Movement Matters

Koolwijk, Pim

2025

DOI (link to publisher)
10.5463/thesis.1039

document version
Publisher's PDF, also known as Version of record

MOVEMENT MATTERS

Exploring the dynamics of motor competence development in early childhood

door

Pim Koolwijk

Cover: Ilse Modder (www.ilsemodder.nl)
Lay-out: Ilse Modder (www.ilsemodder.nl)
Printed by: Gildeprint Enschede (www.gildeprint.nl)
ISBN: 978-94-6496-355-7

This research was performed by The Hague University of Applied Sciences.

This PhD thesis was embedded within Amsterdam Movement Sciences research institute, at the Department of Human Movement Sciences, Vrije Universiteit / University of Amsterdam, the Netherlands.

This research was co-financed by Regieorgaan SIA part of the National Organization for Scientific Research (NWO) (RAAK.PRO 03.123).

Financial support for the printing of this dissertation has kindly been provided by Jan Luiting Fonds.

VRIJE UNIVERSITEIT

MOVEMENT MATTERS

Exploring the dynamics of motor competence development in early childhood

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor of Philosophy
aan de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. J.J.G. Geurts,
volgens besluit van de decaan
van de Faculteit der Gedrags- en Bewegingswetenschappen
in het openbaar te verdedigen
op donderdag 17 april 2025 om 11.45 uur
in de universiteit

door

Pim Koolwijk

geboren te Woerden

promotor: prof.dr. G.J.P. Savelsbergh

copromotoren: dr. S.I. de Vries
dr. R. Mombarg

Ambition

Aspire to climb as high as you can dream

TABLE OF CONTENTS

Chapter 1

General introduction

1

1.1 TRENDS IN MOTOR COMPETENCE AMONG CHILDREN

Movement is an essential aspect of life. Our ability to move is more than just a function that enables us to walk, jump, swim, play or to manipulate objects[1]; it is a critical aspect of human life and development, and has important implications for cognitive and social-emotional development.[2] In order to move and to experience the related effects, *motor competence* is crucial. Motor competence (MC) is suggested as prerequisite for the acquisition of other developmental functions such as perceptual and cognitive skills.[3] Development of fundamental motor skills in early childhood is therefore of utmost importance.

In the last decade, children's motor competence has received increasing academic attention.[4] Several international studies have shown an alarming and negative trend in motor competence development and fitness related variables throughout childhood (e.g., early-, middle-, and late childhood, and adolescence).[5-10] Even more worrying, this negative trend is already seen during early childhood years (age 2 to 5 years).[10,11] Data from longitudinal studies conducted in Europe, Japan and in the USA, showed a decline in motor competence over time since 1957, 1960 and since 2000, respectively.[12,13] Children are struggling with skills like hopping, dribbling, and balancing, but also with object-control skills like throwing and catching.[14]

In the Netherlands a similar trend is noticed. A study including late childhood (LCD) aged children (9-12 years of age) showed a decrease in levels of neuromotor fitness between 1980-2006.[15] This decline was detected in the performance of several neuromotor skills like jumping and sprinting. More recently, a comparison of performing fundamental movement skills (FMS) in 2006 and 2016 showed a similar trend.[16] In this study lower scores were found on six out of seven tested FMS in 2016, with the largest decline in object-control skills.

This negative trend in MC in the last decades is in line with trends in other health related variables. For example, only a small proportion of children and adolescents (27–33%) meets the recommended amount of moderate- to vigorous-intensity physical activity (MVPA) required for ongoing health and well-being.[17] In the Netherlands, 39.6% of the 4–11-year-old Dutch children are not engaging in sufficient PA according to the age-appropriate norms.[18] Furthermore, sedentary behaviour is increasing,[19] even among young children.[20] Children spent, on average, 7.3 hours per day in sedentary activities.[21] Also, the prevalence of overweight and obesity among children and adolescents has risen dramatically in the last decades.[22,23,24] In 2023, 11.3% of Dutch 4-11-year-old children were overweight.[25]

1

1.2 DEFINITION OF MOTOR COMPETENCE

Throughout the last decades several definitions of motor competence have been used.[26] Over time these definitions and descriptions have shifted from biological maturational processes of motor development to different aspects of motor behaviour. It is important to understand how motor competence is conceptualized to allow comparison between studies. In 1977, Wickstrom introduced the term “fundamental skills” as the basis for more advanced and highly specific motor activities including skills such as running, jumping, and throwing.[27] These fundamental motor skills are defined as the foundational components or ‘building blocks’ of more advanced and complex movements necessary for participating in sports, games, or other context-specific physical activities. FMS encompass object-control skills (such as throwing, catching, dribbling, kicking, striking, and underhand rolling), locomotor skills (including walking, running, jumping, hopping, leaping, galloping, sliding, and skipping), and balance/stability skills (non-locomotor skills like body rolling, bending, dodging, stick balancing, one-foot balance, stretching, swinging, turning, and twisting). Logan and colleagues[26] noticed a shift in terminology by researchers in using the global term motor competence to encompass multiple terms used to describe human movement skills (i.e., motor proficiency, motor performance, fundamental movement/motor skill, motor ability, and motor coordination).[2,28] Within this dissertation, motor competence is described as goal-orientated human movement,[28] and is defined as an *individual's degree of proficiency in performing a wide range of motor skills as well as the underlying mechanisms including quality of movement, motor control and coordination.*[29] In short, fundamental movement skills provide the foundation for motor competence. MC reflects a higher level of proficiency in applying those skills in diverse situations. Children with high MC are better equipped to participate in physical activities, sports, and recreational pursuits than children with low MC.[2,30]

1.3 MOTOR COMPETENCE DEVELOPMENT AND THE PROFICIENCY BARRIER

Several motor competence experts have proposed models and metaphors of motor skill development to explain (motor) behaviour across the lifespan such as Bronfenbrenner's Ecological Systems, Gibson's Ecological Perspective, Newell's Constraints model, Hulteen's foundational movement skill model, Gallahue's hourglass model, and other multi-dimensional models.[31-36] Clarke and Metcalfe introduced a well-known model, i.e. the mountain of motor development.[37] According to this metaphor, motor development is compared to learning to climb a mountain: the process takes years, it is a sequential and cumulative process, and it is strongly affected by personal skills and traits of the individual climber.[38] It is also considered a nonlinear process, as the learning process does not flow smoothly from one

stage to the next and differs in pace. The mountain includes an ascent of six passages of motor development: the reflexive period, the preadapted period, the fundamental patterns period, the context-specific period, the skilful period and the compensation period. Each period builds on the skills learned in the previous period. Motor development differs between children and is related to age. However, it is not strictly dependent on age. So, the time spent in each stage of development varies for each individual dependent of factors that determine skill acquisition (e.g., the amount of experience of instruction, the quality of instruction, individual qualities).[38] Figure 1.1 represents a compressed version of the developmental stages in the mountain of motor development, including a proficiency barrier. This proficiency barrier indicates that children who are deprived of learning the fundamental skills before a certain age have difficulty to learn the transitional motor skills.
The proficiency barrier was introduced by Seefeldt.[40] He placed a proficiency barrier between the fundamental motor skills development period, in early childhood, and transitional motor skills period from middle childhood into adulthood. Children with FMS levels above this barrier are considered capable of applying their motor skills in sports, games, and life-long physical activities.[39]

Literature has shown that a physically active lifestyle starts to develop very early in childhood.[41] Although rudimentary movement patterns may be naturally developed with active free play, a mature form of MC is less likely to be achieved without appropriate practice, encouragement, feedback and instruction. As shown in the mountain of motor development, the transition from early childhood (EC) (age 2- to 5-years) to middle childhood (MCD) (age 6- to 9-years), is of great importance to reach the proficiency barrier in a later stage. Therefore, interventions for promoting MC development in EC are essential to ensure life-long physical activity.[26]

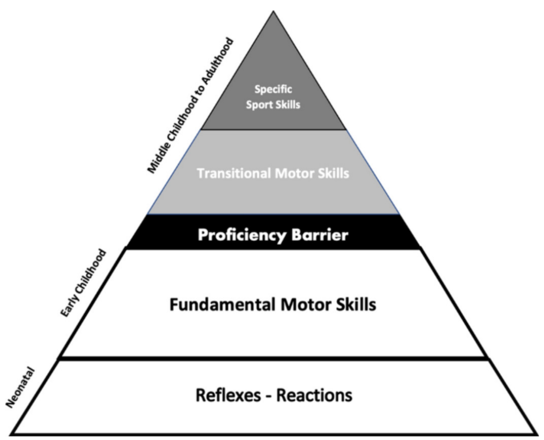

Figure 1.1. The mountain of motor development including Seefeldt's original conception of the proficiency barrier.[39]

1.4 MOTOR COMPETENCE IN A BROADER PERSPECTIVE

Children's motor competence development is related to their physical activity level.[42-46] However, it is debatable to focus only on promoting a higher *quantity* of physical activity, without promoting a higher *quality* of physical activity. A holistic approach that stresses the importance of MC for life-long physical activity is *physical literacy.* Physical literacy (PL) is defined as a "disposition to capitalize on our human-embodied capability wherein the individual has the motivation, confidence, physical competence, knowledge, and understanding to value and take responsibility for maintaining purposeful physical pursuits and activities throughout the life course".[47] This multidimensional concept emphasizes the essential competence, confidence, motivation and knowledge to be physically active for a lifetime. The four components of PL are interconnected. It is likely that motivation and motor confidence increase when MC increases. However, being motor competent in itself does not necessarily promote a desire to be involved in PA. It is often the rewarding satisfaction and enjoyment generated from any experience of certain physical activities that creates interest in further involvement. So, all components of PL must be secured to guarantee life-long physical activity.

While Whitehead[47] described the building blocks of physical literacy, Stodden and colleagues extended their view and proposed a conceptual model in 2008 that describes the relationship between MC, PA, and weight status.[30] Additionally, health-related fitness (HRF) and perceived motor competence (PMC) were suggested as mediating variables in the model. The synergistic nature of relationships among variables is suggested to promote either positive or negative trajectories of PA, HRF, and weight status across childhood and into adolescence. According to this model, individuals with low MC may not exhibit beneficial levels of PA and HRF in their later years and may also face an increased risk of obesity throughout childhood and adolescence.

As research regarding the plausibility of the conceptual model of Stodden et al. expanded, Robinson and colleagues,[48] revised the model in 2015 (see Figure 1.2), largely based on cross-sectional research.[49] Regarding MC and PA, data strongly support a positive relationship between MC and PA across childhood into adolescence.[26,50,51] However, this correlation is low to moderate from EC to MCD. The relationship between MC and multiple aspects of HRF (i.e., cardiorespiratory fitness, muscular strength, muscular endurance, and flexibility) is scarcely documented at EC.[52] The development of MC will initially *promote* HRF in EC and, during middle and late childhood**,** HRF would *mediate* the relationship between MC and PA as increased fitness would hypothetically facilitate continued engagement in PA for longer periods. Within this dissertation focus is being laid on EC and the transition to MCD, therefore the promotion of HRF as a mediating factor of MC development will not be considered.

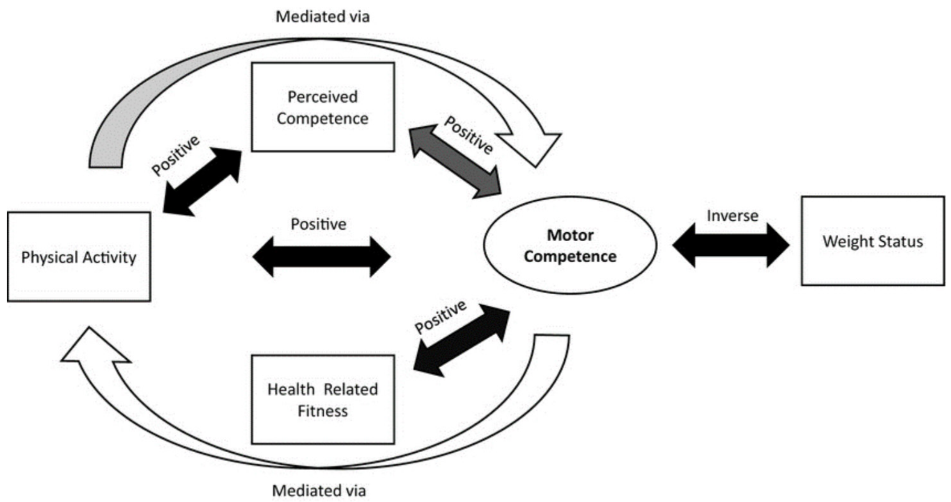

Figure 1.2. Research consensus on motor competence and health-related variables. Black arrow indicates extensively tested: consistent relationship; dark grey arrow indicates moderately tested: variable relationship; partial grey arrow indicates partially tested: some evidence; white arrow indicates limited testing. The direction of the relationship is indicated above the arrows.[48]

Another debatable factor in the model of Robinson et al. is perceived motor competence (PMC). PMC acts as a mediator between MC and PA and is considered to be important during the transition from EC to MCD. PMC refers to an individual's perception of their actual movement capabilities and can be described as the belief in one's own ability to effectively use and apply a variety of general, refined, and specific movement patterns.[53] As children age, associations between PMC, MC and PA are believed to strengthen, coinciding in middle childhood when a child's cognitive ability to accurately assess their competence becomes more established. Within the concept of Stodden et al. (2008),[30] a healthy or unhealthy weight status is an important outcome of the model. Findings from numerous cross-sectional studies involving large samples of children, adolescents, and young adults consistently show an inverse association between MC and weight status.[54] Children who are heavier may find it challenging to engage in certain physical activities and therefore, over time their MC would be lower. On the other hand, MC can also be a precursor of weight status in childhood.

Robinson recommended, in 2015, to conduct longitudinal research and to search for additional variables that may influence the inverse relationship between MC and weight status throughout childhood. Also, the individual developmental pathways of change conceptualized in the original model of Stodden et al. should be examined. During the last years, attention has been given to several lifestyle behaviours during EC (e.g., diet quality, social media, sedentary time, and sleep duration) since the establishment of habits often happens before 3 years of age.[55,56] However, still more research is needed regarding the association of lifestyle-related factors with MC development from EC.

Several other studies found associations of MC and other domains during early childhood. Lima and colleagues,[57] recently provided an extension of Stodden's model in which MC was related to cognition and academic performance.[58-61] This is in line with a conceptual model of Hill and colleagues (2023),[49] that positions MC as a mediator between PA and cognitive and social-emotional outcomes.[58,59,62] Environmental factors, such as socio-economic position and neighbourhood characteristics can affect motor skills development. For example, children from deprived neighbourhoods often start school with less developed motor skills.[63] Overall, it can be concluded that motor competence is a crucial determinant within the spectrum of PA, HRF, PMC and weight status. But MC development is also associated with lifestyle-related factors, cognitive, and socio-emotional outcomes, and environmental aspects. According to Bronfenbrenner,[64] the ecological context of human development consists of individual, social, and physical processes that interact to shape the functioning of the developing child. It should also be recognized that bidirectional interactions between these individual, social, and physical processes yield a more accurate and complete picture of how children develop over time. However, with regard to the development of motor competence in early aged children, much remains to be clarified.

1.5 RESEARCH GAPS

Since 2010 increasing interest has been given to children's MC development to get a grip on the development and its determinants.[4] Still some questions remain to be answered. Within literature, relatively little attention has been paid to the proficiency barrier.[39,65,66] This is in part due to the fact that there is a lack of longitudinal studies examining MC starting from (early) childhood.[2,67] Therefore, identifying children at risk for not reaching the essential proficiency barrier, or children with a delay in MC development, and providing them appropriate and early MC intervention, is challenging.[68] In this dissertation a longitudinal study has been conducted to increase our insight in developmental trajectories of MC during the transition from EC to MCD.

In addition, the conceptual model of Stodden et al. (2008)[30] and the revised version of Robinson et al. (2015)[48] needs to be updated since a lot of cross-sectional and longitudinal research has been done since then.[29,69-71] By updating this conceptual model more insight will be given in the characteristics of children being at risk for a delayed MC development. Therefore, presumed relations need to be (un)supported or strengthened based on

1

evidence. Furthermore, Stodden or Robinson and colleagues [30,48] did not incorporate any social determinants within their conceptual model, while these are likely to have an influence on children's MC and PA.[72,73] In this dissertation, parental influences and aspects of the home environment will be considered as potential determinants of MC development in EC.

Finally, as the lifestyles of the current generation of children are substantially different from previous generations, there is a continuous need for studying MC development and its determinants.[2,74] Accordingly, new interventions need to be developed that are appropriate for the current generation of young children and implemented in different contexts in which they are active. For example, it was pointed out that structured activities during physical education lessons are better in the school context than free play to achieve adequate motor development in preschool children.[75,76] However, it is questionable if, and how, this methodology can be transferred into other contexts like the sports- or neighbourhood setting. Strategies that should lead to a lasting increasement of PA are challenging during EC.[77]

Between 2019 and 2024 a Dutch research consortium conducted a research project called 'Start (V)aardig'. This project was funded by regieorgaan SIA. Regieorgaan SIA is part of the Dutch organization for scientific research (NWO). The consortium consisted of researchers from four different universities of applied sciences, supported by an expert group with various knowledge and expertise (e.g., physical education, human movement science, sport, and education). Our project emerged from the fact that Dutch PE- and sport professionals struggle with the question of how to optimally support early childhood aged children in improving their MC. To answer this question, knowledge is needed about identifying risk groups, modifiable determinants, and effective interventions promoting motor skills of early childhood aged children. The knowledge gained in this project has been published in several scientific and practice-oriented articles and translated into a toolbox for PE- and sports professionals and parents and educational modules for bachelor students, to promote MC of EC-aged children.

1.6 RESEARCH QUESTIONS AND OUTLINE OF THIS DISSERTATION

The purpose of this dissertation was to explore how MC can be optimally promoted in early childhood by sports professionals. The main research question can be formulated as follows: How can motor competence be promoted as efficient and effective as possible in early childhood by sports professionals?

To answer the main question, four sub-questions were formulated:

- How does MC development proceed from early to middle childhood?
- How can children's MC development in early childhood be characterized based on biological, personal and socio-demographic determinants?
- How can children with an undesirable MC development during the transition from early- to middle childhood be identified?
- What is the effectiveness of fundamental movement skills interventions in young children?

This dissertation consists of seven chapters. **Chapter 2** gives a longitudinal insight in motor development from early childhood to middle childhood. Then, in **Chapters 3 and 4**, biological, personal and socio-demographic determinants of MC in early childhood are presented. In **Chapter 5**, characteristics of children with an undesirable MC development during the transition from early childhood to middle childhood are described. **Chapter 6** provides an overview of the effectiveness of fundamental movement skill interventions in young children (2–5 years) and identifies elements that determine the effectiveness of these interventions. Finally, a summary and discussion of the main findings are presented in the epilogue in **Chapter 7.** Besides a discussion, also practical implications for PE- and sport professionals are given in this final chapter.

1

1

REFERENCES

1. Schmidt, R.A., Lee, T.D., Winstein, C., Wulf, G., & Zelaznik, H. N. (2018). *Motor control and learning: A behavioral emphasis*. Human Kinetics.
2. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., Clark, C., Schmidt, M., Morgan, P., & Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*(1), 18.
3. Piek, J.P., Dawson, L., Smith, L.M., & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. *Human Movement Science, 27*(5), 668-681.
4. Wang, J., Qu, S., Zhu, Z., Zhao, X., Song, W., Li, X., Chen, W., & Luo, D. (2023). Global hotspots and trends in research on preschool children's motor development from 2012 to 2022: A bibliometric analysis. *Frontiers in Public Health, 11*, 1118674.
5. Ao, D., Wu, F., Yun, C., & Zheng, X. (2019). Trends in physical fitness among 12-year-old children in urban and rural areas during the social transformation period in China. *Journal of Adolescent Health, 64*(2), 250-257.
6. D'Anna, C., Forte, P., & Pugliese, E. (2024). Trends in physical activity and motor development in young people—Decline or improvement? A review. *Children, 11*(3), 298.
7. Đurić, S., Sember, V., Starc, G., Sorić, M., Kovač, M., & Jurak, G. (2021). Secular trends in muscular fitness from 1983 to 2014 among Slovenian children and adolescents. *Scandinavian Journal of Medicine & Science in Sports, 31*(9), 1853-1861.
8. Monacis, D., & Colella, D. (2023). Increase in BMI and negative muscular strength trends in adolescents in 1990 and 2020: Results from the Regional Observatory of Motor Development in Southern Italy. In *Sport and Fitness in Children and Adolescents* (pp. 1-15). IntechOpen.
9. Radulović, A., Jurak, G., Leskošek, B., Starc, G., & Blagus, R. (2022). Secular trends in physical fitness of Slovenian boys and girls aged 7 to 15 years from 1989 to 2019: A population-based study. *Scientific Reports, 12*(1), 10495.
10. Sirressi, A., & Colella, D. (2010). Prestazione motoria e Body Mass Index dei bambini della scuola primaria. Attività fisica e prevenzione del sovrappeso e dell'obesità. *Italian Journal of Sport Sciences*, 36-44.
11. Roth, K., Ruf, K., Obinger, M., Mauer, S., Ahnert, J., Schneider, W., Graf, C., & Hebestreit, H. (2010). Is there a secular decline in motor skills in preschool children? *Scandinavian Journal of Medicine & Science in Sports, 20*(4), 670-678.
12. Sedlak, P., Pařízková, J., Daniš, R., Dvořáková, H., & Vignerová, J. (2015). Secular changes of adiposity and motor development in Czech preschool children: Lifestyle changes in fifty-five-year retrospective study. *BioMed Research International, 2015*(1), 823841.
13. Sugihara, T., Kondo, M., Mori, S., & Yoshida, I. (2006). Chronological change in preschool children's motor ability development in Japan from the 1960s to the 2000s. *International Journal of Sport and Health Science, 4*, 49-56.
14. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J.D., Wadsworth, D., Rudisill, M., & Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*(10), 1609-1618.
15. Runhaar, J., Collard, D., Singh, A.S., Kemper, H., Van Mechelen, W., & Chinapaw, M. (2010). Motor fitness in Dutch youth: Differences over a 26-year period (1980–2006). *Journal of Science and Medicine in Sport, 13*(3), 323-328.
16. Mombarg, R., De Bruijn, A., Smits, I., Hemker, B.T., Hartman, E., Bosker, R.J., & Timmermans, A.C. (2023). Development of fundamental motor skills between 2006 and 2016 in Dutch primary school children. *Physical Education and Sport Pedagogy, 28*(6), 583-600.
17. Aubert, S., Barnes, J.D., Demchenko, I., Hawthorne, M., Abdeta, C., Abi Nader, P., Sala, J.C.A., Aguilar-Farias, N., Aznar, S., & Bakalár, P. (2022). Global Matrix 4.0 Physical Activity Report Card grades for children and adolescents: Results and analyses from 57 countries. *Journal of Physical Activity and Health, 19*(11), 700-728.
18. RIVM (2024). Overzicht kernindicatoren sport en bewegen, beweegrichtlijnen. Rijksinstituut voor Volksgezondheid en Milieu: Bilthoven, The Netherlands.
19. Basterfield, L., Adamson, A.J., Frary, J.K., Parkinson, K.N., Pearce, M.S., Reilly, J.J., & Gateshead Millennium Study Core Team. (2011). Longitudinal study of physical activity and sedentary behavior in children. *Pediatrics, 127*(1), e24-e30.
20. Kabali, H.K., Irigoyen, M.M., Nunez-Davis, R., Budacki, J.G., Mohanty, S.H., Leister, K.P., & Bonner Jr, R.L. (2015). Exposure and use of mobile media devices by young children. *Pediatrics, 136*(6), 1044-1050.
21. RIVM (2024). Overzicht kernindicatoren sport en bewegen, zitgedrag. Rijksinstituut voor Volksgezondheid en Milieu: Bilthoven, The Netherlands.
22. Abarca-Gómez, L., Abdeen, Z.A., Hamid, Z.A., Abu-Rmeileh, N.M., Acosta-Cazares, B., Acuin, C., Adams, R.J., Aekplakorn, W., Afsana, K., & Aguilar-Salinas, C.A. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *The Lancet, 390*(10113), 2627-2642.
23. De Onis, M., Blössner, M., & Borghi, E. (2010). Global prevalence and trends of overweight and obesity among preschool children. *The American Journal of Clinical Nutrition, 92*(5), 1257-1264.
24. WHO (2024). Obesity and overweight. World Health Organization.
25. CBS (2024). Lengte en gewicht van personen, ondergewicht en overgewicht; vanaf 1981. Centraal Bureau voor de Statistiek.
26. Logan, S.W., Ross, S.M., Chee, K., Stodden, D.F., & Robinson, L.E. (2018). Fundamental motor skills: A systematic review of terminology. *Journal of Sports Sciences, 36*(7), 781-796.
27. Wickstrom, R.L. (1977). *Fundamental motor patterns*.
28. Lorås, H. (2020). The effects of physical education on motor competence in children and adolescents: A systematic review and meta-analysis. *Sports, 8*(6), 88.
29. Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*, 541-551.
30. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306.
31. Cairney, J., Dudley, D., Kwan, M., Bulten, R., & Kriellaars, D. (2019). Physical literacy, physical activity and health: Toward an evidence-informed conceptual model. *Sports Medicine, 49*, 371-383.
32. Goodway, J.D., Ozmun, J.C., & Gallahue, D.L. (2013). Motor development in young children. In *Handbook of Research on the Education of Young Children* (pp. 103-115).
33. Haywood, K.M., & Getchell, N. (2021). *Life span motor development*. Human Kinetics.
34. Hulteen, R.M., Morgan, P.J., Barnett, L.M., Stodden, D.F., & Lubans, D.R. (2018). Development of foundational movement skills: A conceptual model for physical activity across the lifespan. *Sports Medicine, 48*, 1533-1540.

