there are frequent instances where tasks that are grouped into fundamental movement/motor skill assessments would be better classified as motor coordination tasks. For example, the figure 8 dribbling task,³⁵ the 50 meter run,⁴⁷ and the product-oriented tasks of jumping rope, kicking for accuracy, and throwing for distance⁵⁰ all would be better classified as motor coordination due to the gross and fine movement organization needed in their performance. In order to be clear when reporting study findings to researchers, policy makers, and community partners, we must continue to use consistent and correct terminology.

Conclusion

Although the literature is limited, there appears to be at least some evidence that developing proficient movement skills at a young age may have a positive impact on children's physical activity, fitness, body composition, self-beliefs, and executive functioning in later childhood and adolescence in typically developing children. There is still a need for more research in order to better understand these relationships, as well as the impact of movement skills on other aspects of overall health. Future research should employ prospective research designs that begin to examine movement skills and health-related variables in early childhood through to adolescence. Researchers and public health officials

should also begin to implement early movement skill interventions that target both gross and fine movement skills and evaluate whether improving these skills has an impact on other areas of overall health. Intervention studies will not only help further understand the relationship between movement skills and health-related variables but may also act as a protective factor for adverse health events throughout childhood and later in life. It is possible that movement skills may be one of the few modifiable risk factors (whereas socioeconomic status, parental education, etc, are not likely to change) for the prevention of poor health outcomes, such as obesity and depression; thus, it is imperative that we continue to explore these relationships in order to better inform future clinical and public health initiatives aimed at improving children's overall health and well-being. [AJLM](#)

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