1

35. Menescardi, C., De Meester, A., Morbée, S., Haerens, L., & Estevan, I. (2022). The role of motivation in the conceptual model of motor development in childhood. *Psychology of Sport and Exercise, 61*, 102188.
36. Sallis, J.F., Cervero, R.B., Ascher, W., Henderson, K.A., Kraft, M.K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health, 27*, 297-322.
37. Clark, J.E., & Metcalfe, J.S. (2002). The mountain of motor development: A metaphor. In *Motor Development: Research and Reviews* (Vol. 2, pp. 163-190).
38. Payne, V.G., & Isaacs, L.D. (2017). *Human motor development: A lifespan approach*. Routledge.
39. Brian, A., Getchell, N., True, L., De Meester, A., & Stodden, D.F. (2020). Reconceptualizing and operationalizing Seefeldt's proficiency barrier: Applications and future directions. *Sports Medicine, 50*(11), 1889-1900.
40. Seefeldt, V., & Gould, D. (1980). *Physical and Psychological Effects of Athletic Competition on Children and Youth*.
41. Telama, R., Yang, X., Leskinen, E., Kankaanpää, A., Hirvensalo, M., Tammelin, T., Viikari, J.S., & Raitakari, O.T. (2014). Tracking of physical activity from early childhood through youth into adulthood. *Medicine & Science in Sports & Exercise, 46*(5), 955-962.
42. Bardid, F., Rudd, J.R., Lenoir, M., Polman, R., & Barnett, L.M. (2015). Cross-cultural comparison of motor competence in children from Australia and Belgium. *Frontiers in Psychology, 6*, 964.
43. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., Burns, C., & Bardid, F. (2020). Global levels of fundamental motor skills in children: A systematic review. *Journal of Sports Sciences*, 1-37.
44. De Meester, A., Stodden, D., Brian, A., True, L., Cardon, G., Tallir, I., & Haerens, L. (2016). Associations among elementary school children's actual motor competence, perceived motor competence, physical activity and BMI: A cross-sectional study. *PloS One, 11*(10), e0164600.
45. O'Brien, W., Belton, S., & Issartel, J. (2016). Fundamental movement skill proficiency amongst adolescent youth. *Physical Education and Sport Pedagogy, 21*(6), 557-571.
46. Rodrigues, L.P., Stodden, D.F., & Lopes, V.P. (2016). Developmental pathways of change in fitness and motor competence are related to overweight and obesity status at the end of primary school. *Journal of Science and Medicine in Sport, 19*(1), 87-92.
47. Whitehead, M. (2013). Definition of physical literacy and clarification of related issues. *ICSSPE Bulletin, 65*(1.2).
48. Robinson, L.E., Stodden, D.F., Barnett, L.M., Lopes, V.P., Logan, S.W., Rodrigues, L.P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273-1284.
49. Hill, P.J., McNarry, M.A., Mackintosh, K.A., Murray, M.A., Pesce, C., Valentini, N.C., Getchell, N., Tomporowski, P.D., Robinson, L.E., & Barnett, L.M. (2023). The influence of motor competence on broader aspects of health: A systematic review of the longitudinal associations between motor competence and cognitive and social-emotional outcomes. *Sports Medicine*, 1-53.
50. Engel, A.C., Broderick, C.R., van Doorn, N., Hardy, L.L., & Parmenter, B.J. (2018). Exploring the relationship between fundamental motor skill interventions and physical activity levels in children: A systematic review and meta-analysis. *Sports Medicine, 48*(8), 1845-1857.
51. Jones, D., Innerd, A., Giles, E.L., & Azevedo, L.B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of Sport and Health Science, 9*(6), 542-552.

52. Stout, J. (2016). Physical fitness during childhood and adolescence. In *Campbell's Physical Therapy for Children Expert Consult-E-Book* (p. 117). Elsevier.
53. Estevan, I., & Barnett, L.M. (2018). Considerations related to the definition, measurement and analysis of perceived motor competence. *Sports Medicine, 48*(12), 2685-2694.
54. Martins, C., Romo-Perez, V., Webster, E.K., Duncan, M., Lemos, L.F., Staiano, A.E., Okely, A., Magistro, D., Carlevaro, F., & Bardid, F. (2023). Motor competence and body mass index in the preschool years: A pooled cross-sectional analysis of 5545 children from eight countries. *Sports Medicine*, 1-12.
55. Chia, A., Toh, J.Y., Natarajan, P., Cai, S., Ong, Y.Y., Descarpentrie, A., Lioret, S., Bernard, J.Y., Müller-Riemenschneider, F., & Godfrey, K.M. (2024). Trajectories of lifestyle patterns from 2 to 8 years of age and cardiometabolic risk in children: The GUSTO study. *International Journal of Behavioral Nutrition and Physical Activity, 21*(1), 9.
56. Chong, M.F. (2022). Dietary trajectories through the life course: Opportunities and challenges. *British Journal of Nutrition, 128*(1), 154-159.
57. Lima, R.A., Drenowatz, C., & Pfeiffer, K.A. (2022). Expansion of Stodden et al.'s model. *Sports Medicine, 52*(4), 679-683.
58. Collett, B.R., Wallace, E.R., Kartin, D., & Speltz, M.L. (2019). Infant/toddler motor skills as predictors of cognition and language in children with and without positional skull deformation. *Child's Nervous System, 35*, 157-163.
59. Cook, C.J., Howard, S.J., Scerif, G., Twine, R., Kahn, K., Norris, S.A., & Draper, C.E. (2019). Associations of physical activity and gross motor skills with executive function in preschool children from low-income South African settings. *Developmental Science, 22*(5), e12820.
60. Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics, 138*(3).
61. Macdonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: A systematic review. *International Journal of Environmental Research and Public Health, 15*(8), 1603.
62. Kuzik, N., Naylor, P., Spence, J.C., & Carson, V. (2020). Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: Cross-sectional associations using compositional analyses. *PloS One, 15*(8), e0237945.
63. Temple, V.A., Lefebvre, D.L., Field, S.C., Crane, J.R., Smith, B., & Naylor, P. (2019). Object control skills mediate the relationship between neighborhood vulnerability and participation in physical activities. *Journal of Motor Learning and Development, 7*(1), 49-63.
64. Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.
65. De Meester, A., Stodden, D., Goodway, J., True, L., Brian, A., Ferkel, R., & Haerens, L. (2018). Identifying a motor proficiency barrier for meeting physical activity guidelines in children. *Journal of Science and Medicine in Sport, 21*(1), 58-62.
66. Stodden, D.F., True, L.K., Langendorfer, S.J., & Gao, Z. (2013). Associations among selected motor skills and health-related fitness: Indirect evidence for Seefeldt's proficiency barrier in young adults? *Research Quarterly for Exercise and Sport, 84*(3), 397-403.

67. Costa, C.L., Cattuzzo, M.T., Stodden, D.F., & Ugrinowitsch, H. (2021). Motor competence in fundamental motor skills and sport skill learning: Testing the proficiency barrier hypothesis. *Human Movement Science, 80*, 102877.

68. Cameron, K.L., Albesher, R.A., McGinley, J.L., Allison, K., Cheong, J.L., & Spittle, A.J. (2020). Movement-based interventions for preschool-age children with, or at risk of, motor impairment: A systematic review. *Developmental Medicine & Child Neurology, 62*(3), 290-296.

69. Barnett, L.M., Webster, E.K., Hulteen, R.M., De Meester, A., Valentini, N.C., Lenoir, M., Pesce, C., Getchell, N., Lopes, V.P., & Robinson, L.E. (2022). Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Medicine, 52*(4), 875-920.

70. Burns, R.D., & Fu, Y. (2018). Testing the motor competence and health-related variable conceptual model: A path analysis. *Journal of Functional Morphology and Kinesiology, 3*(4), 61.

71. De Meester, A., Barnett, L.M., Brian, A., Bowe, S.J., Jiménez-Díaz, J., Van Duyse, F., Irwin, J.M., Stodden, D.F., D'Hondt, E., & Lenoir, M. (2020). The relationship between actual and perceived motor competence in children, adolescents and young adults: A systematic review and meta-analysis. *Sports Medicine, 50*, 2001-2049.

72. Agard, B., Zeng, N., McCloskey, M.L., Johnson, S.L., & Bellows, L.L. (2021). Moving together: Understanding parent perceptions related to physical activity and motor skill development in preschool children. *International Journal of Environmental Research and Public Health, 18*(17), 9196.

73. Cools, W., De Martelaer, K., Samaey, C., & Andries, C. (2011). Fundamental movement skill performance of preschool children in relation to family context. *Journal of Sports Sciences, 29*(7), 649-660.

74. Elgar, F.J., Pförtner, T., Moor, I., De Clercq, B., Stevens, G.W., & Currie, C. (2015). Socioeconomic inequalities in adolescent health 2002–2010: A time-series analysis of 34 countries participating in the Health Behaviour in School-aged Children study. *The Lancet, 385*(9982), 2088-2095.

75. Ruiz-Esteban, C., Terry Andrés, J., Méndez, I., & Morales, Á. (2020). Analysis of motor intervention program on the development of gross motor skills in preschoolers. *International Journal of Environmental Research and Public Health, 17*(13), 4891.

76. Dapp, L.C., Gashaj, V., & Roebers, C.M. (2021). Physical activity and motor skills in children: A differentiated approach. *Psychology of Sport and Exercise, 54*, 101916.

77. Moss, S., & Gu, X. (2022). Home-and community-based interventions for physical activity and early child development: A systematic review of effective strategies. *International Journal of Environmental Research and Public Health, 19*(19), 11968.

Chapter 2

Changes in motor competence of 4-8 year-old children: a longitudinal study

Pim Koolwijk, Ester de Jonge, Remo Mombarg, Teun Remmers, Dave Van Kann, Ingrid van Aart, Geert Savelsbergh & Sanne de Vries (2024).

*International Journal of Environmental Research and Public Health, 21(2):*190.

ABSTRACT

Objectives

The development of children's motor competence (MC) from early to middle childhood can follow different courses. The purpose of this longitudinal study was to describe and quantify the prevalence of patterns of MC development from early to middle childhood and to identify undesirable patterns.

Design

The study used a longitudinal design. Data were collected in three consecutive years, between February 2020 (T0) and May 2022 (T2). Methods: A total of 1128 typically developing Dutch children (50.2% male) between 4 and 6 years old at baseline (M = 5.35 ± 0.69 years) participated in this study. MC was measured with the Athletic Skills Track and converted into Motor Quotient (MQ) scores. To convert all individual MQ scores into meaningful patterns of MC development, changes in MQ categories were analysed between the different timepoints.

Results

A total of 11 different developmental patterns were found. When grouping the different patterns, five undesirable patterns were found with 18.2% of the children, showing an undesirable pattern of MC development between T0 and T2. The patterns of motor development of the other children showed a normal or fluctuating course.

Conclusions

There is a lot of variation in MC in early and middle childhood. A substantial percentage of young children showed undesirable MC developmental patterns emphasizing the need for early and targeted interventions.

INTRODUCTION

Childhood is a critical time for the development of motor competence (MC). MC enables children and adolescents to successfully participate in various types of physical activity (PA).[1] This is a global term to describe goal-orientated human movement,[2] and can be defined as an individual's degree of proficiency in performing a wide range of motor skills as well as the mechanisms underlying this performance (e.g., motor control and coordination).[3] Considering that MC at a young age contributes to the development of an active lifestyle,[4,5] it is imperative to assess and monitor MC, particularly in early and middle childhood. Clark and Metcalfe[1] proposed a well-recognized model to explain motor behaviours across a lifespan. This 'mountain of motor development' includes an ascent of six passages of motor development starting from birth (the reflexive period) and ending at the compensation period as a time when the system adapts or compensates for detrimental changes in organism constraints. Each period builds on the skills learned in the previous period. Motor development is related, but not strictly dependent on age. So, the time spent in each stage of development varies for each individual depending on factors that determine skill acquisition (e.g., the amount of instruction, the quality of instruction, individual qualities).[6] Parallel to motor development, young children undergo significant biological development across various domains. During the transition from early to middle childhood, children experience steady growth, with an average annual increase in height and body mass. Due to improvement in coordination, fine motor skills (e.g., handling smaller objects, writing, and drawing) are performed with increasing proficiency. Also, neural connections are strengthened, supporting cognitive functions.

Without early experiences, children would be limited in their ability to explore context-specific movement solutions.[7] This limitation can be of danger for the health status of young children since MC has an inverse relationship with developing obesity.[6,8,9] Based on the proficiency barrier introduced by Seefeldt in 1980, not reaching a basic level of fundamental motor skills may restrict children from participating in sport activities, which is considered undesirable. It has been hypothesized that in early childhood (EC) (2–5 years), MC and PA levels display great variability and that during middle childhood (MCD) (6–9 years), this existing relationship is reinforced due to environmental constraints (e.g., parenting style, experiences, opportunities to play, demographics, and social factors) already present at an early age.[10-12] As a result, children with higher levels of MC in childhood have opportunities to participate in a broader and more complex repertoire of physical activities later in life, also leading to a reinforcement of mediating factors (e.g., enjoyment, perceived competence, etc.). In contrast, experiencing lower levels of MC leads to a negative spiral of disengagement in PA and its mediating factors. Studies have shown that these children may be at risk of developing overweight.[11,13]

Although there are historical data regarding the development of health-related fitness variables and PA in EC, trends of MC development within this age group are very limited.[14] However, there seems to be a negative trend over the last five decades regarding group mean levels of MC at an early age.[14,15] It should be noted that this decline in MC differs between the type of fundamental movement skill (FMS) tested.[16] In recent literature, most evidence regarding children's MC in early and middle childhood has been provided by systematic reviews[17-20] or by cross-sectional studies[21-24]. Only a few studies have used a longitudinal design with at least two[25-27] or more[28] follow-up measurements of MC in early childhood. Using longitudinal data is essential for understanding the dynamic and temporal direction of MC development, especially in young children. As indicated, only a few longitudinal studies have been conducted to describe the development of MC in EC and/or the transition to MCD. In a longitudinal study performed by Estevan,[26] more than one hundred young children in the transition of EC/MCD, from 4 to 9 years old, were profiled to detect actual and perceived MC trajectories. Regarding the actual motor competence, object control skills tended to increase over time for boys but decreased over time for girls between 7 and 9 years old. An earlier study with respect to the transition phase of EC/MCD by Bardid and colleagues[29] also showed gender differences in favour of boys regarding object-control skills. Coppens and colleagues[30] reported that MC generally increased over time in children in middle childhood from 6 to 9 years old with individual variations. There was no significant variance between low, average, and highly motor-skill-developed children, and although the gender differences were unclear, in this study, girls made less progress in MC than boys. In contrast with previous studies, Rodrigues[31] tracked MC and physical fitness starting in middle childhood (age six) for four consecutive years. They noticed that not all children improved in MC across childhood years, and some even regressed over time. In the same study conducted by Rodrigues,[31] the object-control skills of girls lagged behind those of boys as they grew older. In general, there seems to be a tendency of increasing MC as children grow older, while girls seem to lag behind in object-control-skill development.

Longitudinal data on MC patterns in children maturing from early to middle childhood are scarce. To our knowledge, individual patterns have only been reported in studies in middle childhood.[30,31] Start (V)aardig (Dutch for 'Skillful Start') was a four-year project containing three subsequent measurements of MC with time intervals of one year each. Taking into account that children's MC can remain stable, increase, or decrease at each of these time intervals, theoretically, 11 different patterns of MC development could occur. Therefore, the objectives of this three-year longitudinal study were to quantify the prevalence of these different patterns of MC development among a sample of school-aged children in transition from early to middle childhood and to identify undesirable patterns. Although MC levels vary in EC, we expected an overall increase in MC since MC development is positively stimulated as a result of appropriate practice, encouragement, feedback, and instruction.[10]

Also, since children generally have positive perceptions of their MC in EC, a window of opportunity is provided for stimulating MC development in the transition from EC to MCD.[32,33] Our hypothesis was that patterns of MC development reflecting an increase between EC and MCD would be the most prevalent. We expected that the prevalence of undesirable patterns would be relatively low. However, for policy makers and sport professionals, it is crucial to find out which part of the study population has an undesirable pattern of MC development.

METHODS

Study sample and data collection

A longitudinal design was used to study 1578 typically developing children (50.2% boys) aged between 4 and 6 years at baseline. The study population included children attending between grades one and two (between 4 and 6 years old) of the Dutch public school system. In total, 36 primary schools participated in the study across three regions of the Netherlands. The participating schools were internship schools of the connected universities representing urban and rural areas of the Netherlands. The population of the schools had a wide range of social economic positions. Written informed consent was given by parents/guardians of all participants (63% consent rate). Exclusion criteria included having less than three valid assessment points, being motor or physically impaired, and not complying with the written informed consent. Prior to the study onset, ethical approval was obtained by the Ethics Committee of the Faculty of Behavioral and Movement Sciences, VU University, Amsterdam, the Netherlands (ref. number VCWE- 2019-139).

The study used a longitudinal prospective cohort design (see Figure 2.1). Data were collected at three subsequent timepoints with a one-year interval between February 2020, timepoint 0 (T0) and May 2022, timepoint 2 (T2). Due to temporary absences (e.g., illness) or permanent origin (e.g., moving to another school), 186 children (11.8%) of the initial study population at T0 dropped out one year later and 261 children (18.8%) dropped out after two years. Demographic information (e.g., child's sex and date of birth) was parent reported via a survey at study enrolment. To study MC patterns, we enrolled all children with three valid measurements of MC (complete MQ data). The present study population consisted of 1128 children (M = 5.35 ± 0.69 years).

Procedures

All participants wore light sport clothing and were barefoot during testing. Trained research assistants assessed the children during the regular physical education lessons. All research assistants participated in a two-hour training session to conduct the measurements according to the standardized testing guidelines.

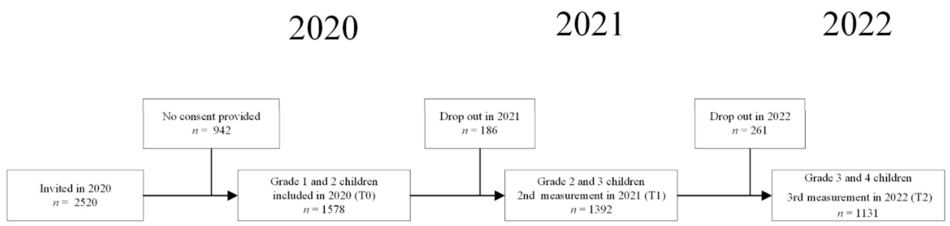

Figure 2.1. Flow diagram of study population.

Measuring motor competence

MC was measured with the Athletic Skills Track (AST), a validated product-orientated assessment tool for primary-school-aged children.[34] The AST-1 was conducted for the youngest children in the age range of 4–6 years; the AST-2 was performed for the age group of 6–9 years old. The tracks included a string of different FMSs (AST-1: n = 5, AST- 2: n = 7) to be completed as quickly as possible. The test–retest reliability of the AST was proven to be high (ICC = 0.881 (95%), CI: 0.780–0.934) for the AST-1 and 0.802 (95% CI: 0.717–0.858) for the AST-2 in a sample of 4–12-year-old Dutch children.[35] The internal consistency of the AST was above the acceptable level of Cronbach's $\alpha > 0.70$ ($\alpha = 0.764$),[35,36] and there was a moderate to high correlation between the time to complete the AST-1 and AST-2 with the age- and sex-related motor quotients of the Körperkoordinations Test für Kinder (AST-1: r = −0.747, p = 0.01 and AST-2: r = −0.646, p = 0.01).[35]

Other measurements

Participants' body height and mass were individually measured to the nearest 0.1 cm using a stadiometer (SECA 217, Hamburg, Germany) and to the closest 0.1 kg using a digital scale (SECA 878dr, Hamburg, Germany) at the start of the test session.

Data analysis

MC was expressed in age- and gender-specific Motor Quotient (MQ) categories. MQ categories were derived from the time to complete the Athletic Skills Track (AST time) using age- and gender-specific norm values described by Hoeboer and colleagues.[34] In brief, an AST-time below the 25th percentile of AST norm values was classified as 'low', an AST time between the 25th and the 75th percentile of the norm values was classified as 'normal', and an AST time above the 75th percentile of the norm values was classified as 'high'. Subsequently, patterns of MC development were defined based on the changes in MQ categories between T0 and T1 and between T1 and T2. Table 2.1 provides an overview of all classifications of motor development. 'Undesirable' patterns were classified based on a combination of the course and the MQ category. In brief, the MQ category may remain stable, continuously change in a certain direction (i.e., increase or decrease), or fluctuate over time.

Table 2.1. Classification of MC patterns

	Pattern	T0	T1	T2
Stable MQ category over time				
a.	**Continuously low ***	**Low**	**Low**	**Low**
b.	Continuously normal	Normal	Normal	Normal
c.	Continuously high	High	High	High
Continuous change of direction in MQ category over time				
d.	**Continuous decrease ***	**High**	**Normal**	**Low**
e.	Continuous increase	Low	Normal	High
Fluctuating direction of change in MQ category over time				
f.	**Decrease before stabilization ***	**Normal**	**Low**	**Low**
	Decrease before stabilization	High	Normal	Normal
g.	**Decrease after increase ***	**Low**	**Normal**	**Low**
	Decrease after increase	Normal	High	Normal
h.	**Decrease after stabilization ***	**Normal**	**Normal**	**Low**
	Decrease after stabilization	High	High	Normal
i.	Increase before stabilization	Low	Normal	Normal
		Normal	High	High
j.	Increase after decrease	Normal	Low	Normal or High
		High	Low or Normal	Normal or High
k.	Increase after stabilization	Low	Low	Normal or High
		Normal	Normal	High

* Patterns classified as undesirable in **bold**.

Classification of undesirable patterns

Obviously, a stable but low MQ category is considered undesirable (pattern a), as is a continuous decrease over time (pattern d). Regarding the fluctuating patterns, we decided to classify some of these to be undesirable based on the assumption that a decrease between T1 and T2 was likely to be a more serious signal of undesirable development than a decrease between T0 and T1. Our motivation underlying this assumption was that a decrease between T0 and T1 could have been affected by the restrictions in response to the COVID-19 pandemic in the Netherlands, whereas a decrease between T1 and T2 could not have been. Additionally, we assumed that a sudden decrease at a slightly older age (i.e., MCD) was a more serious predictor of problems later in life than a decrease at a younger age.[37] Finally, we only considered a decrease to be undesirable when it led the MQ category to drop below the normal value at T2. Therefore, a decrease before or after stabilization (pattern f and h) or after an increase (pattern g) was considered 'undesirable' but only when the MQ categories at all timepoints did not exceed the normal category. Undesirable patterns were based on the prerequisite that every child must possess a basic motor skill level to participate in sports. A decline or failure to reach this level was considered to be undesirable. We will further refer to the selected patterns as 'undesirable' and to the children showing these patterns as 'potential target groups'.

The anthropometric measures of body mass index (BMI) were derived by dividing the children's body mass in kilograms by their height in meters squared. Data analysis was performed with the Statistical Package for the Social Sciences (SPSS version 27.0, 64-bits edition, SPSS Inc., Chicago, IL, USA). Visualizations were obtained with R studio (version 4.2.2, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Baseline characteristics are presented in Table 2.2. In this table, descriptives of the study population (i.e., calendar year, school grade, age, BMI, childhood phase, and sex) are presented for each timepoint (T0, T1, and T2). At baseline, the vast majority (81%) of children were in the EC phase, whereas at T2, almost all the children (97%) reached MCD.

Table 2.2. Time-dependent characteristics of the study population (n = 1131, 50.2% boys) per timepoint (T0–T1–T2).

Characteristics	Timepoint		
	T0	T1	T2
Calendar year	2020	2021	2022
School grade 1*	1 and 2	2 and 3	3 and 4
Age (years)			
Mean (SD)	5.35 (0.69)	6.36 (0.70)	7.26 (0.71)
BMI (kg/m^2)			
Mean (SD)	15.67 (2.22)	15.90 (1.82)	15.79 (1.89)
Childhood phase (%)			
Early childhood	81	33	3
Middle childhood	19	67	97

*1: According to the Dutch school system.

Prevalence of different mc development patterns

Figure 2.2 shows the longitudinal MQ data of the study population. According to Hoeboer and colleagues,[34] MQ scores ≤40 and ≥180 were detected as outliers (n = 3) and therefore removed before analysis. In total, 11 different patterns were predefined.

Of those 11 patterns, the 'continuously normal' pattern was the most prevalent pattern in our study population, followed by all variations of the fluctuating patterns. Both continuously decreasing and increasing patterns were rare.

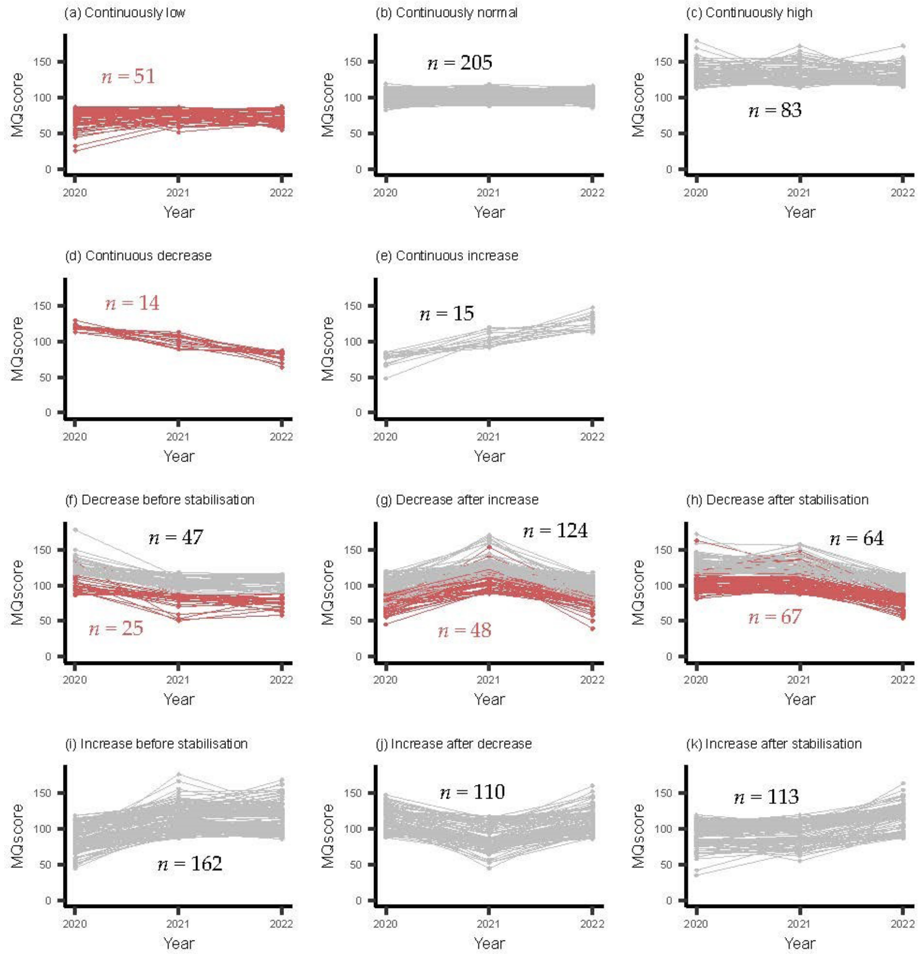

Figure 2.2. Patterns of MC development during early childhood (EC). Red lines indicate undesirable patterns whereas grey lines indicate other patterns.

In total, 18.2% of the children showed an undesirable pattern of MC development from T0 to T2 (patterns: a (4.5%); d (1.2%); f (2.2%); g (4.4%); and h (5.9%)), of which the pattern reflecting a decrease after stabilization (h) was the most prevalent. These undesirable patterns are indicated in Figure 2.2 with the red lines. Post hoc analyses showed that the boy–girl ratio was relatively equally distributed in most of the patterns, although within pattern d (continuous decrease), boys were underrepresented (29% boys) and within pattern k (increase after stabilization), boys were overrepresented (63% boys). An examination of dropouts indicated no notable differences in MQ distribution between those who completed all measurements and those who dropped out at T1 or T2, indicating that the children included in our analysis properly represented the initial study population of 'Start (V)aardig'.

DISCUSSION

The purpose of this longitudinal study was to describe and quantify the prevalence of 11 predefined patterns of MC development from early childhood to middle childhood. Of these 11 patterns, five were classified as 'undesirable'. The majority of the children had a stable 'normal' or increasing 'high' development of MC. However, the undesirable patterns found represented 18.2% of the study population. As stated by Stodden,[11] later revised by Robinson,[13] lower levels of MC at a young age can lead to a negative spiral of disengagement in PA and its mediating factors and increases the risk of developing overweight.

It has been hypothesized that young children have their own calendar regarding MC development.[38] This individuality refers not to the sequence of motor skill learning but more to the rate and extent of motor skill acquisition. Due to environmental constraints (e.g., parenting style, experiences, opportunities to play, demographics, and social factors), great variation in MC in EC is expected.[11,13] This variation in MC was seen in our study with children scoring low, normal, or high at T0. Our study also proved that, as children grow older, MC development varies widely between children. This was in line with a longitudinal study conducted by Coppens[30] who also found variations in MC development of 6–9-year-old children. However, our findings were in contrast with two other studies.[29,39] Bardid[29] followed a Flemish population of 3–8-year-old children, which showed increased proficiency in MC as children grew older. Similar results were found by Reyes[39] with a notable rate of change in MC development from the age of six, in favour of boys performing better than girls. Studies on MC development related to PA and fitness during early childhood[27,40] or during middle childhood[26,41] both emphasized that MC is an important precursor to PA and fitness and is thus important for sport participation as children grow older. It is therefore expected that children would increase in MC during middle childhood. However, our longitudinal study results showed that a considerable percentage of children developed an undesirable pattern of MC, even as they grew older. A possible explanation for this negative course could be an increase in sedentary behaviour due to social media even at a young age. Study results of measurement performed in 2014 showed that children from urban, low-income, and minority communities had almost universal exposure to mobile devices, and most had their own device by age four.[42] Excessive early childhood screen media use is associated with poorer MC, especially among children with long-term exposure.[43] Also, the daily living environment of young children should be considered when explaining negative courses of MC development. A Finnish study revealed that residential density was related to children's MC and their outdoor play behaviour, even during EC.[44]

Undesirable patterns could also be the result of long-term governmental policies regarding physical education (PE) at schools. In the Netherlands, PE lessons (90 min per week) during EC (grade 1 and 2) are mainly given by group teachers, whereas PE during MCD (grade 3 and 4) is given by PE professionals. Some sport clubs offer memberships for 5-year-old children; however, in general, structured training is provided from 6 to 7 years old. Refrainment from PE and sports during the COVID-19 pandemic could have prevented motor development. All participants in the current study experienced a three-month lockdown from 16 March to 11 May 2020, and during January 2021 with restrictions on PA at sport clubs remaining in effect from 16 March to July 2020.[45] Within our results, three patterns (d, f, and j) showed a decrease in MQ scores between T0 and T1 (at the time of lockdown restrictions). To what extent the restrictions had an influence on the children showing this negative course remains unclear. The authors consider it unlikely that the development of children with a 'continuous decrease' (pattern d) were affected by lockdown effects. However, it should be mentioned that the prevalence reported in this study might have slightly overestimated the 'true' prevalence adjusted for potential effects of the lockdown. Results from a Japanese study performed on EC children[46] suggested that the COVID-19 pandemic impeded the development of FMSs, especially those for object-control skills. Studies performed on MCD-aged children showed that the COVID-19 pandemic resulted in decreased motor skills due to children's activities at home, such as increased sleeping habits, increased eating habits, and increased screen time.[47-49] However, a recently published study by den Uil and colleagues[50] showed the COVID- 19 lockdowns in the Netherlands did not negatively affect motor skill development of MCD children. Therefore, more longitudinal research is needed to explore the long-term effects of the COVD-19 pandemic on MC development. The present study is, to our knowledge, one of the few longitudinal studies analysing MC development starting from early childhood on such a large scale. The distribution of the MQ categories measured in our study sample between 2020 and 2022 were representative of the national MC screening in which the same assessment tool was used.[51] Besides the number of participants included, the detailed representation of the different patterns gave a clear insight into MC development during the transition from EC to MCD. Furthermore, the patterns defined in this study were based on a validated categorization of MQ scores by Hoeboer.[34]

Even though this study had certain strengths, it also had limitations. Methodological difficulties occurred when measuring children in the EC phase (e.g., type of assessments used, concentration of children when being tested, etc.) and might have influenced our results. However, well-trained research assistants and a validated assessment tool were valuable in addressing these issues. One of the goals of this study was to present a clear course of MC development during the transition from EC to MCD. As shown in Table 2.2, our study population at T1 was not ideally distributed (33% EC and 67% MCD), so caution is needed in interpreting the results during the transition phase. Despite the dropouts, children who left the study did not differ from the participants included in their MC category. This would suggest that the dropouts did not bias the study results. Although the number of children included in this study was high, after converting the MQ scores into meaningful patterns, the group sizes were not big enough to test for a relationship between sex and EC/MCD phase. Therefore, only the boy/girl ratio was presented. Our assessment tool, the Athletic Skills Track, was a product-orientated assessment tool focused on mastering two of the three FMSs (i.e., locomotor and balance skills). The third FMS (i.e., object-control skills) was not part of the test protocol and was not evaluated.[51] Since locomotor skills normally develop earlier compared with object-control skills,[52] the undesirable patterns found in this study were even more worrying. Individuals during EC without mastering FMSs may require more practice than a child with experience in order to achieve a proficient skill level.[7] In addition, without early, developmentally appropriate experiences, children will be limited in exploring context-specific movement solutions that enhance mobility in more complex movement settings (e.g., you have to be able to run before taking part in soccer, tennis, or basketball). School PE lessons and/or other activities in the domain of sports are needed to improve children's MC and increase PA for optimal health. Identifying undesirable patterns of MC at a young age would enable sport and healthcare professionals to adequately intervene and create prospectives for lifetime sport participation.[53] Since 2010, the number of FMS interventions has been rapidly increasing, indicating the need for stimulating MC development during EC. However, it should be evaluated if youth sports programs afford appropriate interventions to remedy the proficiency barrier for potential target groups or if youth sports programs increase the barrier and contribute to the discontinuation of sport participation in sport and physical activity.[54] A recently conducted systematic review to evaluate the effectiveness of FMS intervention during EC showed that more retention results are needed to evaluate the long-term effect of these interventions.[55]

Besides developing targeted high-quality interventions, more longitudinal studies are needed to determine which modifiable determinants (e.g., BMI, perceived MC, enjoyment, etc.) influence MC development in young children.[10] It is also recommended to consider other contextual factors to better understand and support MC development during the transition from EC to MCD. One such factor is socioeconomic position, which may be positively associated with MC development.[18,25] Finally, longitudinal studies conducted in understudied countries taking into account different environmental and cultural contexts are warranted to gain more insight into global trends of MC development.[10]

CONCLUSIONS

This study proved that MC does not automatically increase as children grow older. The prevalence of 11 predefined developmental MC patterns showed that most of the children displayed a stable 'normal' or fluctuating pattern with 'normal to high' development of MC. However, five undesirable patterns were identified representing almost twenty percent of the participants. Children with an undesirable pattern of MC development could be labelled as potential target groups for motor intervention. The outcome of this study emphasizes the need for early and targeted motor interventions. Also, it is recommended to identify modifiable determinants that are associated with undesirable patterns of MC in order to detect children at risk as early as possible and help them improve their motor skills.

Practical implications

- Physical education (PE) teachers should be aware that motor competence development widely varies during the transition from early to middle childhood.
- More emphasis should be placed on implementing targeted motor interventions focused on potential target groups to avoid the risk of developing an unhealthy, inactive lifestyle.
- Modifiable determinants associated with undesirable patterns of motor competence should be better understood.

2

REFERENCES

1. Clark, J.E., & Metcalfe, J.S. (2002). The mountain of motor development: A metaphor. *Motor Development Research Review, 2*, 183–202.
2. Lorås, H. (2020). The effects of physical education on motor competence in children and adolescents: A systematic review and meta-analysis. *Sports, 8*(6), 88.
3. Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*, 541–551.
4. Haugen, T., & Johansen, B.T. (2018). Difference in physical fitness in children with initially high and low gross motor competence: A ten-year follow-up study. *Human Movement Science, 62*, 143–149.
5. Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise, 15*, 382–391.
6. Payne, V.G., & Isaacs, L.D. (2017). *Human motor development: A lifespan approach*. Routledge.
7. Brian, A., Getchell, N., True, L., De Meester, A., & Stodden, D.F. (2020). Reconceptualizing and operationalizing Seefeldt's proficiency barrier: Applications and future directions. *Sports Medicine, 50*, 1889–1900.
8. Henrique, R.S., Stodden, D.F., Fransen, J., Feitoza, A.H., Ré, A.H., Martins, C.M., & Cattuzzo, M.T. (2020). Is motor competence associated with the risk of central obesity in preschoolers? *American Journal of Human Biology, 32*, e23364.
9. Martins, C., Romo-Perez, V., Webster, E.K., Duncan, M., Lemos, L.F., Staiano, A.E., & Bardid, F. (2023). Motor competence and body mass index in the preschool years: A pooled cross-sectional analysis of 5545 children from eight countries. *Sports Medicine*, 1–12.
10. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., & Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*, 18.
11. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*, 290–306.
12. Altavilla, G., Di Tore, P.A., Raiola, G., & D'Isanto, T. (2017). Physical activity and evolutionary change of motor skills in scholar age. *Acta Kinesiologica, 11*, 7–11.
13. Robinson, L.E., Stodden, D.F., Barnett, L.M., Lopes, V.P., Logan, S.W., Rodrigues, L.P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*, 1273–1284.
14. Roth, K., Ruf, K., Obinger, M., Mauer, S., Ahnert, J., Schneider, W., & Hebestreit, H. (2010). Is there a secular decline in motor skills in preschool children? *Scandinavian Journal of Medicine & Science in Sports, 20*, 670–678.
15. Raczek, J. (2010). Developmental changes of the motor capacity of schoolchildren over three decades (1965–1995). *Sportwissenschaft, 32*, 201–216.
16. Rethorst, S. (2003). Der motorische leistungsstand von 3-bis 7-jährigen–gestern und heute. *Motorik, 26*, 117–126.
17. Barnett, L.M., Webster, E.K., Hulteen, R.M., De Meester, A., Valentini, N.C., Lenoir, M., & Robinson, L.E. (2021). Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Medicine, 52*, 875–920.
18. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Bardid, F. (2020). Global levels of fundamental motor skills in children: A systematic review. *Journal of Sports Sciences, 39*, 717–753.
19. Jones, D., Innerd, A., Giles, E.L., & Azevedo, L.B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of Sport and Health Science, 9*, 542–552.
20. Darrah, J., Senthilsel van, A., & Magill-Evans, J. (2009). Trajectories of serial motor scores of typically developing children: Implications for clinical decision making. *Infant Behavior and Development, 32*, 72–78.
21. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Burns, C. (2018). Age and sex differences in fundamental movement skills among a cohort of Irish school children. *Journal of Motor Learning and Development, 6*, 81–100.
22. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J.D., & Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*, 1609–1618.
23. Navarro-Patón, R., Mecías-Calvo, M., Rodríguez Fernández, J.E., & Arufe-Giráldez, V. (2021). Relative age effect on motor competence in children aged 4–5 years. *Children, 8*, 115.
24. Kokštejn, J., Musálek, M., & Tufano, J.J. (2017). Are sex differences in fundamental motor skills uniform throughout the entire preschool period? *PloS One, 12*, e0176556.
25. Barnett, L.M., Salmon, J., & Hesketh, K.D. (2016). More active pre-school children have better motor competence at school starting age: An observational cohort study. *BMC Public Health, 16*, 1068.
26. Estevan, I., Menescardi, C., García-Massó, X., Barnett, L.M., & Molina-García, J. (2021). Profiling children longitudinally: A three-year follow-up study of perceived and actual motor competence and physical fitness. *Scandinavian Journal of Medicine & Science in Sports, 31*, 35–46.
27. King-Dowling, S., Proudfoot, N.A., Cairney, J., & Timmons, B.W. (2020). Motor competence, physical activity, and fitness across early childhood. *Medicine & Science in Sports & Exercise, 52*, 2342–2348.
28. Henrique, R.S., Bustamante, A.V., Freitas, D.L., Tani, G., Katzmarzyk, P.T., & Maia, J.A. (2018). Tracking of gross motor coordination in Portuguese children. *Journal of Sports Sciences, 36*, 220–228.
29. Bardid, F., Huyben, F., Lenoir, M., Seghers, J., De Martelaer, K., Goodway, J.D., & Deconinck, F.J. (2016). Assessing fundamental motor skills in Belgian children aged 3–8 years highlights differences to US reference sample. *Acta Paediatrica, 105*, e281–e290.
30. Coppens, E., Bardid, F., Deconinck, F.J., Haerens, L., Stodden, D., D'Hondt, E., & Lenoir, M. (2019). Developmental change in motor competence: A latent growth curve analysis. *Frontiers in Physiology, 10*, 1273.
31. Rodrigues, L.P., Stodden, D.F., & Lopes, V.P. (2016). Developmental pathways of change in fitness and motor competence are related to overweight and obesity status at the end of primary school. *Journal of Science and Medicine in Sport, 19*, 87–92.
32. Lopes, V., Barnett, L., & Rodrigues, L. (2016). Is there an association among actual motor competence, perceived motor competence, physical activity, and sedentary behavior in preschool children? *Journal of Motor Learning and Development, 4*, 129–141.
33. LeGear, M., Greyling, L., Sloan, E., Bell, R.I., Williams, B., Naylor, P., & Temple, V.A. (2012). A window of opportunity? Motor skills and perceptions of competence of children in kindergarten. *International Journal of Behavioral Nutrition and Physical Activity, 9*, 29.

34. Hoeboer, J., Krijger-Hombergen, M., Savelsbergh, G., & De Vries, S. (2018). Reliability and concurrent validity of a motor skill competence test among 4-to 12-year old children. *Journal of Sports Sciences, 36*, 1607–1613.
35. Hoeboer, J.J.A.A.M., Ongena, G., Krijger-Hombergen, M., Stolk, E., Savelsbergh, G.J.P., & De Vries, S.I. (2018). The Athletic Skills Track: Age-and gender-related normative values of a motor skills test for 4-to 12-year-old children. *Journal of Science and Medicine in Sport, 21*, 975–979.
36. Brown, H., Hume, C., & ChinAPaw, M. (2009). Validity and reliability of instruments to assess potential mediators of children's physical activity: A systematic review. *Journal of Science and Medicine in Sport, 12*, 539–548.
37. Lloyd, M., Saunders, T.J., Bremer, E., & Tremblay, M.S. (2014). Long-term importance of fundamental motor skills: A 20-year follow-up study. *Adapted Physical Activity Quarterly, 31*, 67–78.
38. Ozmun, J.C., & Gallahue, D.L. (2016). Motor development. In *Adapted Physical Education and Sport* (6th ed., p. 375).
39. Reyes, A.C., Chaves, R., Baxter-Jones, A.D., Vasconcelos, O., Barnett, L.M., Tani, G., & Maia, J. (2019). Modelling the dynamics of children's gross motor coordination. *Journal of Sports Sciences, 37*, 2243–2252.
40. Schmutz, E.A., Leeger-Aschmann, C.S., Kakebeeke, T.H., Zysset, A.E., Messerli-Bürgy, N., Stülb, K., & Puder, J.J. (2020). Motor competence and physical activity in early childhood: Stability and relationship. *Frontiers in Public Health, 8*, 39.
41. Gu, X., Tamplain, P. M., Chen, W., Zhang, T., Keller, M.J., & Wang, J. (2021). A mediation analysis of the association between fundamental motor skills and physical activity during middle childhood. *Children, 8*, 64.
42. Kabali, H.K., Irigoyen, M.M., Nunez-Davis, R., Budacki, J.G., Mohanty, S.H., Leister, K.P., & Bonner, R.L., Jr. (2015). Exposure and use of mobile media devices by young children. *Pediatrics, 136*, 1044–1050.
43. Felix, E., Silva, V., Caetano, M., Ribeiro, M.V., Fidalgo, T.M., Rosa Neto, F., & Caetano, S.C. (2020). Excessive screen media use in preschoolers is associated with poor motor skills. *Cyberpsychology, Behavior, and Social Networking, 23*, 418–425.
44. Niemistö, D., Finni, T., Haapala, E.A., Cantell, M., Korhonen, E., & Sääkslahti, A. (2019). Environmental correlates of motor competence in children—The skilled kids study. *International Journal of Environmental Research and Public Health, 16*, 1989.
45. RIVM. (2023). Tijdlijn van coronamaatregelen. Bilthoven: Rijksinstituut voor Volksgezondheid en Milieu.
46. Abe, T., Kitayuguchi, J., Fukushima, N., Kamada, M., Okada, S., Ueta, K., & Mutoh, Y. (2022). Fundamental movement skills in preschoolers before and during the COVID-19 pandemic in Japan: A serial cross-sectional study. *Environmental Health and Preventive Medicine, 27*, 26.
47. Ayubia, N., & Komaini, A. (2021). The impact of the COVID-19 pandemic on children's motor skills (literature review). *Children, 90*, 5.
48. Carballo-Fazanes, A., Rodrigues, L.P., Silva, R., Lopes, V.P., & Abelairas-Gómez, C. (2022). The developmental trajectory of motor competence of children that lived the COVID-19 confinement period: A four-year follow-up study in Portuguese children. *Journal of Functional Morphology and Kinesiology, 7*, 64.
49. Pombo, A., Luz, C., de Sá, C., Rodrigues, L.P., & Cordovil, R. (2021). Effects of the COVID-19 lockdown on Portuguese children's motor competence. *Children, 8*, 199.
50. den Uil, A.R., van Doorn, H., Schweitzer, M., Janssen, M., Scholte, R.H., & Busch, V. (2023). The effects of the COVID-19 lockdowns on motor skill development of 6-and 7-year old children in the Netherlands: A longitudinal study. *BMC Public Health, 23*, 1–10.
51. De Haagse Hogeschool. (2022) Motoriek Peil. Retrieved from https://www.dehaagsehogeschool.nl/over-de-haagse/nieuws/motoriek-peil-2022-weinig-verschillen-motoriek-kinderen-op-basis-van-sociaal
52. Van Kann, D.H.H., Koolwijk, P., de Kok, T., Vos, S.B., De Vries, S.I., Mombarg, R., & Remmers, T. (2022). Applying an ecosystem approach to explore modifiable factors related to the risk for low motor competence in young children. *Journal of Science and Medicine in Sport, 25*, 890–895.
53. Loprinzi, P.D., Davis, R.E., & Fu, Y. (2015). Early motor skill competence as a mediator of child and adult physical activity. *Preventive Medicine Reports, 2*, 833–838.
54. Malina, R.M. (2014). Top 10 research questions related to growth and maturation of relevance to physical activity, performance, and fitness. *Research Quarterly for Exercise and Sport, 85*, 157–173.
55. Koolwijk, P., Hoeboer, J., Mombarg, R., Savelsbergh, G., & De Vries, S. (2023). Fundamental movement skill interventions in young children: A systematic review. *International Journal of Sport and Exercise Psychology*, 1–23.

Chapter 3

Differences in motor competence, enjoyment and weight status of young children (4-6 years)

Pim, P. Koolwijk, Annemarie, A.M.H de Witte, Remo, R.M. Mombarg, Teun, T. Remmers, Dave, D.H.H. Van Kann, Ingrid, I. van Aart, Geert, G.J.P. Savelsbergh, Sanne, S.I. de Vries (2022).

Journal of Physical Education and Sport, 22(6), 1471-1479.

ABSTRACT

Background
Although research on children's motor competence is a growing field of interest, especially among young children (4-6 years), several questions remain to be answered. Differences in children's motor competence and their determinants must be made transparent since early childhood is a critical period for the development of fundamental movement skills, and thereby a lifelong active lifestyle and health.

Objective
The purpose of this cross-sectional study was to determine differences in actual motor competence (AMC), perceived motor competence (PMC) and enjoyment of physical activity among young children with different weight status.

Methods
AMC, PMC and enjoyment were measured among 1708 children (50.4% male, mean age: 5.34 ± 0.73 years) from 36 primary schools in the Netherlands. AMC was measured by using the Athletic Skills Track (AST-1). The Pictorial Scale of Perceived Movement Skill Competence for Young Children was used for determining PMC and enjoyment of physical activity was measured using a Visual Analogue Scale. The data was analysed using a three-way ANOVA to examine the differences between AMC, PMC and enjoyment by sex (boys/girls), age (4, 5, 6 years) and weight status (normal, overweight, obesity).

Results
Overall, AMC was ranked as 'average motor gifted'. Average PMC and enjoyment scores were 3.31 (SE 0.01) (1-4 scale) and 4.41 (SE 0.02) (1-5 scale) respectively. No interaction effects were found between sex, age and weight status on AMC or PMC. However, there was a statistically significant two-way interaction effect for enjoyment between age and weight status ($F(4,1454) = 2.464$, $p = .043$). Relative enjoyment scores for normal weight and overweight groups between high and low enjoyment were distributed 99% to 1%. However, in the obese group there was a distribution of 92% to 8% between high and low enjoyment.

Conclusions
The results of this study suggest that there are no significant differences in AMC and PMC between children of different sex, ages (4, 5 and 6 years), and weight status in this age group. However, children with obesity more often experience less enjoyment during physical activity than children with another weight status. Targeted intervention for increasing enjoyment during physical activity in combination with reducing obesity seems advisable even at young age.

INTRODUCTION

Early childhood is a period of rapid growth and therefore important for the development of different competences, such as motor competence (MC). MC is a global term used to reflect various other terminologies that have been applied previously (i.e., motor proficiency, motor performance, fundamental movement/motor skills, motor ability and motor coordination) to describe goal-orientated human movement.[1,2] MC can be defined as a person's ability to execute different motor acts, including coordination of fine and gross motor skills that are necessary to manage everyday tasks.[3-6] MC enables children and adolescents to successfully participate in various types of physical activity (PA).[7-10] Stodden et al. (2008)[11] suggested in their developmental model that developing MC is foundational for engagement in PA. A few years later Robinson et al. (2015)[2], in a revision of the model of Stodden et al. (2008)[11], hypothesized that lacking MC leads to a negative spiral of withdrawal in PA as children lack the competence and confidence to move and will not enjoy participation in activities which they believe they will not be successful. There is evidence that MC is related to several underlying mechanisms as perceived motor competence (PMC),[12] weight status,[2] and enjoyment.[13,14] PMC is an important factor that mediates the role between actual motor competence (AMC) and PA.[2,15-17] PMC refers to an individual's perception of their actual movement capabilities and can be described as the belief in one's own ability to effectively use and apply a variety of general, refined, and specific movement patterns.[2,18] Without being specified by numbers, an optimal level of PMC in combination with AMC seem to be important for engaging children and adolescents in physical activity and sports.[5,19,20] Various studies have shown that besides PMC, enjoyment is also positively related to PA in children and youth.[21-25] Enjoyment is defined as a "positive affective response to the sport experience that reflects generalized feelings such as pleasure, liking, and fun".[26-28] Loprinzi and colleagues (2015)[14] proposed a conceptual model in which enjoyment of PA is a potentially indirect pathway to mediate the relationship between AMC and PA at early childhood. Enjoyment is often discussed regarding intrinsic motivation but generally, enjoyment is a broader and more inclusive construct derived from internal and external origins.

Young children, 4- to 6- years, are in a crucial phase of developing AMC levels since many of the fundamental motor skills (FMS) such as running, jumping, throwing and catching are developed during this phase of life.[29] Although research on AMC, PMC and enjoyment in young children is a growing field of interest, several questions remain to be answered. For example, clarification is needed on the development of AMC, PMC and enjoyment during early childhood and how they are related to each other. Also, potential confounding variables (e.g., socio-economic background, race- and cultural differences) as well as methodological difficulties when measuring young children (e.g., type of assessments used, concentration of children when being tested) might be of influence on the findings and need to be explored.

As mentioned, proficiency in FMS is a prerequisite for engagement in PA which is partly influenced by underlying determinants, including PMC[15] and enjoyment.[22] However, the status of AMC, PMC and enjoyment, specifically at 4, 5 and 6 years old, is understudied and information on the differences in these outcome measures between boys and girls and children with different weight status is inconclusive.[29-31]

With respect to sex, a tendency is found with boys demonstrating more proficient object control skills (as part of motor competence)[13,32] and girls demonstrating better locomotor skills at young age (3-8 years old).[29,33-35] It has been suggested that object control skills relate most strongly to boys' habitual PA since boys participate in popular activities at primary school age such as soccer, Australian football, and basketball.[36] However, sex differences could also be attributed to environmental, contextual and socio-cultural factors.[37,38] In a study conducted among Belgian and US children (4-5 years old), Belgian children performed significantly higher on MC compared to US peers.[39] With respect to PMC, higher PMC levels were found in boys compared to girls.[15,38] These findings are in contrast with a review done by De Meester et al. (2020)[30] which showed no sex differences for AMC and PMC.

The sequence of MC development and skill acquisition during early childhood is rather stable, from rudimentary movement patterns (i.e., reaching and grasping) to FMS development.[40] However, the rate and extent of development are largely individually determined since a mature form of MC is likely to be achieved with appropriate practice, encouragement, feedback and instruction. Regarding MC development, differences are noticed. A large cross-sectional study conducted among 3–6-year-old US children showed that approximately 77% of the measured children were at risk for developmental delay in MC.[41] However, a longitudinal study by Schmutz and colleagues (2020)[42] showed highly stable MC levels throughout early childhood (2-6 years old).

Furthermore, in the last decade there has been an increasing interest in the relationship between AMC, PMC and enjoyment with weight status at (early) childhood.[43] Multiple cross-sectional studies showed an inverse relationship between AMC and Body Mass Index (BMI) indicating that lower AMC is accompanied with overweight and obesity.[44-47] In their review Trecroci and colleagues[48] also showed a negative relationship between AMC with weight status among children from 6-10 years old. These effects are especially visible when a task requires manipulation of total body mass.[4] Without adequate motor skill improvements, BMI related differences in AMC become more pronounced as children grow older.[4]

In summary, previous studies have shown insight into the underlying determinants of developing MC. However, most research has been conducted among older children, starting at middle childhood age (from 6 years). The differences in AMC, PMC and enjoyment between children of different age, sex and weight status are not yet unequivocal in the literature due to confounding factors and methodological issues. This study includes a large sample size of young children in which different determinants of MC development have been measured at the same time. Therefore, the purpose of this study is to examine the differences in AMC, PMC and enjoyment for boys and girls aged 4, 5 and 6 years with different weight status. Insight into these differences is crucial and can help develop effective practices and policies on FMS promotion, essential for a lifelong PA.

MATERIAL AND METHODS

Participants

This cross-sectional study collected data from 1708 young children (860 boys; 50.4%) with a mean age of 5.34 years (SD ± 0.73) old from 36 primary schools in southern, western and northern urban and suburban parts of the Netherlands. The directors of the schools were informed about the nature, aims and procedures of the study. Before assessment, written informed consent was obtained from the parents or guardians of the children. The study was approved by the Ethics Committee of the Faculty of Behavioural and Movement Sciences, VU Universiteit Amsterdam, the Netherlands (ref. number VCWE-2019-139). All measurements took place between February and September 2020. To be included in the analyses, a child had to complete all measurements. Table 3.1 shows an overview of the background characteristics and test results of the children included.

Procedure

Trained research assistants assessed AMC, PMC and enjoyment in physical activity of the children during a regular 50-minute physical education (PE) lesson at school. All research assistants participated in a two-hour training session to conduct the tests according to the protocol. Body height and weight of the children were measured individually to the nearest 0.1 cm using a stadiometer (SECA 217, Hamburg, Germany) and to the closest 0.1 kg using a digital scale (SECA 878dr, Hamburg, Germany) at the start of the PE lesson. At the time of testing the children wore regular sportswear without socks and shoes. The age of the children was determined at the day of data collection by subtracting the date of measurement from the date of birth.

Actual motor competence

AMC was measured with the Athletic Skills Track (AST). The AST is an age specific track that consists of a series of 5–7 detached activities based on coordinative abilities (i.e., coupling, spatial orientation, and balance ability).[49] In this study, AST-1 (age group 4, 5 and 6 years old) was used consisting of the following five activities: (1) Walking, (2) Traveling jumps, (3) Alligator crawl, (4) Slaloming, and (5) Clambering. Prior to the measurement, the research assistant demonstrated the participating children how to complete the track.

Each child performed, on bare feet, three practice trials and one test trial. During the practice trials feedback was given when necessary. The time to complete the track was registered to the nearest 0.1 second by the research assistant using a stopwatch. The test-retest reliability of the AST-1 was high (ICC = 0.881 (95%), CI: 0.780– 0.934) in a study among 4–12-year-old children.[49] The internal consistency of the AST-1 was above the acceptable level of Cronbach's α > 0.70 (α = 0.764) and the validity of the AST-1 was high when compared to the Körperkoordinations Test für Kinder (KTK) (r = −0.747, P = 0.01).[50]

Perceived motor competence

To measure PMC, the 12-indicator Pictorial Scale of Perceived Movement Skill Competence for Young Children (PMSC) was used.[51] The children were individually assessed on six locomotor (LOC) skills (i.e., running, galloping, hopping, leaping, horizontal jumps, and height jumps) and six object control (OC) skills (i.e., striking a stationary ball, stationary dribbling, kicking, catching, overhand throw, and underhand roll) using a pictorial instrument.[51-53] Children were required to choose which picture was most like them (i.e., "this child is pretty good at throwing, this child is not that good at throwing, which child is most like you?") and within the chosen picture were asked to further indicate their perceived competence on a scale from 1 till 4. Options for the 'good performance' picture included: 'really good at ...' (rated as four points) or 'pretty good at ...' (three points); and for the 'poor performance' picture: 'sort of good at ...' (two points) or 'not that good at ...' (one point). Test-retest reliability scores of the PMSC for 4- to 7-year-old children were excellent (ICCs for all 12 skills: 0.83, the six LOC-items: 0.82 and the six OC-items: 0.78). The internal consistency of the PMSC was above the acceptable level of Cronbach's α > 0.60 for LOC as well as OC skills and high correlation coefficients were reported between the pictorial scores and the Test of Gross Motor Development-2 (TGMD-2) (r = 0.82-0.90).[51,53]

Enjoyment

All children completed a six-item 'smileyometer' individually to assess the enjoyment of being physically active on a 5-point Likert Scale from one 'not nice at all' to five 'very nice'. Children were asked to point out one smiley which matched best to the specific question (i.e., "what do you think of the PE class at school?"). The questions, accompanied by corresponding images, were based on five 'active' constructs (i.e., participating during the PE lessons, swimming, playing outdoors at the school yard, playing outdoor elsewhere, and participating in sports at the sports club) and one sedentary or 'passive' construct (i.e., conducting a sedentary activity such as watching television/tablet). The smileyometer has been widely adopted and applied in research studies with children.[54-56] It is easy to complete and requires no writing for young children. The reliability and age effect of the smileyometer have been positively evaluated in young children.[57]

Data analysis

Based on the time to complete the AST, motor quotient (MQ) scores were generated with the formula; MQ = (50th percentile AST-1/time AST-1) × 100. For PMC, the average score of the 12 PMSC-items was calculated and taken as outcome measure. A higher score reflects higher PMC (range 1 – 4).[51] Enjoyment outcomes were determined by calculating the average scores of the five 'active' items and one 'sedentary' score (scale 1-5). In addition, the enjoyment data was dichotomized into two categories (low enjoyment ≤ 3 and high enjoyment > 3). From the anthropometric measures (body mass and body height) body mass index (BMI) was derived by dividing the child's weight in kilograms by their height in meters squared. Next, BMI was labelled in three meaningful categories, i.e., normal weight, overweight and obesity based on age- and sex-related cut offs.[58]

After removing outliers (> three standard deviations below or above the mean) descriptive statistics (means and standard errors) were generated to characterize AMC, PMC and enjoyment by sex, age and weight status. The data was analysed using a three-way ANOVA (2 × 3 × 3) (Sex [boys, girls] × Age [4 years, 5 years, 6 years] × weight status [normal weight, overweight and obesity])) to compare mean group differences. Results with p-values <0.05 were considered statistically significant. A Shapiro-Wilks test was used to check on normality of distributions before analysis. The assumption of normality was violated for some groups in the PMC and enjoyment analysis. When the assumption of normality was violated, no further statistical analyses were performed. Homogeneity of variance was checked using Levene's test. When the assumption of homogeneity of variances was violated, the significance threshold was set to p<0.01.[59] Significant multivariate main and interaction effects were analysed by means of univariate F-tests and estimation of means and standard errors of the outcome variable by levels of the interacting variables. Bonferroni correction was applied to multivariate tests. In addition, the relative distributions within the categorized enjoyment data for the different weight statuses were examined. Data analysis was performed with the Statistical Package for the Social Sciences (SPSS version 27.0, 64-bits edition, SPSS Inc, Chicago, Illinois).

RESULTS

Table 3.1 shows an overview of the Actual Motor Competence (AMC), Perceived Motor Competence (PMC) and Enjoyment scores (ENJ) for groups of children with different sex, age and weight status.

Table 3.1. Actual Motor Competence (AMC), Perceived Motor Competence (PMC) and Enjoyment (ENJ) by sex, age and weight status.

	Age (in years)	Weight status	AMC	SE	n	PMC	SE	n	ENJ	SE	n
Boys	4 years old	*normal weight*	102	1.37	237	3.25	0.03	226	4.36	0.04	215
		overweight	90	5.64	14	3.19	0.14	13	4.39	0.16	14
		obesity	103	12.19	3	3.31	0.29	3	4.58	0.34	3
	5 years old	*normal weight*	102	1.16	333	3.36	0.03	324	4.39	0.03	307
		overweight	106	4.85	19	3.42	0.12	18	4.46	0.14	17
		obesity	100	7.04	9	3.29	0.18	8	3.66	0.21	8
	6 years old	*normal weight*	102	1.79	140	3.38	0.04	135	4.40	0.05	137
		overweight	101	4.85	19	3.34	0.12	18	4.46	0.14	18
		obesity	98	8.62	6	3.15	0.22	5	4.53	0.24	6
	total	*normal weight*	102	21.23	710	3.33	0.49	685	4.38	0.61	659
		overweight	100	19.29	52	3.33	0.61	49	4.44	0.51	49
		obesity	100	13.67	18	3.25	0.48	16	4.13	0.86	17
Girls	4 years old	*normal weight*	101	1.42	222	3.28	0.03	233	4.39	0.04	220
		overweight	104	4.50	22	3.31	0.11	21	4.62	0.13	20
		obesity	105	7.04	9	3.11	0.17	9	4.48	0.20	9
	5 years old	*normal weight*	102	1.15	335	3.30	0.03	318	4.45	0.03	320
		overweight	98	3.99	28	3.20	0.10	27	4.43	0.11	28
		obesity	99	4.85	19	3.30	0.12	17	4.33	0.14	18
	6 years old	*normal weight*	101	2.00	112	3.28	0.05	113	4.52	0.06	109
		overweight	102	4.72	20	3.61	0.12	18	4.59	0.14	17
		obesity	90	7.98	7	3.37	0.19	7	4.63	0.24	6
	total	*normal weight*	101	20.93	669	3.29	0.49	664	4.44	0.57	649
		overweight	101	22.47	70	3.34	0.56	66	4.53	0.57	65
		obesity	99	24.04	35	3.26	0.52	33	4.42	0.75	33
	Overall	*normal weight*	102	21.08	1379	3.31	0.49	1349	4.41	0.59	1308
		overweight	101	21.10	122	3.34	0.58	115	4.49	0.55	114
		obesity	99	20.96	53	3.26	0.50	49	4.32	0.80	50

Regarding AMC, no significant interaction effects were found between sex, age and weight status. Likewise, no interaction effects were found between sex, age and weight status on PMC. However, there was a statistically significant two-way interaction effect between age and weight status for enjoyment (F (4, 1454) = 2,464, p = .043). While post-hoc analyses were not performed because the assumptions for normality were violated for some groups of sex and weight status, the dichotomized enjoyment data was further explored. The absolute and relative distributions of the dichotomized enjoyment data were examined for the normal weight, overweight and obese weight group (Table 3.2).

Table 3.2. Absolute (n) and relative (%) values for the categorized enjoyment data (low enjoyment ≤ 3 and high enjoyment > 3) divided over the weight groups normal weight, overweight and obese for children between 4 and 6 years old.

Enjoyment category	Weight status		
	Normal weight n (%)	Overweight n (%)	Obese n (%)
Low enjoyment ≤3	19 (1.45%)	1 (0.9%)	4 (8.0%)
High enjoyment >3	1289 (98.55%)	113 (99.1%)	46 (92%)
Total	1308	114	50

For the normal weight and overweight groups, the distribution between high and low enjoyment scores is 99% to 1%. However, in the obese group there is a notable difference distribution of 92% to 8%. However, it should be noted that the absolute numbers in the low enjoyment group are low.

DISCUSSION

In this study, we examined differences in AMC, PMC and enjoyment between boys and girls aged 4, 5 or 6 years old with different weight status. For AMC and PMC, no significant differences were found between children of different age, sex and weight. However, an interaction effect of weight status was found for enjoyment. When looking at the relative distribution between high and low enjoyment categories, this distribution is different for the obese children (92% versus 8%) compared to the children with normal weight or overweight (99% versus 1%). This means, relatively more 4-, 5- and 6-year-old children with obesity experience less enjoyment during physical activity than children with other weight status.

Actual motor competence

In this study sex, age and weight status did not have a significant effect on AMC. This is not in line with the study of Navarro et al. (2021)[60] which found that 5-years-old girls score significantly better than boys on several items of the Movement Assessment Battery for Children-2 (MABC-2). Kokštejn[61] showed similar results: 3- and 4-year-old girls had higher total-, fine motor skill, and balance scores compared to boys. However, there were no sex differences for total test or balance scores in 5- and 6-year-olds, while 6-year-old boys outperformed girls in aiming and catching. With respect to weight status, Laukkanen and colleagues (2017)[62] did not find a significant association between BMI at early childhood and AMC at middle childhood although a trend was noticed in girls from the age of 4 onwards. An explanation for the different study results is that there is a wide range of individual differences in the development of motor competence between different ages and sex,[63] and that these differences do not remain stable throughout the preschool period.[61] The chosen assessment tool might play an important role in determining the differences. In the present study AMC is assessed with the Athletic Skills Track.

This track measured how fast children can perform a diverse range of locomotor movements but does not distinguish separate motor skills such as balance or catching. There are many assessment tools to evaluate MC in children and adolescents. The use of several MC assessment tools by different studies and countries precludes direct comparisons across the globe. Indeed, there is no universal agreement about what might constitute a "gold standard" assessment of MC. Alternatively, the construction of an international standardized field-based assessments of MC would ensure comparability between populations and over time.[31]

Perceived motor competence

No significant distinction was found in perceived motor competence for children of different sex, age and weight. A study done by Spessato et al. (2013)[64] among 4–7-year-old children found that obese children experience less perceived motor competence compared with normal weight children. Noordstar et al. (2016)[65] stated that PMC is diminishing as children grow older with boys generally representing higher PMC scores compared with girls. As children's cognitive capacities continue to develop over time (6-8 years) they become more accurate in assessing their own motor competence via comparison against peers and their level of success.[43,66,67] This results in a stronger correlation between actual- and perceived MC. Similar findings were reported by Liong[68] stating that less accurate perceptions of their own skills lead to an overestimation of their abilities at young age (age 5-8 years). A clarification for the discrepancy between actual- and perceived MC scores at young age can be found that young children tend to confuse the wish to be competent with the reality, resulting in high scores due to misunderstanding the content.[5] According to Stodden et al. (2008)[11] the relationship between AMC and PMC will just emerge in young children.

Enjoyment

The experience of enjoyment during physical activity seems a critical factor for children's motivation to participate in exercise settings.[14,21,22,69-72] Since enjoyment is increased by success experience in being able to demonstrate motor competence, being overweight can have a negative influence because it prevents physical activity, resulting in lack of success.[46] The relationship between enjoyment and BMI, however, is rarely being studied in young children. Although in our study a statistically significant difference was not found, the results did show a relative discrepancy between enjoyment and weight status. Similar research conducted among older children led to divergent results. A longitudinal study done by Prochaska and colleagues (2003)[73] with an average study population of 9.5 years, did not find differences between PE enjoyment and weight status. However, Barr-Anderson et al. (2008)[74] did find a relationship among 12-year-old children with higher BMI levels associated with lower levels of PE class enjoyment. Worth mentioning is that in this study overweight girls expressed the lowest enjoyment levels.

Practical implications

Based on the present study, for AMC development, sex, age and weight status do not have to be taken into account at a young age. Also, the fact that no significant differences were found in PMC for the children participating in this study ensures the sport professional to implement a wide range of activities to stimulate PA. However, it is plausible that there is a difference in enjoyment among children who are obese. Although it is not the case for all children with obesity, an important signal is being sent. Moving a heavier body mass against gravity during physical activity may decrease the motivation of obese children to be involved in physical activity programs, which in turn negatively affects their motor competence. And this negative spiral at young age will likely affect sport participation later in life. So, PE teachers at primary schools and other professionals involved in sports should be aware of this and therefore it's important to promote motor competence and physical activity programs for young children. Within these programs, especially children who are obese should be stimulated to choose physical activities that they like to do in a safe pedagogical climate.

Limitations and further research

As earlier mentioned, younger children have a less accurate perception of their actual skills, tending to overestimate their ability.[44,67,68,75] In our study this has led to an unequal distribution of the PMC scores with children scoring maximum scores. Similar skewed distributions were also found for enjoyment scores. Both assessment tools measuring PMC and enjoyment work with item scales in which the children had to make their own choices, so perception is necessary. A complicated factor is that within the literature the construct of enjoyment during physical activity is being described and interpreted subjectively.[76] This limits understanding of the construct and makes it hard to measure it in a valid manner. In addition, the different assessment methods measured different aspects of motor competence and physical activity. Therefore, the results obtained by assessment tools, which all have been validated for the target population,[49,51,57] should be interpreted with caution. Many age x weight groups were not normally distributed, making further statistical analysis impossible. Also, since the number of subjects in the obesity group is small, finding specific results is limited. Further research should focus more on children with overweight / obesity to gain better insight in the results found.

As cognitive capacities continue to develop over time it is interesting to find out what the outcomes of a longitudinal study design will be. Longitudinal data can provide a more accurate insight if, and when, differences in AMC, PMC and enjoyment for boys and girls with different weight status will emerge during primary school, and consequently, when specific interventions targeting motor competence can best be applied.

Although the results found in this study were not statistically significant, the data provided in this large-scale population with more than 1700 children involved, did contribute to get a better insight in the sociodemographic and biological determinants of young children's MC.

CONCLUSIONS

The results of this study suggest that there are no significant differences in actual and perceived motor competence between boys and girls within the age group 4-to-6-years old and with different weight status. For enjoyment there is a difference for children who experience a lot of enjoyment and less enjoyment. Relatively more 4-, 5- and 6-year-old children with obesity experience less enjoyment during physical activity than children with another weight status. The findings provide important information to professionals when developing effective practices and policies on FMS promotion.

REFERENCES

1. Lorås, H. (2020). The effects of physical education on motor competence in children and adolescents: A systematic review and meta-analysis. *Sports, 8*(6), 88.
2. Robinson, L.E., Stodden, D.F., Barnett, L.M., Lopes, V.P., Logan, S.W., Rodrigues, L.P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273-1284.
3. Barnett, L.M., Lai, S.K., Veldman, S. L., Hardy, L.L., Cliff, D.P., Morgan, P.J., ... Ridgers, N.D. (2016). Correlates of gross motor competence in children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 46*(11), 1663-1688.
4. D'Hondt, E., Deforche, B., De Bourdeaudhuij, I., & Lenoir, M. (2009). Relationship between motor skill and body mass index in 5-to 10-year-old children. *Adapted Physical Activity Quarterly, 26*(1), 21-37.
5. Estevan, I., & Barnett, L.M. (2018). Considerations related to the definition, measurement and analysis of perceived motor competence. *Sports Medicine, 48*(12), 2685-2694.
6. Henderson, S.E. (1992). *Movement assessment battery for children*. The Psychological Corporation.
7. Barnett, L.M., Morgan, P.J., van Beurden, E., & Beard, J.R. (2008). Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: A longitudinal assessment. *International Journal of Behavioral Nutrition and Physical Activity, 5*(1), 1-12.
8. Clark, J.E., & Metcalfe, J.S. (2002). The mountain of motor development: A metaphor. *Motor Development: Research and Reviews, 2*(163-190), 183-202.
9. Hesketh, K.R., O'Malley, C., Paes, V.M., Moore, H., Summerbell, C., Ong, K.K., ... Van Sluijs, E.M. (2017). Determinants of change in physical activity in children 0–6 years of age: A systematic review of quantitative literature. *Sports Medicine, 47*(7), 1349-1374.
10. Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise, 15*(4), 382-391.
11. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306.
12. Khodaverdi, Z., Bahram, A., Stodden, D., & Kazemnejad, A. (2016). The relationship between actual motor competence and physical activity in children: Mediating roles of perceived motor competence and health-related physical fitness. *Journal of Sports Sciences, 34*(16), 1523-1529.
13. Bardid, F., Lenoir, M., Huyben, F., De Martelaer, K., Seghers, J., Goodway, J.D., & Deconinck, F.J. (2017). The effectiveness of a community-based fundamental motor skill intervention in children aged 3–8 years: Results of the "Multimove for kids" project. *Journal of Science and Medicine in Sport, 20*(2), 184-189.
14. Loprinzi, P.D., Davis, R.E., & Fu, Y. (2015). Early motor skill competence as a mediator of child and adult physical activity. *Preventive Medicine Reports, 2*, 833-838.
15. Babic, M.J., Morgan, P.J., Plotnikoff, R.C., Lonsdale, C., White, R.L., & Lubans, D.R. (2014). Physical activity and physical self-concept in youth: Systematic review and meta-analysis. *Sports Medicine, 44*(11), 1589-1601.
16. Barnett, L.M., Morgan, P.J., Van Beurden, E., Ball, K., & Lubans, D.R. (2011). A reverse pathway? Actual and perceived skill proficiency and physical activity. *Medicine & Science in Sports & Exercise, 43*(5), 898-904.

17. Hulteen, R.M., True, L., & Pfeiffer, K.A. (2020). Differences in associations of product-and process-oriented motor competence assessments with physical activity in children. *Journal of Sports Sciences, 38*(4), 375-382.
18. Robinson, L.E., Veldman, S.L., Palmer, K.K., & Okely, A.D. (2017). A ball skills intervention in preschoolers: The CHAMP randomized controlled trial. *Medicine and Science in Sports and Exercise, 49*(11), 2234-2239.
19. Clark, C.C., Moran, J., Drury, B., Venetsanou, F., & Fernandes, J.F. (2018). Actual vs. perceived motor competence in children (8–10 years): An issue of non-veridicality. *Journal of Functional Morphology and Kinesiology, 3*(2), 20.
20. He, Q., Ng, J.Y., Cairney, J., Bedard, C., & Ha, A.S. (2021). Association between physical activity and fundamental movement skills in preschool-aged children: Does perceived movement skill competence mediate this relationship? *International Journal of Environmental Research and Public Health, 18*(3), 1289.
21. Cairney, J., Kwan, M.Y., Velduizen, S., Hay, J., Bray, S.R., & Faught, B.E. (2012). Gender, perceived competence and the enjoyment of physical education in children: A longitudinal examination. *International Journal of Behavioral Nutrition and Physical Activity, 9*(1), 1-8.
22. Carroll, B., & Loumidis, J. (2001). Children's perceived competence and enjoyment in physical education and physical activity outside school. *European Physical Education Review, 7*(1), 24-43.
23. Moore, J.B., Yin, Z., Hanes, J., Duda, J., Gutin, B., & Barbeau, P. (2009). Measuring enjoyment of physical activity in children: Validation of the physical activity enjoyment scale. *Journal of Applied Sport Psychology, 21*(S1), S116-S129.
24. Owen, M., Kerner, C., Newson, L., Noonan, R., Curry, W., Kosteli, M., & Fairclough, S. (2019). Investigating adolescent girls' perceptions and experiences of school-based physical activity to inform the girls' peer activity intervention study. *Journal of School Health, 89*(9), 730-738.
25. Tremblay, M.S., Kho, M.E., Tricco, A.C., & Duggan, M. (2010). Process description and evaluation of Canadian physical activity guidelines development. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 1-16.
26. Boyd, M.P., & Yin, Z. (1996). Cognitive-affective sources of sport enjoyment in adolescent sport participants. *Adolescence, 31*(122), 383.
27. McCarthy, P.J., Jones, M.V., & Clark-Carter, D. (2008). Understanding enjoyment in youth sport: A developmental perspective. *Psychology of Sport and Exercise, 9*(2), 142-156.
28. Scanlan, T.K., Carpenter, P.J., Lobel, M., & Simons, J.P. (1993). Sources of enjoyment for youth sport athletes. *Pediatric Exercise Science, 5*(3), 275-285.
29. Figueroa, R., & An, R. (2017). Motor skill competence and physical activity in preschoolers: A review. *Maternal and Child Health Journal, 21*(1), 136-146.
30. De Meester, A., Barnett, L.M., Brian, A., Bowe, S.J., Jimenez-Diaz, J., Van Duyse, F., ... Lenoir, M. (2020). The relationship between actual and perceived motor competence in children, adolescents and young adults: A systematic review and meta-analysis. *Sports Medicine, 50*(11), 1-49.
31. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., ... Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*(1), 18.
32. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., ... Bardid, F. (2021). Global levels of fundamental motor skills in children: A systematic review. *Journal of Sports Sciences, 39*(7), 717-753.
33. Cliff, D.P., Okely, A.D., Smith, L.M., & McKeen, K. (2009). Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science, 21*(4), 436-449.
34. Iivonen, S., & Sääkslahti, A.K. (2014). Preschool children's fundamental motor skills: A review of significant determinants. *Early Child Development and Care, 184*(7), 1107-1126.
35. Junaid, K. A., & Fellowes, S. (2006). Gender differences in the attainment of motor skills on the movement assessment battery for children. *Physical & Occupational Therapy in Pediatrics, 26*(1-2), 5-11.
36. Okely, A.D., & Wright, J. (1997). The gender bias in fundamental motor skills tests—A new agenda needed!
37. Malina, R.M., Cumming, S.P., & Silva, M.J.C. (2016). Physical activity and movement proficiency: The need for a biocultural approach. *Pediatric Exercise Science, 28*(2), 233-239.
38. Robinson, L.E. (2011). The relationship between perceived physical competence and fundamental motor skills in preschool children. *Child: Care, Health and Development, 37*(4), 589-596.
39. Brian, A., Bardid, F., Barnett, L.M., Deconinck, F.J., Lenoir, M., & Goodway, J.D. (2018). Actual and perceived motor competence levels of Belgian and United States preschool children. *Journal of Motor Learning and Development, 6*(s2), S320-S336.
40. Ozmun, J.C., & Gallahue, D.L. (2016). Motor development. In *Adapted Physical Education and Sport* (6th ed., p. 375).
41. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J.D., ... Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*(10), 1609-1618.
42. Schmutz, E.A., Leeger-Aschmann, C.S., Kakebeeke, T.H., Zysset, A.E., Messerli-Bürgy, N., Stülb, K., ... Puder, J.J. (2020). Motor competence and physical activity in early childhood: Stability and relationship. *Frontiers in Public Health, 8*, 39.
43. D'Hondt, E., Deforche, B., Vaeyens, R., Vandorpe, B., Vandendriessche, J., Pion, J., ... Lenoir, M. (2011). Gross motor coordination in relation to weight status and age in 5-to 12-year-old boys and girls: A cross-sectional study. *International Journal of Pediatric Obesity, 6*(sup3), 556.
44. De Meester, A., Maes, J., Stodden, D., Cardon, G., Goodway, J., Lenoir, M., & Haerens, L. (2016). Identifying profiles of actual and perceived motor competence among adolescents: Associations with motivation, physical activity, and sports participation. *Journal of Sports Sciences, 34*(21), 2027-2037.
45. Lubans, D.R., Morgan, P.J., Cliff, D.P., Barnett, L.M., & Okely, A.D. (2010). Fundamental movement skills in children and adolescents. *Sports Medicine, 40*(12), 1019-1035.
46. Morano, M., Colella, D., & Caroli, M. (2011). Gross motor skill performance in a sample of overweight and non-overweight preschool children. *International Journal of Pediatric Obesity, 6*(sup2), 42-46.
47. Nervik, D., Martin, K., Rundquist, P., & Cleland, J. (2011). The relationship between body mass index and gross motor development in children aged 3 to 5 years. *Pediatric Physical Therapy, 23*(2), 144-148.
48. Trecroci, A., Invernizzi, P.L., Monacis, D., & Colella, D. (2021). Actual and perceived motor competence in relation to body mass index in primary school-aged children: A systematic review. *Sustainability, 13*(17), 9994.
49. Hoeboer, J., Krijger-Hombergen, M., Savelsbergh, G., & De Vries, S. (2018). Reliability and concurrent validity of a motor skill competence test among 4-to 12-year old children. *Journal of Sports Sciences, 36*(14), 1607-1613.
50. Hoeboer, J., De Vries, S., Krijger-Hombergen, M., Wormhoudt, R., Drent, A., Krabben, K., & Savelsbergh, G. (2016). Validity of an athletic skills track among 6-to 12-year-old children. *Journal of Sports Sciences, 34*(21), 2095-2105.

51. Barnett, L.M., Ridgers, N.D., Zask, A., & Salmon, J. (2015). Face validity and reliability of a pictorial instrument for assessing fundamental movement skill perceived competence in young children. *Journal of Science and Medicine in Sport, 18*(1), 98-102.
52. Lopes, V.P., Barnett, L.M., Saraiva, L., Gonçalves, C., Bowe, S.J., Abbott, G., & Rodrigues, L.P. (2016). Validity and reliability of a pictorial instrument for assessing perceived motor competence in Portuguese children. *Child: Care, Health and Development, 42*(5), 666-674.
53. Valentini, N.C., Barnett, L.M., Bandeira, P.F.R., Nobre, G.C., Zanella, L.W., & Sartori, R.F. (2018). The pictorial scale of perceived movement skill competence: Determining content and construct validity for Brazilian children. *Journal of Motor Learning and Development, 6*(s2), S189-S204.
54. Hoeboer, J., De Vries, S., Mast, D., & Savelsbergh, G. (2017). Children's enjoyment of a motor skill test in physical education. *Journal of Physical Education Research, 4*(4), 1-16.
55. Read, J.C., MacFarlane, S., & Casey, C. (2002). Endurability, engagement and expectations: Measuring children's fun. In *Interaction Design and Children* (Vol. 2, pp. 1-23).
56. Sim, G., & Horton, M. (2012). Investigating children's opinions of games: Fun toolkit vs. this or that. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 70-77).
57. Read, J.C. (2008). Validating the fun toolkit: An instrument for measuring children's opinions of technology. *Cognition, Technology & Work, 10*(2), 119-128.
58. Cole, T.J., Bellizzi, M.C., Flegal, K.M., & Dietz, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ, 320*(7244), 1240.
59. Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*. Routledge.
60. Navarro-Patón, R., Mecías-Calvo, M., Rodríguez Fernández, J.E., & Arufe-Giráldez, V. (2021). Relative age effect on motor competence in children aged 4–5 years. *Children, 8*(2), 115.
61. Kokštejn, J., Musálek, M., & Tufano, J.J. (2017). Are sex differences in fundamental motor skills uniform throughout the entire preschool period? *PloS One, 12*(4), e0176556.
62. Laukkanen, A., Pesola, A.J., Finni, T., & Sääkslahti, A. (2017). Body mass index in the early years in relation to motor coordination at the age of 5–7 years. *Sports, 5*(3), 49.
63. Kambas, A., Michalopoulou, M., Fatouros, I.G., Christoforidis, C., Manthou, E., Giannakidou, D., ... Gourgoulis, V. (2012). The relationship between motor proficiency and pedometer-determined physical activity in young children. *Pediatric Exercise Science, 24*(1), 34-44.
64. Spessato, B.C., Gabbard, C., Robinson, L., & Valentini, N.C. (2013). Body mass index, perceived and actual physical competence: The relationship among young children. *Child: Care, Health and Development, 39*(6), 845-850.
65. Noordstar, J.J., van der Net, J., Jak, S., Helders, P.J., & Jongmans, M.J. (2016). Global self-esteem, perceived athletic competence, and physical activity in children: A longitudinal cohort study. *Psychology of Sport and Exercise, 22*, 83-90.
66. Harter, S. (1999). *The construction of the self: A developmental perspective*. New York: Guilford.
67. Pesce, C., Masci, I., Marchetti, R., Vazou, S., Sääkslahti, A., & Tomporowski, P.D. (2016). Deliberate play and preparation jointly benefit motor and cognitive development: Mediated and moderated effects. *Frontiers in Psychology, 7*, 349.
68. Liong, G.H., Ridgers, N.D., & Barnett, L.M. (2015). Associations between skill perceptions and young children's actual fundamental movement skills. *Perceptual and Motor Skills, 120*(2), 591-603.
69. Burns, R.D., Fu, Y., & Podlog, L.W. (2017). School-based physical activity interventions and physical activity enjoyment: A meta-analysis. *Preventive Medicine, 103*, 84-90.
70. Dismore, H., & Bailey, R. (2011). Fun and enjoyment in physical education: Young people's attitudes. *Research Papers in Education, 26*(4), 499-516.
71. Haas, P., Yang, C., & Dunton, G.F. (2021). Associations between physical activity enjoyment and age-related decline in physical activity in children—results from a longitudinal within-person study. *Journal of Sport and Exercise Psychology, 43*(3), 205-214.
72. Sallis, J.F., Prochaska, J.J., Taylor, W.C., Hill, J.O., & Geraci, J.C. (1999). Correlates of physical activity in a national sample of girls and boys in grades 4 through 12. *Health Psychology, 18*(4), 410.
73. Prochaska, J.J., Sallis, J.F., Slymen, D.J., & McKenzie, T.L. (2003). A longitudinal study of children's enjoyment of physical education. *Pediatric Exercise Science, 15*(2), 170-178.
74. Barr-Anderson, D.J., Neumark-Sztainer, D., Lytle, L., Schmitz, K.H., Ward, D.S., Conway, T.L., ... Pate, R.R. (2008). But I like PE: Factors associated with enjoyment of physical education class in middle school girls. *Research Quarterly for Exercise and Sport, 79*(1), 18-27.
75. Flavell, J.H. (1999). Cognitive development: Children's knowledge about the mind. *Annual Review of Psychology, 50*(1), 21-45.
76. Dudley, D., Okely, A., Pearson, P., & Cotton, W. (2011). A systematic review of the effectiveness of physical education and school sport interventions targeting physical activity, movement skills and enjoyment of physical activity. *European Physical Education Review, 17*(3), 353-378.

Chapter 4

Applying an ecosystem approach to explore modifiable factors related to the risk for low motor competence in young children

D.H.H. Van Kann, P. Koolwijk, T. de Kok, S.B. Vos, S.I. de Vries, R. Mombarg, I. van Aart, G.J.P. Savelsbergh, J.J.M.M. Hoeboer, T. Remmers (2022).

Journal of Science and Medicine in Sport, 25(11), 890-895.

ABSTRACT

Objectives

Early childhood is a crucial phase for motor development in which differences between children can manifest. These differences might be related to factors in ecosystems in which children are raised, of which little is currently known. The current study's purpose was to explore which modifiable factors in children's ecosystems are associated with the odds for low versus higher motor competence (MC) in 4- to 6-year-old children.

Design

A cross-sectional study design was conducted to investigate which modifiable social and physical factors in the home environment and direct living environment were associated with differences in MC.

Methods

Children's MC was measured through the Athletic Skills Track in 612 4- to 6-year-olds, from 10 primary schools in Eindhoven, the Netherlands. Parenting practices, characteristics of the home environment, and perceptions of the direct living environment were assessed through parental questionnaires. Hierarchical logistic regression analyses were conducted to evaluate factors associated with low MC in children.

Results

The presence of a garden at home and higher perceived sports facilities in the direct living environment decreased the likelihood of children being classified as low MC. Moreover, stronger parental active transportation routines and more discouraging physical activity parenting practices resulted in lower odds of low MC. In addition, girls were more at risk for low MC.

Conclusions

Characteristics of the social and physical home environment and direct living environment were associated with MC disparities during early childhood. Both parenting practices and parental physical activity-involved behaviours are relevant modifiable factors related to differences in children's MC.

INTRODUCTION

Children's motor competence (MC) has declined in recent decades,[1] which is alarming as this is associated with decreased fitness,[2] lower levels of physical activity (PA), and higher levels of sedentary behaviour (SB),[3] as well as with developmental delay in young children.[4] Further, MC is negatively associated with weight status.[5] As the development of MC starts during early childhood[6] and is conceptually interrelated with PA, preventing any delays or deficiencies in MC and PA during this period is vital from a public health perspective.[7] Yet, a majority of studies focused on curation of existing deficiencies in MC.[8] In parallel, most research on determinants of MC has been conducted on relatively strong but non-modifiable individual factors, such as age, gender and cultural background, whereas some more recent studies have looked at more modifiable socio-ecological factors of MC in children.[5] To some extent, inter-individual MC differences will always be present due to individual factors,[9] but increased understanding of the role of environments to which children are exposed the most during their first years of life can lead to more equal developmental opportunities for each child.[7] For example, Niemisto[10] reported that more supporting outdoor environments in the vicinity of childcare centres (i.e. less residential density) fosters children's MC development. Other studies have also highlighted important modifiable factors of MC and PA within the physical and social environments of childcare settings.[11] However, as young children spend a substantial proportion of time at home, more empirical evidence is needed on modifiable factors of children's MC within the broader socio-ecological system of their home setting.

Empirical evidence on the interacting influence of the physical and social environment in the home and neighbourhood setting on young children's MC is scarce.[12] For example, Barnett[13] found that availability of appropriate play equipment in the home setting was associated with better locomotor and object control skills in children. Likewise, parental modelling behaviour and parenting practices may be important factors for young children, as parents are considered 'gatekeepers' to either facilitate or restrict their child from viable motor learning experiences[10] and PA or SB.[14] Most research conducted on the associations between parents and young children's MC focus on parental beliefs, cognitive factors concerning the importance of PA, and parental PA behaviour.[15] Physical activity parenting practices (PAPPs) are more proximal factors for actual parenting behaviour that can be observed in and experienced by children.[16] To date, however, associations between PAPPs and children's MC are less well documented.

Therefore, the purpose of the current study was to explore whether physical and social environmental factors in the home environment and direct living environment are associated with MC. In order to effectively intervene during early childhood, it is vital to prioritize children that would benefit most from an intervention and also target relevant modifiable factors. Therefore, it is of interest to investigate whether children with low MC would show different modifiable home- and living conditions compared to children with normal or high MC, as this can have significant impact on future interventions. Consequently, this study wants to contribute to developing new ideas on how to prevent and reduce MC disparities and inequalities during early childhood.

METHODS

The current exploratory study used a cross-sectional research design in which a convenience sample of 10 primary schools located in Eindhoven, the Netherlands participated. Children in grades 1 and 2 (4-6 years old) in these schools were eligible for participation. Data were part of a larger cross-national project on children's fundamental MC development, 'Start(V)aardig'. Parents received written information about the study and were asked for written consent to participate in the study. In total, 701 parents (64.1%) consented. Children's measures included MC and body height and weight. Additionally, all participating parents received a questionnaire in which physical and social factors in the home environment and direct living environment were measured. Data collection took place in the period January-February 2020, just before restrictions came into force as a result of the COVID-19 pandemic. Child measures were collected through school visits by a team of trained researchers, while questionnaires were attached to the informed consent form. Ethical approval was obtained by the Ethical Research Committee of the Free University (VU) in Amsterdam, the Netherlands (VCWE-2020-137).

Children's MC was measured by the Athletic Skills Track (AST)-1. The AST is a feasible tool for measuring children's MC in a physical education setting.[17] AST-1 showed high test-retest reliability, an acceptable level of internal consistency and high validity compared to the Körperkoordinations Test für Kinder (KTK).[17] This circuit-based measurement tool was designed for children in grades 1 and 2 and consists of 5 consecutive activities: 1) walking/balancing; 2) travelling jumps; 3) alligator crawl; 4) slaloming; and 5) clambering. Children were instructed to complete the track in bare feet as quickly as possible. After receiving their instructions, the children were allowed to go on a practice round of the circuit three times before the actual test trial. Children's time to complete the track was measured in seconds (1 decimal). Next, gender- and age-related cut-off values, based on a Dutch national reference sample, were applied to classify children into five MC-categories; very low (n=73; 11.9%), low (n=125; 20.4%), average (n=301; 49.2%), high (n=74; 12.1%) and very high (n=39; 6.4%). In order to evaluate meaningful differences with sufficiently large categories of children, we decided to further collapse these five categories as having very low or low MC (category 1), having an average MC (category 2) or having high or very high MC (category 3).[18]

Children's body height and weight were measured in gym clothes, without shoes. Height was measured with an accuracy of 1mm using a stadiometer (Seca 217, Hamburg, Germany) and weight using a digital scale with an accuracy of 0.1kg (Seca 878dr, Hamburg, Germany). Children's BMI was defined by weight (kg) divided by height $(m)^2$. The IOTF-based cut-off values were applied to classify weight status (underweight till overweight).

Physical activity parenting practices (PAPPs) were measured using a questionnaire comprising 27 statements on how often parents used a certain practice.[19] A Dutch translation was applied based on pre-school PAPPs, that were contextually transferred from a childcare context to the home environment as applied by Harms.[20] Each statement was measured using a 5-point Likert scale (1=never through 5=always). These statements were clustered into 16 encouraging practices, e.g. 'How often do you play active games with your child?' (α=0.75), and 11 discouraging PAPPs, e.g. 'How often do you keep your child busy with inactive activities?' (α=0.65). For both clusters the mean score for all single items were used (1-5). In addition, we measured parental active transportation routines (PATRns) using 5 statements (α=0.82) using a 5-point Likert scale (1= 'I totally disagree' through 5= 'I totally agree'),[21] Examples of items of the PATRns scale are 'Going somewhere by foot is a habit for me.' and 'If I travel short distances, I always tend to walk or ride my bike'. Negatively framed items were recoded to ensure a positive score being linked to a positive behavioural outcome.

In addition, parents were asked about their perception of the physical and social characteristics of the home and direct living environment. Physical home environmental factors were measured through the availability of play opportunities at home, i.e. space and suitability either indoors and outdoors, based on the Environmental and Policy Evaluation Observation as a Self-Report (EPAO-SR) instrument.[22] Perceptions of physical affordances in the neighbourhood in which they lived were measured using single-item statements on the supportiveness for being physically active in terms of active play (availability of playgrounds) and sports (availability of sports facilities), which previously turned out to be relevant factors for young children's outside play.[23] Perceptions of the supportiveness of the social environment in the direct living environment were measured through traffic safety, social safety, and availability of peers to play with. All statements could be answered on a 5-point Likert scale (1= 'I totally disagree' through 5='I totally agree'). Finally, additional factors in the questionnaire were parental educational level, cultural background, and number of siblings present in the household. Parental educational level was classified into three levels according to the UNESCO's International Standard Classification of Education, while cultural background was dichotomized into Western versus non-Western background according to the definitions applied by the Statistics Netherlands.

To examine whether children with low MC would have different physical or social conditions in their home and direct living environment compared to children with higher MC, hierarchical logistic regression analyses were conducted with a dichotomous representation of MC categories (i.e. low MC versus average- and high MC). In this way, we investigated which factors significantly contributed to the odds of children's classification as low MC compared to average- or high MC. Based on the social-ecological framework variables were entered hierarchically, differentiating between first socio-demographic (most proximal), then variables of the home environment, and finally variables in the direct living environment of children (most distal). The first model consisted of demographic covariates (i.e. age, gender, BMI, number of siblings of the child, and cultural background and parental educational level). The second model was complemented by three social factors in the home environment (i.e. encouraging PAPPs, discouraging PAPPs and PATRns). The final model was enriched with parental perceptions of the physical and social environment in the neighbourhood, which were operationalised as presence of a garden and the perception of availability of playgrounds, availability of sports facilities, traffic safety concerns, social safety concerns, and presence of peers. Statistical analyses were performed using SPSS 25.0 (IBM Corp, Armonk, NY, USA) and statistical significance was defined as $p<0.05$.

RESULTS

In total, 612 children (87.3% of consenting children) provided valid measures on the Athletic Skills Track. The main reason for drop-out was absence during the measurement day at schools (N=77). The mean age of the participating children was 5.22 (SD=0.62) years, with a mean BMI of 15.37 (SD=1.31) kg/m^2. We found roughly equal distributions of IOTF-based under- and overweight percentages across the MC-categories. Gender was equally distributed (N=308 boys and N=304 girls). A majority of the children had one sibling (59.5%), were raised in a family with a Western cultural background (75.8%) and by highly educated parents (66.7% at least bachelor education). The sample was lightly skewed towards low MC; 198 (32.4%) children were classified as having a very low or low MC, while 113 (18.5%) children were classified as having a high or very high MC with respect to the age- and gender-specific national cut-off values. The percentage of girls was higher in the low MC category compared with the average- and high MC. Conversely, boys showed higher percentages in high MC compared to average- and low MC (Table 6.1). Moreover, the relative contribution of girls compared to boys was significantly higher in low MC (OR=1.63; $p<0.01$), but lower in high MC (OR=0.61; $p<0.01$).

Of the 612 children that participated in the measurements, 610 (99.7%) parents returned a completed questionnaire. Encouraging physical activity parental practices (PAPPs) were expressed more often than discouraging practices, while a large variation was observed in parental active transportation routines (PATRns) (M=2.70; SD=1.67). Over 85% of our sample had access to a garden. Neighbourhoods were perceived as supportive in terms of availability of playgrounds (M=4.44; SD=0.93), availability of sports facilities (M=3.84; SD=1.22), availability of age-related peers (M=3.59; SD=1.32) and, in general, parents expressed low concerns about social safety issues (M=2.27; SD=1.24). Concerns about traffic safety varied across respondents (M=3.03; SD=1.45), while increasing with age (Table 4.1). Further, differences between MC classifications were found for parental perceptions of sports facilities in the living environment (F (2,576) =3.181, $p=0.04$). However, post-hoc analyses revealed only marginally significant differences between low and average MC ($p=0.07$) and low and high MC ($p=0.10$). Observed differences between MC categories for the presence of number of siblings and PATRns were non-significant.

Logistic regression models showed that girls were more than twice as likely to be categorised as low MC than in the category average or high MC (OR=2.20; $p<0.01$). In addition, more discouraging PAPPs (OR=0.48; $p=0.01$) and stronger PATRns (OR=0.79; $p=0.03$) were found to be social home environmental factors that decreased the likelihood of children being classified as low MC compared to high- and average MC categories. The presence of a garden decreased the likelihood of children being classified as low MC (OR=0.84; $p=0.02$). Moreover, children whose parents perceived higher availability of sports facilities in their direct living environment were less often classified as low MC (OR=0.80; $p=0.02$) (Table 4.2). Nagelkerke's R^2 was .115 and increased significantly while adding environmental factors.

Table 4.1. Descriptive statistics for total sample and stratified per level of motor competence

	Total (N=612)		Low MC (N=198)		Average MC (N=301)		High MC (N=113)	
	M (SD)	N (%)	M (SD)	N (%)	M (SD)	N (%)	M (SD)	N (%)
Child demographics								
Age	5.22 (0.62)		5.21 (0.65)		5.23 (0.61)		5.19 (0.60)	
MC	2.81 (1.01)		N.A.		N.A.		N.A.	
Gender								
Boys		308 (50.3)		76 (38.4)		164 (54.5)		68 (60.2)
Girls		304 (49.7)		122 (61.6)		137 (45.5)		45 (39.8)
BMI (*n*=595)	15.37 (1.31)		15.37 (1.49)		15.36 (1.25)		15.39 (1.16)	
Underweight (IOTF)		88 (14.8%)		30 (15.5%)		39 (13.3%)		19 (17.8%)
Overweight (IOTF)		35 (5.9%)		14 (7.2%)		15 (5.1%)		6 (5.6%)
Family environment								
Siblings								
No siblings		95 (15.7)		41 (21.0)		41 (13.7)		13 (11.5)
1 sibling		361 (59.5)		112 (57.4)		178 (59.5)		71 (62.8)
2 or more siblings		151 (24.9)		42 (21.5)		80 (26.8)		29 (25.7)
Cultural background								
Western		453 (75.8)		145 (74.4)		225 (76.8)		83 (75.5)
Non-Western		145 (24.2)		50 (25.6)		68 (23.2)		27 (24.5)
Parental educational level								
Low (no, primary)		18 (3.2)		5 (2.6)		8 (2.7)		2 (1.8)
Middle (pre-vocational – lower vocational)		170 (30.1)		54 (28.4)		81 (27.7)		35 (32.1)
High (higher vocational, university degree)		377 (66.7)		131 (68.9)		203 (69.5)		72 (66.1)
Social home environment (1-5)								
Parenting practices encouraging	3.42 (0.47)		3.40 (0.50)		3.44 (0.45)		3.39 (0.45)	
Parenting practices discouraging	2.30 (0.43)		2.27 (0.44)		2.31 (0.42)		2.32 (0.40)	

Table 4.1. Continued.

	Total (N=612)		Low MC (N=198)		Average MC (N=301)		High MC (N=113)	
	M (SD)	N (%)	M (SD)	N (%)	M (SD)	N (%)	M (SD)	N (%)
PATRns	2.70 (1.67)		2.56 (1.70)		2.73 (1.62)		2.85 (1.73)	
Physical home environment								
Garden – active play opportunity								
No		79 (12.9)		33 (16.7)		34 (11.3)		12 (10.6)
Yes, (almost) no space		43 (7.0)		14 (7.1)		23 (7.6)		6 (5.3)
Yes, limited space		182 (29.7)		58 (29.3)		92 (30.6)		32 (28.3)
Yes, (almost) unlimited space		308 (50.3)		93 (47.0)		152 (50.5)		63 (55.8)
In home – active play opportunity								
(Almost) no space		16 (2.7)		7 (3.6)		5 (1.7)		4 (3.6)
Limited space		240 (40.3)		77 (40.1)		116 (39.6)		47 (42.3)
Almost unlimited space for active play		340 (57.0)		108 (56.3)		172 (58.7)		60 (54.1)
Physical neighbourhood (1-5)								
Availability playground	4.44 (0.93)		4.41 (0.93)		4.43 (0.98)		4.50 (0.76)	
Availability sports facilities	3.84 (1.22)		3.66 (1.27)		3.91 (1.18)		3.96 (1.21)	
Social neighbourhood (1-5)								
Perceived traffic safety	3.03 (1.45)		2.96 (1.43)		3.02 (1.48)		3.19 (1.41)	
Perceived social safety	2.27 (1.24)		2.30 (1.24)		2.22 (1.25)		2.33 (1.23)	
Perceived availability of peers	3.59 (1.32)		3.50 (1.37)		3.69 (1.27)		3.50 (1.36)	

Table 4.2. Odds of being classified as low MC compared to average- or high MC

	Model 1		Model 2		Model 3	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Personal factors						
Gender (boys=reference)	**2.14 (1.46 – 3.13)**	**<0.01**	**2.12 (1.43-3.13)**	**<0.01**	**2.20 (1.47-3.28)**	**<0.01**
Social home environment						
Parenting practices encouraging			0.75 (0.49-1.14)	0.22	0.84 (0.54-1.30)	0.43
Parenting practices discouraging			**0.54 (0.32-0.90)**	**0.02**	**0.48 (0.28-0.83)**	**0.01**
PATRns			0.89 (0.79-1.00)	0.05	**0.79 (0.65-0.96)**	**0.03**
Physical home environment						
Garden – active play opportunity					**0.84 (0.55-1.27)**	**0.02**
Physical neighbourhood						
Availability playground					1.06 (0.82-1.38)	0.65
Availability sports facilities					**0.80 (0.66-0.96)**	**0.02**
Social neighbourhood						
Perceived traffic unsafety					0.94 (0.80-1.12)	0.54
Perceived social unsafety					1.09 (0.89-1.34)	0.39
Perceived availability of peers					0.99 (0.85-1.18)	0.98
Nagelkerke's R^2	.053		.079		.115	

Note: Only significant demographic variables are displayed in the table. All models were corrected for the covariates: age, BMI, number of siblings, cultural background, and parental educational level. All these covariates were not significant.

DISCUSSION

The main finding of the current study is that the MC of 4- to 6-year-old children is associated with several modifiable factors in the social and physical home environment and direct living environment. This knowledge can help us to prevent MC differences during early childhood.

In early childhood, we found gender-related differences in MC. Although these gender differences have been consistently found in MC,[7] this shows that girls in our sample had relatively lower MC compared to the age- and gender specific national representative sample. The gender specific cut-off values allowed girls to spend slightly more time to accomplish the AST.[18] An explanation for this may be partly attributed to a sampling effect, with relatively more girls living in (more urbanised) vulnerable neighbourhoods with fewer affordances in their physical environment. Namely, earlier studies showed that these neighbourhood factors were related MC development.[10] Another explanation may be that young boys are more allowed and encouraged to be physically active, irrespective of PA-related barriers that parents experience in their ecosystem.[24] Consequently, young girls' PA and MC may be more vulnerable for these barriers. Future studies are recommended to further unravel these gender differences.

The relationship between higher PATRns and decreased odds of low MC might be explained by the habitual character of PA behaviour that is reflected in PATRns. If parental routines in using active transportation are stronger, children implicitly observe active behaviour by role models, which is in line with positive association between parental, mostly maternal, PA and children's MC.[13,15] Particularly in early childhood, children tend to copy behaviour as a way of learning. The more frequent use of active transportation by parents could either be considered as a good example for the child to be physically active but may also be considered as a proxy of an active lifestyle. The latter may also be an explanation for the positive relationship that was found between the perceived availability of sports facilities in the direct living environment and decreased odds of low MC. The parent-perceived availability of sports facilities is associated with higher levels of sports participation in adults,[25] so it could be hypothesised that these parents perform sports themselves more often, again implicitly setting a good example as a role model for their young children.[14]

In line with previous work,[26] the presence of a garden was linked with lower odds of being categorised as low MC. The presence of gardens could be considered as an indicator of lower levels of residential density, higher neighbourhood SES status, and better affordances for children to be physically active.[27] Gardens may be important environments for MC development in young children, as these can serve as PA affordance regardless of potential (safety) barriers that parents perceive in their neighbourhood. Additional sensitivity analyses in our study also showed significant positive correlations between the presence of gardens and a Western cultural background, slightly higher educational levels, the presence of more peers and siblings to support PA, and better perceived physical PA supportiveness of neighbourhoods (Supplementary Table S4.1). Consequently, the presence of gardens is not a modifiable factor, but this advocates the compensation for this lack of opportunity to create more supportive physical and social environments in areas where this affordance is more often lacking in order to positively affect these children's development, including PA and MC.[28]

In contrast to our expectations, encouraging PAPPs were not associated with the level of MC in children. This may be explained by the fact PAPPs are operationalized as parenting practices regarding PA, and not necessarily for MC.[14] We even found an initially unexpected finding in the direction of discouraging PAPPs on MC. Discouraging PAPPs are by their nature more likely to be used in situations in which children are active a priori, e.g. 'How often do you tell your child he/she can hurt him/herself when being physically active?'. This example of a discouraging PAPP item could be considered as actual discouragement of PA but may be only relevant to use in a situation in which a child is playing in such an active manner that getting hurt may actually be a risk. This mechanism was also seen in a study examining the role of parents in facilitating outside play in young children, where the presence of parental rules regarding outside play (e.g. minimum of time spent outside or limitation of screen time) was associated with less outside play.[29] In contrast to the authors' expectations, parents may provide rules regarding outside play if they feel that this is necessary, based on the behaviour of their child, and subsequently report their child as being relatively less active.[29] Combining our findings and existing evidence of parental behaviours and the mediating pathway through PA[30] further legitimates the need to target parental PA behaviours and children PA simultaneously in order to create synergy in children's motor development.

To our knowledge, this is one of the few studies investigating the influence of the broader ecosystem on young children's MC, with a particular focus on modifiable factors, which is considered as a major strength to reduce MC disparities during early childhood. Moreover, this study used a rather large sample of child-parent dyads and had an exceptional high response rate for the parental questionnaire (99.7% gave consent for their child to participate). However, this exploratory study used a rather rudimentary way of operationalizing children's MC into three main categories. Future studies are encouraged to increase the precision of MC measurement, for example by combining results from multiple diverse motor tasks or by differentiating between object-control, locomotor- and stability competencies. We performed sensitivity analyses to investigate whether the same explanatory variables would also explain high MC vs. low- and average MC. This showed that some previously significant variables (i.e. discouraging parenting practices, perceived availability of sports facilities and PATRns) attenuated. For gender and the presence of a garden, we found that these factors increased the odds of being classified as high MC compared to low- and average MC (Supplementary Table S4.2). In addition, a cross-sectional design was used, implicating that no causal

pathways could be found. Longitudinal studies focusing on modifiable factors in the home and direct living environments are warranted to better understand the relationship between social-ecological influences on children's motor development. Furthermore, the exploratory character of this study was found in the inclusion of less well researched and non-validated measures, such as PAPPs and PATRns. Like many other studies focusing on the environment-behaviour relation, the explained variance was relatively limited, but the increase in explained variance in our hierarchical models indicated the added value of these measures in addition to previously studied factors, such as parental beliefs and behaviours. A limitation of the study was the lack of objective measures of the physical environment as well as the limited number of environmental characteristics included, which were included as single items. Including both objective and subjective measures on environmental characteristics could be helpful to limit the potential bias caused by parents who consider their environments to be in line with their own perceptions concerning PA. Finally, the current study did not include PA measurements, preventing us from testing mediating associations caused by PA levels of children. Future studies are recommended to include a valid measure for long-term PA, and simultaneously study environmental factors in multiple, relevant settings to which children are exposed.

CONCLUSION

Characteristics of the social and physical home environment and direct living environment were associated with MC disparities during early childhood. Both parenting practices and parental PA-involved behaviours are relevant modifiable factors. Additionally, supportive actions in public spaces in neighbourhoods with a high concentration of houses with a lack of gardens could compensate for this lack. In particular, girls' MC development should be prioritised in order to prevent gender-related differences in MC (and resultant consequences) during later phases in life. Therefore, improved understanding of specific features and affordances of modifiable physical and social and environmental factors affecting girls' MC is warranted.

Practical implications

- The presence of a garden at home is associated with decreased odds of low motor competence during early childhood
- Neighbourhoods in which gardens are often lacking should be prioritised for providing supporting environmental initiatives
- Parenting practices and parental perceptions of their direct living environment are associated with children's motor competences
- Targeting parental physical activity behaviour besides children's motor competence is likely to create synergy in motor competence development
- Young girls' motor development should be better understood and prioritised in preventive initiatives

REFERENCES

1. Anselma, M., Collard, D.C.M., van Berkum, A., Twisk, J.W.R., Chinapaw, M.J.M., & Altenburg, T.M. (2020). Trends in neuromotor fitness in 10-to-12-year-old Dutch children: A comparison between 2006 and 2015/2017. *Frontiers in Public Health, 8*, 556.
2. Haugen, T., & Johansen, B.T. (2018). Difference in physical fitness in children with initially high and low gross motor competence: A ten-year follow-up study. *Human Movement Science, 62*, 143-149.
3. Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise, 15*(4), 382-391.
4. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J.D., ... Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*(10), 1609-1618.
5. Barnett, L.M., Webster, E.K., Hulteen, R.M., De Meester, A., Valentini, N.C., Lenoir, M., & Robinson, L.E. (2022). Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Medicine, 52*(4), 875-920.
6. Lubans, D.R., Morgan, P.J., Cliff, D.P., Barnett, L.M., & Okely, A.D. (2010). Fundamental movement skills in children and adolescents. *Sports Medicine, 40*(12), 1019-1035.
7. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., ... Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*(1), 18.
8. Jimenez-Diaz, J., Chaves-Castro, K., & Salazar, W. (2019). Effects of different movement programs on motor competence: A systematic review with meta-analysis. *Journal of Physical Activity and Health, 16*(8), 657.
9. Baker, J., Wattie, N., & Schorer, J. (2019). A proposed conceptualization of talent in sport: The first step in a long and winding road. *Psychology of Sport and Exercise, 43*, 27-33.
10. Niemistö, D., Finni, T., Cantell, M., Korhonen, E., & Sääkslahti, A. (2020). Individual, family, and environmental correlates of motor competence in young children: Regression model analysis of data obtained from two motor tests. *International Journal of Environmental Research and Public Health, 17*(7), 2548.
11. Zeng, N., Johnson, S.L., Boles, R.E., & Bellows, L.L. (2019). Social-ecological correlates of fundamental movement skills in young children. *Journal of Sport and Health Science, 8*(2), 122-129.
12. Barnett, L.M., Lai, S.K., Veldman, S.L.C., Hardy, L.L., Cliff, D.P., Morgan, P.J., ... Ridgers, N.D. (2016). Correlates of gross motor competence in children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 46*(11), 1663-1688.
13. Barnett, L.M., Hnatiuk, J.A., Salmon, J., & Hesketh, K.D. (2019). Modifiable factors which predict children's gross motor competence: A prospective cohort study. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1), 129.
14. Sleddens, E.F C., Gubbels, J.S., Kremers, S.P.J., van der Plas, E., & Thijs, C. (2017). Bidirectional associations between activity-related parenting practices, and child physical activity, sedentary screen-based behavior and body mass index: A longitudinal analysis. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 89.
15. Derikx, D., Houwen, S., Meijers, V., Schoemaker, M.M., & Hartman, E. (2021). The relationship between social environmental factors and motor performance in 3- to 12-year-old typically developing children: A systematic review. *International Journal of Environmental Research and Public Health, 18*(14).
16. Sleddens, E.F., Gerards, S.M., Thijs, C., de Vries, N.K., & Kremers, S.P. (2011). General parenting, childhood overweight and obesity-inducing behaviors: A review. *International Journal of Pediatric Obesity, 6*(2-2), e12-27.
17. Hoeboer, J., De Vries, S., Krijger-Hombergen, M., Wormhoudt, R., Drent, A., Krabben, K., & Savelsbergh, G. (2016). Validity of an athletic skills track among 6- to 12-year-old children. *Journal of Sports Sciences, 34*(21), 2095-2105.
18. Hoeboer, J.J.A.A.M., Ongena, G., Krijger-Hombergen, M., Stolk, E., Savelsbergh, G.J.P., & De Vries, S.I. (2018). The athletic skills track: Age- and gender-related normative values of a motor skills test for 4- to 12-year-old children. *Journal of Science and Medicine in Sport, 21*(9), 975-979.
19. O'Connor, T.M., Cerin, E., Hughes, S.O., Robles, J., Thompson, D., Baranowski, T., ... Lee, R.E. (2014). Psychometrics of the preschooler physical activity parenting practices instrument among a Latino sample. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 3.
20. Harms, L.S.E., Gerards, S.M.P.L., Kremers, S.P.J., de Vries, N.K., & Jansen, M.W.J. (2021). Involving parents in promoting healthy energy balance-related behaviors in preschoolers: A mixed methods impact and process evaluation of SuperFIT. *Nutrients, 13*, 1605.
21. Van Kann, D.H.H., Kremers, S.P.J., De Vries, S.I., De Vries, N.K., & Jansen, M.W.J. (2015). Parental active transportation routines (PATRns) as a moderator of the association between neighborhood characteristics and parental influences and active school transportation. *Environment and Behavior, 48*(7), 946-965.
22. Ward, D.S., Mazzucca, S., McWilliams, C., & Hales, D. (2015). Use of the environment and policy evaluation and observation as a self-report instrument (EPAO-SR) to measure nutrition and physical activity environments in child care settings: Validity and reliability evidence. *International Journal of Behavioral Nutrition and Physical Activity, 12*(1), 124.
23. Remmers, T., Van Kann, D., Gubbels, J., Schmidt, S., De Vries, N., & Kremers, S. (2014). Moderators of the longitudinal relationship between the perceived physical environment and outside play in children: The KOALA birth cohort study. *International Journal of Behavioral Nutrition and Physical Activity, 11*, 150.
24. Brown, B., Mackett, R., Gong, Y., Kitazawa, K., & Paskins, J. (2008). Gender differences in children's pathways to independent mobility. *Children's Geographies, 6*(4), 385-401.
25. Hoekman, R., Breedveld, K., & Kraaykamp, G. (2017). Sport participation and the social and physical environment: Explaining differences between urban and rural areas in the Netherlands. *Leisure Studies, 36*(3), 357-370.
26. Armstrong, G., Maitland, C., Lester, L., Trost, S.G., Trapp, G., & Christian, H. (2019). Associations between the home yard and preschoolers' outdoor play and physical activity. *Public Health Research & Practice, 29*(1), e2911907.
27. Christian, H., Ball, S.J., Zubrick, S.R., Foster, S., Giles-Corti, B., Wood, L., & Boruff, B. (2017). Relationship between the neighbourhood built environment and early child development. *Health & Place, 48*, 90-101.
28. Christian, H., Zubrick, S.R., Foster, S., Giles-Corti, B., Bull, F., Wood, L., ... Boruff, B. (2015). The influence of the neighborhood physical environment on early child health and development: A review and call for research. *Health & Place, 33*, 25-36.
29. Remmers, T., Broeren, S.M.L., Renders, C.M., Hirasing, R.A., van Grieken, A., & Raat, H. (2014). A longitudinal study of children's outside play using family environment and perceived physical environment as predictors. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 76.
30. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306.

SUPPLEMENTARY TABLES

Table S4.1. Sensitivity analyses investigating differences in the physical- and social neighbourhoods from children with- and without the availability of a garden

	Total (N=612)		Presence Garden (N=574)		Absence Garden (N=31)		p-value for difference
	M (SD)	N (%)	M (SD)	N (%)	M (SD)	N (%)	
Family environment							
Siblings							
No siblings		95 (15.7)		80 (14.0%)		13 (43.3%)	< 0.01
1 sibling		361 (59.5)		345 (60.4%)		14 (46.7%)	
2 or more siblings		151 (24.9)		146 (25.6%)		3 (10.0%)	
Cultural background							
Western		453 (75.8)		498 (86.8%)		22 (71.0%)	0.01
Non-Western		145 (24.2)		76 (13.2%)		9 (29.0%)	
Parental educational level							
Low (no, primary)		18 (3.2)		12 (2.2%)		3 (10.3%)	0.02
Middle (pre-vocational – lower vocational)		170 (30.1)		163 (29.2%)		7 (24.1%)	
High (higher vocational, university degree)		377 (66.7)		383 (68.6%)		19 (65.5%)	
Physical neighbourhood (1-5)							
Availability playground	4.44 (0.93)		4.46 (0.91)		3.87 (1.11)		< 0.01
Availability sports facilities	3.84 (1.22)		3.87 (1.22)		3.33 (1.18)		0.02
Social neighbourhood (1-5)							
Perceived traffic safety	3.03 (1.45)		3.02 (1.45)		3.10 (1.45)		0.78
Perceived social safety	2.27 (1.24)		2.24 (1.23)		2.59 (1.43)		0.15
Perceived availability of peers	3.59 (1.32)		3.64 (1.30)		2.73 (1.48)		< 0.01

Table S4.2. Odds of being classified as high MC compared to average- or low MC

	Model 1		Model 2		Model 3	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Personal factors						
Gender (boys=reference)	**0.61 (0.38-0.97)**	**0.04**	**0.62 (0.39-0.99)**	**0.04**	**0.60 (0.37-0.98)**	**0.04**
Social home environment						
Parenting practices encouraging			0.95 (0.58-1.56)	0.84	0.89 (0.53-1.51)	0.68
Parenting practices discouraging			1.51 (0.84-2.71)	0.17	1.50 (0.80-2.82)	0.20
PATRns			1.12 (0.97-1.29)	0.13	1.14 (0.98-1.32)	0.09
Physical home environment						
Garden – active play opportunity					**1.35 (1.03-1.75)**	**0.03**
Physical neighbourhood						
Availability playground					1.12 (0.80-1.56)	0.50
Availability sports facilities					1.13 (0.89-1.42)	0.33
Social neighbourhood						
Perceived traffic unsafety					1.11 (0.92-1.35)	0.28
Perceived social unsafety					0.98 (0.77-1.24)	0.86
Perceived availability of peers					0.88 (0.73-1.06)	0.18
Nagelkerke's R2	**.019**		**.032**		**.063**	

Note: Only significant demographic variables are displayed in the table. All models were corrected for the covariates: age, BMI, number of siblings, cultural background, and parental educational level. All these covariates were not significant.

Chapter 5

Characteristics of children with an undesirable motor competence development during the transition from early to middle childhood: results of a 2-year longitudinal study

Pim Koolwijk, Ester de Jonge, Remo Mombarg, Teun Remmers, Dave Van Kann, Ingrid van Aart, Geert Savelsbergh and Sanne de Vries (2024).

International Journal of Environmental Research and Public Health, 21(11), 1460.

ABSTRACT

Objective

Motor competence development from early to middle childhood is accompanied by great variance. This course can be influenced by many factors in the ecosystem. The objective of this study was to examine which individual characteristics are associated with an undesirable motor competence development during the transition from early to middle childhood.

Methods

A longitudinal study was conducted between February 2020 and May 2022. Actual and perceived motor competence and the potential determinants physical activity enjoyment, weight status, and organized sports participation of children (49% boys) aged 4–6 years old at T0 (n = 721) were measured at two points in time, separated by a two-year interval. Associations between potential determinants and AMC, including interactions with time, were analysed using linear mixed-effect regression models with continuous motor quotient scores as outcome variables.

Results

Overweight, obesity, and lack of organized sports participation were associated with lower motor quotient scores over time. Multivariate analyses showed that associations of weight status (overweight and obesity) and sports participation with motor quotient scores remained significant after adjustment for variations in perceived motor competence and physical activity enjoyment.

Conclusions

Excessive body weight and lack of sports participation from early childhood to middle childhood are associated with an increased risk of an undesirable motor competence development over time.

5

BACKGROUND

Early childhood (2- to 5-years of age) is characterized by rapid growth and development. It is considered a critical period for establishing healthy behaviours, such as physical activity.[1-3] One potential factor underlying participation in sports and physical activity is motor competence.[4-7] Motor competence (MC) is defined as an individual's degree of proficiency in performing a wide range of motor skills as well as the mechanisms underlying this performance (e.g., motor control and coordination).[8] Clarke and Metcalfe,[9] in 2002, introduced a well-recognized model, i.e., the mountain of motor development, in which the different stages of MC development are described. This 'mountain' includes an ascent of six passages of MC development: the reflexive period, the preadapted period, the fundamental patterns period, the context-specific period, the skilful period, and the compensation period. Each period builds on the skills learned in the previous period. In their model, MC development is considered a nonlinear process, as the learning process within each child does not develop smoothly from one stage to the next and differs in pace. Previous studies have shown that a significant number (20–30%) of children between early childhood (EC) and middle childhood (MCD) (6- to 9-years of age) exhibit undesirable MC development.[10-15] Although children may naturally develop rudimentary motor skills through maturation, achieving proficient forms of skills may only be achieved in a developmentally appropriate environment. During EC, physical activity (PA) influences the development of MC through a variety of movement experiences, and vice versa.[7,16] However, increasing the amount of PA does not guarantee the gradual and positive development of MC.[3,13,17,18] MC development is also influenced by other determinants. These determinants can be categorized into individual characteristics (e.g., gender, ethnicity, age, PA), education-related programs (intervention programs for stimulating MC), social environments (e.g., parental style and family-related variables), and physical environments (e.g., traffic infrastructure, playground facilities).[19-21] In this manuscript, we focus on the individual characteristics of MC development.

Regarding the individual characteristics that may influence MC development, an Australian study showed that children in low-income communities, especially boys and underweight and overweight children, have higher odds of being at risk for a delay in MC.[22] Weight status (quantified by body mass index (BMI))[8,23] and perceived motor competence (PMC)[24-27] are, in general, well-recognized determinants for MC development in either EC or MCD. Several studies have shown a negative relationship between BMI and MC.[28-30] Recently, an international motor development consortium analyzed the association between BMI and MC in a large multicountry sample of EC-aged children (n = 5545).[31] A negative association was found between BMI and overall (locomotor and object control skills) MC.[31] Other, longitudinal, studies also found that the weight status of EC-aged children is an important predictor of children's MC in MCD.[23,32]

5

Evidence regarding this negative association was strengthened by a systematic review performed by Barnett et al.[24] in which longitudinal and experimental evidence in support of Stodden's conceptual model was evaluated.[33] In this model, it has been hypothesized that the synergistic relationship between MC and PA is mediated by PMC, health-related fitness variables, and weight status, with this relationship expected to strengthen over time.[33] In the review by Trecroci and colleagues,[34] the relation between actual motor competence (AMC) and PMC with weight status in MCD children was investigated. A negative association was found between AMC and PMC and weight status. However, after the risk of bias was assessed, the level of evidence linked to this association remained uncertain and lacking.

In the context of this study, PMC is used to refer to an individual's awareness and belief in his/her capabilities in goal-directed human fundamental movement skills and what would be considered as MC.[35] Children with lower PMC are at risk of losing motivation to participate in movement-related tasks and reduce PA engagement.[36] PMC mediates the relation between AMC and children's level of PA during EC and MCD.[24,27,37-39] However, during the early years, this relationship is not always that strong,[36] and sometimes results are mixed.[40,41] Stodden (2008),[33] later revised by Robinson and colleagues (2015),[6] suggested that as children age and cognitively develop, the relationship between their actual MC and their perceived MC becomes stronger. However, longitudinal evidence is needed to confirm this relationship in the transition from EC to MCD.

In addition to children's perception of their motor competence, enjoyment of physical activities may also be an important individual characteristic of prolonged participation in sports and physical activities.[42,43] Especially in EC, PA drives the development of MC, whereas proficient levels of MC will increase PA during MCD.[33] It has been argued that the execution of motor skills on its own is insufficient for motor learning and its development if it is not linked with positive emotions.[44,45] Studies show that children who enjoy participation in physical education (PE) are more physically active than those who do not enjoy PE.[46-49] In line with this, one would expect an association between the enjoyment of physical activities with MC development. However, to our knowledge, the relationship between enjoyment of PA and MC development over time is still understudied.

Further, by the time children go to school (at age 4 within the Dutch school system), education-related programs such as physical education (PE) lessons and sports clubs are important for MC stimulation.[50,51,52] A recently conducted Dutch study indicated that determinants in the social and physical home environment and direct living environment are associated with MC disparities during EC. Additionally, parenting practices and parental PA involved behaviours are relevant modifiable factors related to differences in children's MC.[53] Finally, excessive screen media use has been associated with poor MC development and decreased PA in EC-aged children, especially among those with prolonged exposure.[19]

Thus, longitudinal evidence regarding individual characteristics of children during the transition from EC to MCD is needed.[54,55] Besides more longitudinal evidence during this transition phase, establishing risk profiles of children from whom MC development is lagging behind is crucial for developing targeted interventions. To date, undesirable patterns of MC development associated with individual characteristics such as weight status, PMC, PA enjoyment and sports participation have only been examined in mostly cross-sectional studies with relatively small sample sizes. Therefore, the objective of this study is to examine which individual characteristics are associated with an undesirable MC development during the transition from early to middle childhood. Based on cross-sectional studies, it is expected that children with an undesirable MC development are characterized by a higher BMI, lower PA enjoyment scores, and lower organized sports participation. Regarding PMC, lower scores are expected for children who exhibit undesirable MC development.

METHODS

Study design and participants

For the purpose of this study, longitudinal data from the 'Start (V)aardig' project (Dutch for 'Skilful Start') was used. This data was gathered among a convenience sample of children aged 4–6 years old from 36 primary schools across the Netherlands with variations in geographic area (i.e., rural/city), school types (i.e., Catholic/public) and socioeconomic position (i.e., six categories ranging from low ≤ −0.20 to high ≥ 0.20). Numerical indicators of the socioeconomic position of the school region were based on wealth, education level, and employment history of households).[56] The participating schools were all internship schools of connected universities. AMC, PMC, PA enjoyment, weight status, and organized sports participation of children aged 4–6 years old were measured at two points in time, separated by a two-year interval (i.e., baseline and one follow-up measurement). All assessments were performed during a regular 50-minute PE lesson at school. Baseline data (T0) were collected between February and May 2020, covering a total sample of 1128 children (5.35 years of age (SD ± 0.69), with 50% boys). The first follow-up measurement of AMC was conducted between February and April 2021 (T1), and the second follow-up measurement was conducted among 721 children (7.48 year of age (SD ± 0.62), with 49% boys) between March and May 2022 (T2). This data was used to determine undesirable patterns of MC development over time.[14] Parents gave written informed consent for their children's participation (63% consent rate). This study received ethical approval from the Ethics Committee of the Faculty of Behavioural and Movement Sciences, VU University Amsterdam, the Netherlands (ref. number VCWE-2019-139).

Assessment

Actual Motor Competence

AMC was measured with the Athletic Skills Track (AST). The AST is an age-specific track consisting of a series of 5–7 detached activities based on coordinative abilities (i.e., coupling, spatial orientation, and balance ability) to be completed as quickly as possible.[57] In this study, AST-1 (age group 4–6 years old) and AST-2 (age group 6–9 years old) were used with the difficulty of the tasks ascending from AST-1 to AST-2. AST-1 consisted of the following five fundamental movement skill tasks: (1) walking, (2) traveling jumps, (3) alligator crawl, (4) slaloming, and (5) clambering. AST-2 consisted of: (1) walking, (2) traveling jumps, (3) hopscotch, (4) alligator crawl (backward), (5) running (backward), (6) pencil roll, and (7) clambering. The time to complete the track was registered to the nearest 0.1 second by a research assistant using a stopwatch. The test–retest reliability of the AST was proven to be high (ICC = 0,881, 95% CI: 0.780–0.934) for AST-1 and AST-2 (ICC = 0.802 95% CI: 0.717–0.858) in a sample of 4–12-year-old Dutch children.[58] The internal consistency was above the acceptable level of Cronbach's $\alpha > 0.70$ (AST-1: $\alpha = 0.764$; AST-2, $\alpha = 0.700$), and the validity of the AST was high when correlated with the Körperkoordinations Test für Kinder (KTK) (AST-1: $r = -0.747$, $P = 0.01$; AST-2: $r = -0.646$, $P = 0.01$).[58]

Perceived motor competence

To measure PMC, the 12-indicator Pictorial Scale of Perceived Movement Skill Competence for Young Children (PMSC) was used.[59] The children were individually assessed by the research assistant for six locomotor (LOC) skills and six object control (OC) skills using a pictorial instrument.[59,60,61] Children were shown a page with two cartoon illustrations of children undertaking each skill, one better than the other, and asked to identify which child is most like them (i.e., 'this child is pretty good at throwing, this child is not that good at throwing, which child is most like you?'). Once selected, choices were further refined by asking 'are you really good at …' (scored as 4 points) or 'pretty good at …' (3 points) if the competent picture was selected; or 'are you sort of good at …' (2 points) or 'not too good at …' (1 point), if the 'not so competent' picture was selected. Test–retest reliability scores of the PMSC for 4- to 7-year-old children were excellent (ICCs for all 12 skills: 0.83, the six LOC items: 0.82 and the six OC items: 0.78). The internal consistency of the PMSC was above the acceptable level of Cronbach's $\alpha > 0.60$ for LOC as well as OC skills, and high correlation coefficients were reported between the pictorial scores and the Test of Gross Motor Development-2 (TGMD-2) ($r = 0.82$–0.90).[59,61]

Physical activity enjoyment

In order to assess children's enjoyment of being physically active, a 'smileyometer' was used. On a 5-point Likert scale ranging from one 'not nice at all' to five 'very nice', children were individually asked by a research assistant to point out one smiley that best matched the specific question. The questions, accompanied by corresponding images, contain four different contexts of PA: (1) PE lessons, (2) a playground at school, (3) a playground in their own neighborhood, and (4) organized sports in a sports club. Additionally, one sedentary context was assessed (i.e., watching television/tablet). The smileyometer has been widely adopted and applied in research studies with children.[62,63,64] It is easy to complete and requires no reading or writing skills from young children. The reliability and age effect of the smileyometer have been positively evaluated in young children.[65]

Sports participation

Next to PA enjoyment, children were asked if they were participating in a sports club on a regular basis. Participating in swimming lessons to obtain a swimming diploma was not included as a sports club activity. Sports participation was assessed by showing a picture of an organized sports setting. If children said they were participating, a follow-up question was asked if they could tell what sport they were doing.

Weight status

At the start of the PE lesson, body height and body weight of the children were measured individually by a research assistant to the nearest 0.1 cm using a stadiometer (SECA 217, Hamburg, Germany) and to the closest 0.1 kg using a digital scale (SECA 878dr, Hamburg, Germany). Children were measured without wearing shoes.

Procedure

Data collection took place in a regular 50-minute PE lesson during school hours. The lesson started with a general introduction by the PE teacher. Additional explanations and demonstrations were given by the research assistants at the specific test item. To minimize the emphasis on measuring, the children were instructed to play regular PE activities. The children were called in small groups to perform a specific test with the research assistant. The children wore regular sportswear and were barefoot during testing. The questionnaires to measure PMC, PA enjoyment, and sports participation started with a short introduction and an example. When the child understood, the research assistant read out the real questions to the child individually and filled in their answers. All research assistants participated in a two-hour training session to conduct the tests according to the protocol. Additionally, a supervisor was always present to ensure measurement quality and to organize the test setting.

Data analysis

MC was expressed in age- and gender-specific motor quotient (MQ) categories. Based on the time to complete the AST, MQ-scores were generated with the following formula: MQ = (50th percentile AST/time AST) × 100.[58] AST time below the 25th percentile of AST norm values (corresponding with MQ categories very low and low) was categorized as 'low', an AST time between the 25th and the 75th percentile of the norm values (corresponding with MQ category normal) was classified as 'normal', and an AST time above the 75th percentile of the norm values (corresponding with MQ categories high and very high) was classified as 'high'. Subsequently, patterns of MC development were defined based on the changes in MQ categories between T0 and T1 and between T1 and T2. The definition of an undesirable pattern is extensively described by Koolwijk and colleagues (2024)[14] and is based on a combination of the course of the absolute MQ scores and their categories over time.

The sum scores of PMC and PA enjoyment were categorized as 'low', 'middle', or 'high'. PMC scores were calculated for LOC skills (n = 6) and OC (n = 6) skills separately. Sports participation was categorized as 'yes' (positively) or 'no' (negatively). BMI was calculated by dividing body weight (kg) by the square of the body height (m) while controlling for gender and age. Next, BMI was categorized into three meaningful categories, i.e., normal weight, overweight and obese, based on age- and gender-related cut off values.[66] High PMC, high PA enjoyment, normal weight status, and active sports club participation were included in the models as reference categories.

First, Spearman's correlation coefficients were calculated for the correlations between PMC and PA enjoyment scores and to check for multicollinearity. To establish individual characteristics of AMC development, data was analyzed using linear mixed-effect (LME) models with continuous MQ scores on T0 and T2 as outcome variables. PMC, PA enjoyment, weight status, and sports participation were modeled as categorical exposure variables at both timepoints. Additionally, linear trends were explored for PMC, PA enjoyment, and weight status. Subsequently, the interaction of each determinant with time, reflected by the timepoint of data collection, was assessed by comparing the model fit of an LMM including this interaction term with the same model without this interaction term using ANOVA. The results of univariate analyses reflect the effect estimates adjusted for age and gender. As PMC was modeled using the sum of scores of 6 elements, these analyses were adjusted for the number of missing elements. When significant interaction was observed, effect estimates were reported for T0 and T2 separately. All models were adjusted for age and gender since MQ scores are age- and gender-standardized scores.

For significant determinants of AMC, children were grouped according to the change in these determinants between T0 and T2. For example, the categorical change in the determinant 'weight status' could be grouped as 'developed overweight' (increase), or 'developed a normal weight' (decrease) or remained stable (stable). For each of these groups, the proportion of children with AMC development previously classified as 'undesirable' was calculated. Descriptive data analysis was performed with the Statistical Package for the Social Sciences (SPSS version 27.0, 64-bit edition, SPSS Inc., Chicago, IL, USA). p values ≤ 0.05 were considered statistically significant. Regression modeling using the lme4- package and visualizations were obtained with R studio (version 4.2.2, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

In this longitudinal design, our original study population contained 1131 children. After removing outliers based on MQ scores and excluding participants who had not undertaken all measurements at T0 and T2, our study sample consisted of 721 children (50.2% boys). In Table 5.1, sum scores and categorizations of AMC and potential determinants (i.e., PMC, PA enjoyment, organized sports participation, and weight status) are presented for timepoints T0 and T2. PMC and PA enjoyment scores were high at both timepoints, with slightly more variance in PMC scores at T2. The PMC sum scores of LOC skills were moderately correlated with PMC OC skills sum scores (Spearman's rho = 0.54 at T0 and 0.52 at T2, $p < 0.01$) and weakly correlated with the sum scores of PA enjoyment (Spearman's rho = 0.16 at T0 and 0.14 at T2, $p < 0.01$). Since there was no multicollinearity, all potential determinants were entered in the LME models.

Significant determinants of AMC

Two determinants were significantly associated with the MQ score on T0 and T2: weight status and organized sports participation (Figure 5.1). More specifically, overweight, obesity, and no organized sports participation were longitudinally associated with lower MQ scores. Interaction with time was observed only for weight status, and this association increased in strength over time, $\beta = -1.52$ (95% CI = −6.71 to 3.66) for overweight and $\beta = -1.41$ (95% CI = −8.81 to 5.98) for obesity at T0, and $\beta = -7.57$ (95% CI = −12.38 to −2.76) for overweight and $\beta = -10.15$ (95% CI −17.73 to −2.570) for obesity at T2. Multivariate analyses showed that associations of weight status and sports participation with MQ scores remained significant after adjustment for variation in PMC and PA enjoyment.

The proportion of children with an undesirable pattern of MC development was elevated not only when children developed overweight or obesity over time (22.7%) but also in children who had decreased in weight status over time (26.5%) (Table 5.2). With regard to sports participation, the proportion of children with undesirable MC development was also elevated among children who did not participate in organized sports during the full study period, as well as children who stopped participating in sports during the follow-up measurement (24% in both groups).

Table 5.1. Characteristics of AMC and potential determinants at timepoint T0 and T2 (n = 721).

	Timepoint							
	T0				T2			
AMC								
MQ score (Mean (SD))	102.74 (19.5)				102.64 (19.8)			
Categorical (n=721/%) *								
Very low	55		8%		54		7%	
Low	106		15%		103		14%	
Normal	382		53%		381		53%	
High	123		17%		119		17%	
Very high	55		8%		64		9%	
Individual determinants								
PMC per set of skills								
	LOC		OC		LOC		OC	
Sum score (Median (IQR))	21	(18-23)	20	(17-22)	20	(17-22)	19	(17-21)
Categorical (n/%)								
Low (sum score 6-12)	15	2%	27	4%	9	1%	29	4%
Middle (sum score 13- 18)	171	24%	246	34%	258	36%	314	44%
High (sum score 19-24)	535	74%	448	62%	454	63%	378	52%
Enjoyment of PA								
Sum score (Median (IQR))	14 (12-15)				14 (13-15)			
Categorical (n/%)								
Low (sum score 3- 6)	2		<1%		0		0%	
Middle (sum score 7 -11)	131		18%		76		11%	
High (sum score 12-15)	587		81%		644		89%	
Missing	1		<1%		1		<1%	
Weight status								
BMI in kg/m^2 (Median (IQR))	15.44		(14.63-16.6)		15.61		(14.59-16.8)	

Table 5.1. Continued.

	Timepoint			
	T0		T2	
Categorical (n/%)				
Normal weight	630	87%	600	83%
Overweight	60	8%	64	9%
Obesity	27	4%	24	3%
Missing	4	1%	33	6%
Organized sports participation (n/%)				
Yes	253	35%	521	72%
No	465	64%	199	28%
Missing	3	<1%	1	<1%

* Categorical distribution of MQ scores of original study population (n = 1131): 9.7% very low, 14.6% low, 52.0% normal, 15.1% high, and 8.6% very high. AMC: Actual Motor Competence, MQ: Motor Quotient, PMC: Perceived Motor Competence, LOC: Locomotor skills, OC: Object Control skills, PA: Physical Activity, BMI: Body Mass Index.

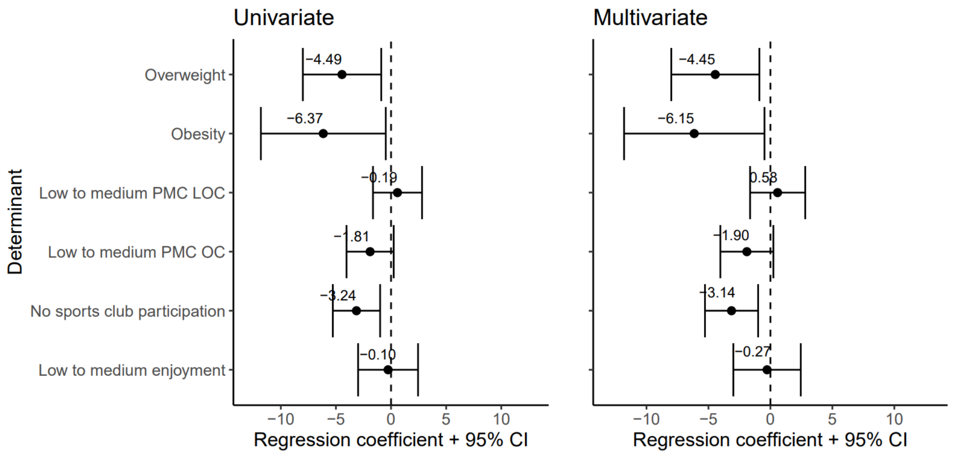

Figure 5.1. Univariate and multivariate associations of measured determinants: weight status (overweight and obesity), PMC (LOC and OC skills), sports participation, and enjoyment of PA, with the MQ scores. For each determinant, positive regression coefficients (β) reflect associations with higher MQ score and therefore a higher motor competence, whereas negative regression coefficients reflect associations with lower MQ scores. Regression coefficients (and confidence intervals) of the fixed effects represent differences in MQ scores between specified determinant and the reference category.

Table 5.2. Categorical changes in determinants by pattern of MC development.

Determinant	Categorical changes over time (T0–T2)	Children with an undesirable Pattern of MC development (%)
Weight status	Increase	22.7
	Decrease	26.5
	Stable	18.7
Organized sports participation	Engaged in sports participation	17.8
	Dropped out sports participation	24.3
	Stable (member)	16.9
	Stable (non-member)	24.2

DISCUSSION

The purpose of this study was to examine individual characteristics of children that might explain the undesirable pattern of MC development during the transition from EC to MCD in this group of children. Almost 19% of the Dutch children showed an undesirable pattern in MC development from EC to MCD.[14] This percentage falls within the range of cross-cultural differences in children's MC development in Europe.[67,68] In southern Europe, approximately 40% of MCD-aged children exhibit worrying MC development against 10% in northern parts of Europe. Our study results reveal that children showing an undesirable pattern of MC development can be recognized by their weight status and sports participation at baseline and undesirable changes between EC and MCD. Excessive weight (overweight and obesity) is associated with lower MQ scores over time. This is in line with previous studies carried out with children in early childhood[29,31,69] and middle childhood,[34,67] as well as during the transition from EC to MCD.[23,28] An unexpected finding was that among a small group of children who decreased in weight status between EC and MCD an undesirable pattern of MC development was seen. A clear explanation is hard to find but may have to do with the chosen cut-off values for BMI classification. It might also be that a higher weight status in the past may negatively affect MC status followed by a delayed development later on. Another explanation may be that these children suffer from an undiagnosed coordinative movement disorder. And finally, it could also be that the neurological motor system needs to adapt after a biomechanical change, just like in puberty, when motor coordination is temporarily disturbed when adolescents suddenly grow.[70]

In our study, an association was found between sports participation and MC development. In the literature, findings are inconsistent. This inconsistency may be due to the overall goal of sports participation for EC-aged children. While some studies emphasize the value of sports participation for learning motor skills and increasing MC,[68,71-75] other studies emphasize the benefits of sports membership on psychological and social outcomes.[76] Our results emphasize that lacking or quitting participating in organized sports can be of risk for MC development. However, children may also withdraw from sports because of their poor motor skills. Therefore, by asking why children stop participating in organized sports, more information can be gathered, which can help sports clubs professionalize and respond to the needs of children.

In summary, our hypotheses that an undesirable course of MC development is related to higher weight status and lower sports participation can be confirmed. The results of this study contribute to Robinson's revised conceptual model,[6] in which children's BMI negatively predicts MC, and sports participation is positively related to MC development over time.

In addition to these main results, other findings regarding potential determinants of MC development are highlighted. With regard to PMC, no significant associations were found between LOC and OC skills scores and MC development over time. As expected, in early childhood, children often confuse the wish to be competent with reality due to a misunderstanding of the content, which leads to overestimation.[77] From MCD, children are better capable of assessing their competencies, as they are more able to compare their abilities with peers based on cognitive development.[78] Within the current study, as children grow older (i.e., timepoint T2), there is considerably more variation in overall reported PMC scores, which suggests more cognitive abilities to reflect their competencies with peers. However, significant associations between PMC/MC during the transition from EC to MCD were not yet found, which is in line with a recent study by Niemistö and colleagues (2023).[27] Finally, the literature has shown that PA enjoyment positively influenced MC and prolonged PA behaviours throughout childhood.[42,79] However, in our data, no such relation was found. Therefore, this part of our hypothesis is rejected. A possible explanation for this finding could be the young age of our study population or the type of assessment used. Positive experiences and enjoyment of physical activities at a young age are important for prolonged sports participation. PE lessons at schools play an important role in providing these experiences. However, within our age category, most of the PE lessons are provided by generalists instead of PE professionals. Observations during PE lessons, conducted in a Dutch study by Adank and colleagues,[80] showed that teaching practices given by PE professionals rather than by generalists are crucial for fostering PE enjoyment. Although this study was conducted with an older population (10–12-year-old children), the results could be applicable to younger children in early and middle childhood.

Limitations

Several important limitations should be considered when interpreting our findings. First, because of the COVID-19 pandemic, all children in the current study experienced a three-month lockdown with restrictions on PA at sports clubs in 2020. Refrainment from PE and sports participation could have impacted drop-out rates in organized sports participation and swimming lessons, as well as prevented children's longitudinal MC development. Secondly, some methodological issues were present due to the assessments used in this study. Within this study, the 4-point (PMC) and 5-point (enjoyment) visual analog assessment tools were carefully chosen for alignment with our young study population. However, due to a lack of variance, group sizes were too small to perform meaningful regression analyses for the children with very low to low PMC or very low to lower PA enjoyment separately. Thirdly, the AST-1 and AST-2 are product-orientated rather than process-oriented MC assessment tools that focus on locomotor and balance skills. The Athletic Skills Track is a convenient, easy-to-administer, low-cost MC tool that can be used repeatedly in the PE setting.[81,82] This contributes to maintaining a high response rate in performing longitudinal research. However, the results might have been different for process-oriented MC values derived by other assessment tools (e.g., the TGMD-3, M-ABC, MOBAK test). In addition, object control skills were not determined. Fourth, with regard to research bias, some remarks need to be made. A significant sample of the original study population was excluded from our analyses because they did not complete all the measurements. Since the distribution of MQ scores in our current study population is similar to our previously conducted longitudinal study, there is no selection bias.

Practical implications and future perspectives

The outcomes of our study highlight the importance for sports and PE professionals to have a child-centered approach to support healthy MC development. Besides high-quality PE lessons and sports programs, children's weight status should be monitored on a regular basis. In the Netherlands, initiatives are growing for schools in low-income neighborhoods to consult a public health advisor or a nutritionist to help create a healthy school policy and provide parental support for questions related to children's health, physical activity, and nutrition. It is also the responsibility of PE teachers and other sports professionals to have a clear overview of the sports network (e.g., sports clubs, playgrounds, and other PA facilities in the neighborhood) of the school population. Eventually, helping young children to orientate on the wide range of sports activities meeting their needs will motivate children to join local sports, PA, and play initiatives.

Further research is needed to better understand long-term MC development from EC to MCD and to adolescence in a changing society where sedentary behaviour is growing. Besides long-term research, differences in MC development may be due to several individual and environmental factors, such as the time allocated to PE during school, the physical home environment, and governmental policy regarding organized sports participation. In this study, PA levels have not been registered. It is, however, interesting to incorporate PA measurements via accelerometery to determine how levels of moderate to vigorous physical activity are associated with undesired MC development and weight status. Besides the level of PA, sedentary behaviour should also be taken into account, since this is also related to MC development.[83] It would also be good to examine the relationship between social and physical environmental determinants and MC development and to pay more attention to gender differences regarding MC development. In general, studies have shown that boys are better at OC skills, whereas girls may be more competent in stability-demanding tasks and LOC skills.[84] Also, boys tend to report higher PMC compared with girls,[85] with differences between countries worldwide.[86] It would be interesting to determine which determinants explain differences in MC development between boys and girls. Finally, researchers and practitioners should develop targeted interventions focusing on the high-risk population highlighted in this study.

CONCLUSIONS

This longitudinal study provides valuable insights into individual characteristics that are associated with an undesirable development of MC during the transition from EC to MCD. Excessive body weight and lack of sports participation between EC and MCD increase the risk of an undesirable MC development. Sport professionals play a crucial role in stimulating MC development from an early age and should especially support this subgroup of children. Further longitudinal research is needed to detect other determinants of undesirable MC development from EC into MCD.

REFERENCES

1. Goldfield, G.S., Harvey, A., Grattan, K., & Adamo, K.B. (2012). Physical activity promotion in the preschool years: A critical period to intervene. *International Journal of Environmental Research and Public Health, 9*, 1326–1342.
2. Jones, D., Innerd, A., Giles, E.L., & Azevedo, L.B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of Sport and Health Science, 9*, 542–552.
3. Wang, J., Qu, S., Zhu, Z., Zhao, X., Song, W., Li, X., Chen, W., & Luo, D. (2023). Global hotspots and trends in research on preschool children's motor development from 2012 to 2022: A bibliometric analysis. *Frontiers in Public Health, 11*, 1118674.
4. Haugland, E.S., Nilsen, A.K.O., Okely, A.D., Aadland, K.N., & Aadland, E. (2023). Multivariate physical activity association patterns for fundamental motor skills and physical fitness in preschool children aged 3–5 years. *Journal of Sports Sciences, 41*, 654–667.
5. Logan, S.W., Webster, E.K., Getchell, N., Pfeiffer, K.A., & Robinson, L.E. (2015). Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: A systematic review. *Kinesiology Review, 4*, 416–426.
6. Robinson, L.E., Stodden, D.F., Barnett, L.M., Lopes, V.P., Logan, S.W., Rodrigues, L.P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*, 1273–1284.
7. Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P., & Gao, Z. (2017). Effects of physical activity on motor skills and cognitive development in early childhood: A systematic review. *BioMed Research International, 2017*, 2760716.
8. Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*, 541–551.
9. Clark, J.E., & Metcalfe, J.S. (2002). The mountain of motor development: A metaphor. *Motor Development Research Review, 2*, 183–202.
10. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Bardid, F. (2020). Global levels of fundamental motor skills in children: A systematic review. *Journal of Sports Sciences, 39*, 717–753.
11. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., Wadsworth, D., Rudisill, M., & Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*, 1609–1618.
12. Henrique, R.S., Bustamante, A.V., Freitas, D.L., Tani, G., Katzmarzyk, P.T., & Maia, J.A. (2018). Tracking of gross motor coordination in Portuguese children. *Journal of Sports Sciences, 36*, 220–228.
13. King-Dowling, S., Proudfoot, N.A., Cairney, J., & Timmons, B.W. (2020). Motor competence, physical activity, and fitness across early childhood. *Medicine & Science in Sports & Exercise, 52*, 2342–2348.
14. Koolwijk, P., De Jonge, E., Mombarg, R., Remmers, T., Van Kann, D., van Aart, I., Savelsbergh, G., & De Vries, S. (2024). Changes in motor competence of 4–8-year-old children: A longitudinal study. *International Journal of Environmental Research and Public Health, 21*, 190.
15. Rodrigues, L.P., Stodden, D.F., & Lopes, V.P. (2016). Developmental pathways of change in fitness and motor competence are related to overweight and obesity status at the end of primary school. *Journal of Science and Medicine in Sport, 19*, 87–92.
16. Niemistö, D., Finni, T., Cantell, M., Korhonen, E., & Sääkslahti, A. (2020). Individual, family, and environmental correlates of motor competence in young children: Regression model analysis of data obtained from two motor tests. *International Journal of Environmental Research and Public Health, 17*, 2548.
17. Schmutz, E.A., Leeger-Aschmann, C.S., Kakebeeke, T.H., Zysset, A.E., Messerli-Bürgy, N., Stülb, K., Arhab, A., Meyer, A.H., Munsch, S., Puder, J.J., & Jenni, O.G. (2020). Motor competence and physical activity in early childhood: Stability and relationship. *Frontiers in Public Health, 8*, 39.
18. Xin, F., Chen, S., Clark, C., Hong, J., Liu, Y., & Cai, Y. (2020). Relationship between fundamental movement skills and physical activity in preschool-aged children: A systematic review. *International Journal of Environmental Research and Public Health, 17*, 3566.
19. Felix, E., Silva, V., Caetano, M., Ribeiro, M.V., Fidalgo, T.M., Neto, F.R., Sanchez, Z.M., Surkan, P.J., Martins, S.S., & Caetano, S.C. (2020). Excessive screen media use in preschoolers is associated with poor motor skills. *Cyberpsychology, Behavior, and Social Networking, 23*, 418–425.
20. Iivonen, S., & Sääkslahti, A.K. (2014). Preschool children's fundamental motor skills: A review of significant determinants. *Early Child Development and Care, 184*, 1107–1126.
21. Ozmun, J.C., & Gallahue, D.L. (2016). Motor development. In *Adapted Physical Education and Sport* (6th ed., p. 375).
22. Veldman, S.L., Jones, R.A., Chandler, P., Robinson, L.E., & Okely, A.D. (2020). Prevalence and risk factors of gross motor delay in pre-schoolers. *Journal of Paediatrics and Child Health, 56*, 571–576.
23. Lima, R.A., Soares, F.C., Queiroz, D.R., Aguilar, J.A., Bezerra, J., & Barros, M.V. (2021). The importance of body weight status on motor competence development: From preschool to middle childhood. *Scandinavian Journal of Medicine & Science in Sports, 31*, 15–22.
24. Barnett, L.M., Webster, E.K., Hulteen, R.M., De Meester, A., Valentini, N.C., Lenoir, M., Pesce, C., Getchell, N., Lopes, V.P., & Robinson, L.E. (2021). Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Medicine, 52*, 875–920.
25. Duncan, M.J., Jones, V., O'Brien, W., Barnett, L.M., & Eyre, E.L. (2018). Self-perceived and actual motor competence in young British children. *Perceptual and Motor Skills, 125*, 251–264.
26. Estevan, I., Menescardi, C., García-Massó, X., Barnett, L.M., & Molina-García, J. (2021). Profiling children longitudinally: A three-year follow-up study of perceived and actual motor competence and physical fitness. *Scandinavian Journal of Medicine & Science in Sports, 31*, 35–46.
27. Niemistö, D., Barnett, L.M., Laukkanen, A., Tolvanen, A., & Sääkslahti, A. (2023). Perceived motor competence in early childhood predicts perceived and actual motor competence in middle childhood. *Scandinavian Journal of Medicine & Science in Sports, 33*, 2025–2038.
28. Barros, W.M.A., da Silva, K.G., Silva, R.K.P., Souza, A.P.d.S., da Silva, A.B.J., Silva, M.R.M., Fernandes, M.S.d.S., de Souza, S. L., & Souza, V.d.O.N. (2022). Effects of overweight/obesity on motor performance in children: A systematic review. *Frontiers in Endocrinology, 12*, 759165.
29. Henrique, R.S., Stodden, D.F., Fransen, J., Feitoza, A.H., Ré, A.H., Martins, C.M., dos Prazeres, T.M.P., & Cattuzzo, M.T. (2020). Is motor competence associated with the risk of central obesity in preschoolers? *American Journal of Human Biology, 32*, e23364.
30. Logan, S.W., Scrabis-Fletcher, K., Modlesky, C., & Getchell, N. (2011). The relationship between motor skill proficiency and body mass index in preschool children. *Research Quarterly for Exercise and Sport, 82*, 442–448.
31. Martins, C., Romo-Perez, V., Webster, E.K., Duncan, M., Lemos, L.F., Staiano, A.E., Okely, A., Magistro, D., Carleva-

5

5

ro, F., & Bardid, F. (2023). Motor competence and body mass index in the preschool years: A pooled cross-sectional analysis of 5545 children from eight countries. *Sports Medicine, 54*, 505–516.

32. Coppens, E., Bardid, F., Deconinck, F.J., Haerens, L., Stodden, D., D'Hondt, E., & Lenoir, M. (2019). Developmental change in motor competence: A latent growth curve analysis. *Frontiers in Physiology, 10*, 1273.
33. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M. A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*, 290–306.
34. Trecroci, A., Invernizzi, P.L., Monacis, D., & Colella, D. (2021). Actual and perceived motor competence in relation to body mass index in primary school-aged children: A systematic review. *Sustainability, 13*, 9994.
35. Estevan, I., & Barnett, L.M. (2018). Considerations related to the definition, measurement and analysis of perceived motor competence. *Sports Medicine, 48*, 2685–2694.
36. Hall, C.J., Eyre, E.L., Oxford, S.W., & Duncan, M.J. (2019). Does perception of motor competence mediate associations between motor competence and physical activity in early years children? *Sports, 7*, 77.
37. Foulkes, J.D., Knowles, Z., Fairclough, S.J., Stratton, G., O'Dwyer, M.V., & Foweather, L. (2021). Is foundational movement skill competency important for keeping children physically active and at a healthy weight? *International Journal of Environmental Research and Public Health, 19*, 105.
38. He, Q., Ng, J.Y., Cairney, J., Bedard, C., & Ha, A.S. (2021). Association between physical activity and fundamental movement skills in preschool-aged children: Does perceived movement skill competence mediate this relationship? *International Journal of Environmental Research and Public Health, 18*, 1289.
39. Strotmeyer, A., Herrmann, C., & Kehne, M. (2022). A longitudinal analysis of reciprocal relationships between actual and perceived motor competencies and physical self-concept in primary-school age children. *Psychology of Sport and Exercise, 63*, 102269.
40. Brian, A., Bardid, F., Barnett, L.M., Deconinck, F.J., Lenoir, M., & Goodway, J.D. (2018). Actual and perceived motor competence levels of Belgian and United States preschool children. *Journal of Motor Learning and Development, 6*, S320–S336.
41. Estevan, I., Molina-García, J., Bowe, S.J., Álvarez, O., Castillo, I., & Barnett, L.M. (2018). Who can best report on children's motor competence: Parents, teachers, or the children themselves? *Psychology of Sport and Exercise, 34*, 1–9.
42. Burns, R.D., Fu, Y., & Podlog, L.W. (2017). School-based physical activity interventions and physical activity enjoyment: A meta-analysis. *Preventive Medicine, 103*, 84–90.
43. Cairney, J., Kwan, M.Y., Velduizen, S., Hay, J., Bray, S.R., & Faught, B.E. (2012). Gender, perceived competence and the enjoyment of physical education in children: A longitudinal examination. *International Journal of Behavioral Nutrition and Physical Activity, 9*, 1–8.
44. Cairney, J., Dudley, D., Kwan, M., Bulten, R., & Kriellaars, D. (2019). Physical literacy, physical activity and health: Toward an evidence-informed conceptual model. *Sports Medicine, 49*, 371–383.
45. Navarro-Patón, R., Lago-Ballesteros, J., Basanta-Camiño, S., & Arufe-Giraldez, V. (2019). Relation between motivation and enjoyment in physical education classes in children from 10 to 12 years old. *Journal of Human Sport and Exercise, 14*, 527–537.
46. Carroll, B., & Loumidis, J. (2001). Children's perceived competence and enjoyment in physical education and physical activity outside school. *European Physical Education Review, 7*, 24–43.

5

47. Dishman, R.K., Motl, R.W., Saunders, R., Felton, G., Ward, D.S., Dowda, M., & Pate, R.R. (2005). Enjoyment mediates effects of a school-based physical-activity intervention. *Medicine & Science in Sports & Exercise, 37*, 478–487.
48. Loprinzi, P.D., Davis, R.E., & Fu, Y. (2015). Early motor skill competence as a mediator of child and adult physical activity. *Preventive Medicine Reports, 2*, 833–838.
49. Monacis, D., Trecroci, A., Invernizzi, P.L., & Colella, D. (2022). Can enjoyment and physical self-perception mediate the relationship between BMI and levels of physical activity? Preliminary results from the regional observatory of motor development in Italy. *International Journal of Environmental Research and Public Health, 19*, 12567.
50. Dapp, L.C., Gashaj, V., & Roebers, C.M. (2021). Physical activity and motor skills in children: A differentiated approach. *Psychology of Sport and Exercise, 54*, 101916.
51. Domville, M., Watson, P.M., Richardson, D., & Graves, L.E.F. (2019). Children's perceptions of factors that influence PE enjoyment: A qualitative investigation. *Physical Education and Sport Pedagogy, 24*, 207–219.
52. McKenzie, T.L., & Lounsbery, M.A. (2013). Physical education teacher effectiveness in a public health context. *Research Quarterly for Exercise and Sport, 84*, 419–430.
53. Van Kann, D., Koolwijk, P., De Kok, T., Vos, S.B., De Vries, S.I., Mombarg, R., Van Aart, I., Savelsbergh, G., Hoeboer, J., & Remmers, T. (2022). Applying an ecosystem approach to explore modifiable factors related to the risk for low motor competence in young children. *Journal of Science and Medicine in Sport, 25*, 890–895.
54. Costa, C.L., Cattuzzo, M.T., Stodden, D.F., & Ugrinowitsch, H. (2021). Motor competence in fundamental motor skills and sport skill learning: Testing the proficiency barrier hypothesis. *Human Movement Science, 80*, 102877.
55. Lopes, L., Santos, R., Coelho-E-Silva, M., Draper, C., Mota, J., Jidovtseff, B., Clark, C., Schmidt, M., Morgan, P., & Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*, 18.
56. Centraal Bureau voor de Statistiek. (2022). *Statusscore per Wijk en Buurt o.b.v. Welvaart, Opleidingsniveau en Arbeid*. Heerlen, The Netherlands: Centraal Bureau voor de Statistiek.
57. Hoeboer, J., Ongena, G., Krijger-Hombergen, M., Stolk, E., Savelsbergh, G., & De Vries, S.I. (2018). The athletic skills track: Age-and gender-related normative values of a motor skills test for 4-to 12-year-old children. *Journal of Science and Medicine in Sport, 21*, 975–979.
58. Hoeboer, J., Krijger-Hombergen, M., Savelsbergh, G., & De Vries, S. (2018). Reliability and concurrent validity of a motor skill competence test among 4-to 12-year old children. *Journal of Sports Sciences, 36*, 1607–1613.
59. Barnett, L.M., Ridgers, N.D., Zask, A., & Salmon, J. (2015). Face validity and reliability of a pictorial instrument for assessing fundamental movement skill perceived competence in young children. *Journal of Science and Medicine in Sport, 18*, 98–102.
60. Lopes, V.P., Barnett, L.M., Saraiva, L., Gonçalves, C., Bowe, S.J., Abbott, G., & Rodrigues, L.P. (2016). Validity and reliability of a pictorial instrument for assessing perceived motor competence in Portuguese children. *Child: Care, Health and Development, 42*, 666–674.
61. Valentini, N.C., Barnett, L.M., Bandeira, P.F.R., Nobre, G.C., Zanella, L.W., & Sartori, R.F. (2018). The pictorial scale of perceived movement skill competence: Determining content and construct validity for Brazilian children. *Journal of Motor Learning and Development, 6*, S189–S204.
62. Hoeboer, J., De Vries, S., Mast, D., & Savelsbergh, G. (2017). Children's enjoyment of a motor skill test in physical education. *Journal of Physical Education Research, 4*, 1–16.

5

63. Read, J.C., MacFarlane, S., & Casey, C. (2002). Endurability, engagement and expectations: Measuring children's fun. In *Papers Presented at Interaction Design and Children* (Vol. 2, pp. 1–23).
64. Sim, G., & Horton, M. (2012). Investigating children's opinions of games: Fun toolkit vs. this or that. In *Proceedings of the 11th International Conference on Interaction Design and Children* (pp. 70–77).
65. Read, J.C. (2008). Validating the fun toolkit: An instrument for measuring children's opinions of technology. *Cognition, Technology & Work, 10*, 119–128.
66. Cole, T.J., Bellizzi, M.C., Flegal, K.M., & Dietz, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ, 320*, 1240.
67. Laukkanen, A., Bardid, F., Lenoir, M., Lopes, V.P., Vasankari, T., Husu, P., & Sääkslahti, A. (2020). Comparison of motor competence in children aged 6-9 years across northern, central, and southern European regions. *Scandinavian Journal of Medicine & Science in Sports, 30*, 349–360.
68. Wälti, M., Sallen, J., Adamakis, M., Ennigkeit, F., Gerlach, E., Heim, C., Jidovtseff, B., Kossyva, I., Labudová, J., Masaryková, D., ... & Scheuer, C. (2022). Basic motor competencies of 6-to 8-year-old primary school children in 10 European countries: A cross-sectional study on associations with age, sex, body mass index, and physical activity. *Frontiers in Psychology, 13*, 804753.
69. Morano, M., Colella, D., & Caroli, M. (2011). Gross motor skill performance in a sample of overweight and non-overweight preschool children. *International Journal of Pediatric Obesity, 6*, 42–46.
70. Caçola, P., Getchell, N., Srinivasan, D., Alexandrakis, G., & Liu, H. (2018). Cortical activity in fine-motor tasks in children with developmental coordination disorder: A preliminary fNIRS study. *International Journal of Developmental Neuroscience, 65*, 83–90.
71. D'Hondt, E., Deforche, B., Gentier, I., De Bourdeaudhuij, I., Vaeyens, R., Philippaerts, R., & Lenoir, M. (2013). A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. *International Journal of Obesity, 37*, 61–67.
72. Henrique, R.S., Ré, A.H., Stodden, D.F., Fransen, J., Campos, C.M., Queiroz, D.R., & Cattuzzo, M.T. (2016). Association between sports participation, motor competence and weight status: A longitudinal study. *Journal of Science and Medicine in Sport, 19*, 825–829.
73. Hudson, K.N., Ballou, H.M., & Willoughby, M.T. (2021). Improving motor competence skills in early childhood has corollary benefits for executive function and numeracy skills. *Developmental Science, 24*, e13071.
74. Queiroz, D.d.R., Ré, A.H.N., Henrique, R.d.S., Moura, M.d.S., & Cattuzzo, M.T. (2014). Participation in sports practice and motor competence in preschoolers. *Motriz: Revista de Educação Física, 20*, 26–32.
75. Salaj, S., Krmpotic, M., & Stamenkovic, I. (2016). Are specific programs a threat to overall motor development of preschool children? *Kinesiologia Slovenica, 22*, 47–55.
76. Harlow, M., Wolman, L., & Fraser-Thomas, J. (2020). Should toddlers and preschoolers participate in organized sport? A scoping review of developmental outcomes associated with young children's sport participation. *International Review of Sport and Exercise Psychology, 13*, 40–64.
77. Harter, S. (1999). *The construction of the self: A developmental perspective*. New York, NY: Guilford.
78. De Meester, A., Barnett, L.M., Brian, A., Bowe, S.J., Jiménez-Díaz, J., Van Duyse, F., Irwin, J.M., Stodden, D.F., D'hondt, E., Lenoir, M., & Haerens, L. (2020). The relationship between actual and perceived motor competence in children, adolescents and young adults: A systematic review and meta-analysis. *Sports Medicine, 50*, 2001–2049.
79. Colella, D., Monacis, D., & d'Arando, C. (2020). Motor performances in relation to perceived physical self-efficacy, enjoyment and BMI in primary school children. *European Journal of Physical Education and Sport Science, 6*.
80. Adank, A.M., Van Kann, D.H., Borghouts, L.B., Kremers, S.P., & Vos, S.B. (2024). That's what I like! Fostering enjoyment in primary physical education. *European Physical Education Review, 30*, 283–301.
81. Hoeboer, J.J.A.A.M. (2019). *The development of the athletic skills track: A new motor competence assessment* (Ph.D. thesis). Vrije Universiteit Amsterdam, Amsterdam, The Netherlands.
82. Klingberg, B., Hoeboer, J.J.A.A.M., Schranz, N., Barnett, L.M., De Vries, S.I., & Ferrar, K. (2019). Validity and feasibility of an obstacle course to assess fundamental movement skills in a pre-school setting. *Journal of Sports Sciences, 37*, 1534–1542.
83. Adank, A.M., Van Kann, D.H.H., Hoeboer, J.J.A.A.M., De Vries, S.L., Kremers, S.P.J., & Vos, S.B. (2018). Investigating motor competence in association with sedentary behavior and physical activity in 7-to 11-year-old children. *International Journal of Environmental Research and Public Health, 15*, 2470.
84. Zheng, Y., Ye, W., Korivi, M., Liu, Y., & Hong, F. (2022). Gender differences in fundamental motor skills proficiency in children aged 3–6 years: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 19*, 8318.
85. Pesce, C., Masci, I., Marchetti, R., Vannozzi, G., & Schmidt, M. (2018). When children's perceived and actual motor competence mismatch: Sport participation and gender differences. *Journal of Motor Learning and Development, 6*, S440–S460.
86. Feitoza, A.H.P., Henrique, R.d.S., Barnett, L.M., Ré, A.H.N., Lopes, V.P., Webster, E.K., Robinson, L.E., Cavalcante, W.A., & Cattuzzo, M.T. (2018). Perceived motor competence in childhood: Comparative study among countries. *Journal of Motor Learning and Development, 6*, S337–S350.

5

Chapter 6

Fundamental movement skill interventions in young children: a systematic review

Pim, P. Koolwijk, Joris, J.J.A.A.M. Hoeboer, Remo, R.M. Mombarg,
Geert, G.J.P. Savelsbergh, Sanne, S.I. de Vries (2023).

International Journal of Sport and Exercise Psychology, 1-23.

ABSTRACT

The aim of this systematic review was to provide an overview of the effectiveness of fundamental movement skill interventions in young children (2–5 years) and to identify elements that determine the effectiveness of these interventions. A systematic literature search was conducted in four electronic databases (PubMed, Academic Search Complete, Education Resources Information Centre and SPORTDiscus). First, intervention-related data (e.g., intervention length, volume, focus, and content) was extracted. Next, the methodological quality and risk of bias of the selected studies were evaluated using a 10-item checklist. Sixteen studies (13 randomised controlled trials and 3 controlled trials) met the inclusion criteria of which 9 had a high methodological quality. Fourteen studies reported statistically significant intervention effects, ranging from small negative to very strong positive effects. Four studies executed a retention test of which two showed positive effects. Elements that influence the effectiveness are: incorporating all fundamental movement skills in the intervention with a variety of activities; combining deliberate practice and deliberate play; the intervention length; the intervention volume and; providing a training programme with coaching during the intervention for the professional involved in delivering the intervention. However more studies containing retention tests are needed.

INTRODUCTION

The foundation for an active lifestyle is formed in early childhood (2–5 years).[1,2,3] Regular physical activity (PA) at young age is associated with several short- and long-term positive health effects on the physiological status[4] and the circulatory systems.[5] Also, there seems to be a positive relationship between being physically active at young age and developing an active lifestyle in adulthood.[6,7,8] For being physically active, developing fundamental movement skills (FMS) in early childhood is critical.[9,10] FMS can be divided into three groups: i.e., object control/ manipulative skills (e.g., throwing, catching, dribbling, kicking, striking, and rolling underhand), locomotor skills (e.g., walking, running, jumping, hopping, leaping, galloping, sliding, and skipping), and balance/ stability skills (e.g., body rolling, bending, dodging, stick balancing, one-foot balancing, stretching, swinging, turning, and twisting).[11] A common misconception is that children learn FMS automatically.[8] A growing body of evidence suggests that an increasing number of children do not obtain proficiency in FMS.[12-17] Although these studies represent different time periods and different countries (Germany, Australia, Finland, and Belgium), in general they report declining levels of children's motor skills competence. These findings are of major concern as children with high FMS have been linked with positive health-related outcomes. Several cross-sectional studies showed a positive association between FMS and PA in youth,[18,19,20] and a few longitudinal studies have found evidence for the suspected causal pathways between FMS and PA.[6,7,9,21,22] The increasing number of young children with low proficiency in FMS emphasise the need to get more insight in this decline and look for working elements in changing these trends. Particularly considering that delayed FMS development at an early age does not diminish with normative growth but may increase in the absence of proper intervention.[10] In recent years several reviews and meta-analyses have been conducted on the effectiveness of FMS interventions in young children. For example, Van Capelle et al. (2017)[23] completed a review and meta-analyses on 20 studies to quantify the improvement in FMS after intervention in 3–5-year-old children. They stated that children should practice at least three times per week, 30 minutes per session. Similar recommendations were formulated by Engel and colleagues in 2018[24] based on their review and meta-analyses of FMS interventions for 3–12-year-old children. Results of 18 studies indicated that training the FMS in pre-schoolers at least three times a week can improve motor skill proficiency as well as increase PA intensity. Finally, Wick et al. (2017)[25] published a review and meta-analyses about FMS enhancing intervention programmes among 2–6 year-old children. A total of 30 studies were included that provided intervention programmes that lasted at least four weeks. Although they found effects of interventions on FMS proficiency in young children, these studies need to be interpreted with care as they are limited by shortcomings in study design. Based on earlier reviews and meta-analyses, it is important that FMS interventions start during preschool and early school years.[13,26]

Next to an early intervention start, the content of an intervention also seems important.[25] According to the review that Riethmuller et al. (2010) conducted,[27] effective FMS interventions consist of a mix of deliberate play (unstructured activities) and deliberate practice (structured activities). Deliberate play is meant to increase motor flexibility and intrinsically motivate to be physically active, which maximises fun and enjoyment and provides immediate fulfilment. Deliberate practice refers to a special type of practice that is purposeful and systematic .[28] While regular practice might include mindless repetitions, deliberate practice requires focused attention and is conducted with the specific goal of improving performance.[29] Next to an early intervention start and intervention content also the professional involved plays an important role for succeeding an intervention. Riethmuller and colleagues (2010)[27] concluded that staff requires substantial training and guidance to increase the effectiveness of FMS interventions. In summary, several reviews and meta-analyses have been conducted on the effectiveness of FMS interventions. There is evidence that FMS interventions can be effective on the short term if they consist of a combination of deliberate play and deliberate practice if they are conducted at least three times per week and if they are supervised by trained staff members. However, a diverse range of study designs, intervention characteristics and assessments used were found.[23,25,27,30,31] Most of these studies provided limited information on the specific elements of the FMS interventions. To further increase the effectiveness of the FMS interventions a better understanding of the underlying working mechanisms is needed. For example, it is not clear which of the specific FMS (intervention focus) should be incorporated to gain the best results and how the FMS could be best instructed (deliberate practice and/or deliberate play). Also, the type of activities (intervention content) needs to be specified in order to optimise the intervention programmes as well as guidelines regarding a minimum intervention length in order to be effective. In addition, also relevant for professionals might be information about the frequency and duration of each intervention session in terms of the weekly intervention volume. Besides the intervention elements, information of which assessment tools are recommended, and what kind of education or training is needed for the professionals that deliver the intervention needs to be provided. In the previous reviews these elements were not described in detail. To our knowledge no studies on the effectiveness of FMS interventions have been reported since the latest review which included studies published before July 2017.[24] Therefore, there were two main objectives of this study: (1) to conduct a systematic review to provide evidence on the effectiveness of FMS interventions in young children (2–5 years); and (2) to identify elements that determine the effectiveness of these interventions.

METHOD

A systematic review was conducted on intervention studies that aimed to enhance FMS levels of young children aged 2–5 years. The guidelines in the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement were followed.[32]

Study inclusion and exclusion criteria

The review was restricted to original peer-reviewed published studies applying the following inclusion criteria: (1) published between January 2000 and December 2022; (2) the intervention focused on typically developing children between 2 and 5 years old (interventions with a target population of 5-year old which extended in time were also included); (3) validated FMS assessments were used (studies using measurement batteries that incorporated an assessment of fine motor skills, health-related fitness or that included a focus on a skill unique to a particular sport were excluded); (4) interventions in which the main component or one of the components focused on the development of FMS (interventions that solely focused on increasing physical activity or preventing obesity were excluded). Furthermore, all settings (e.g., childcare centre, kindergarten, preschool, primary or elementary school, sport clubs) were included and no countries were excluded in the selection process. Studies were excluded if it was a duplicate study, if no full text was available, and if the studies were not original research (i.e., review articles, surveys, conference abstracts, or book chapters). Finally, also studies not published in English were excluded.

Information sources and search strategy

The search strategy was developed by three authors (P.K., J.H., S.d.V.). Four electronic databases were searched by two authors (P.K., J.H.), i.e., PubMed, Academic Search Complete, Education Resources Information Centre (ERIC), and SPORTDiscus. Search terms were divided into three groups: (1) population (i.e., toddler OR toddlers OR children OR child* OR youth* OR school OR primary OR elementary OR pre-school); (2) study design (i.e., random* OR clinic* OR trial OR intervention OR evaluation OR experiment OR programme* OR pilot OR feasibility); and (3) intervention type (i.e., physical activity OR exercise OR motor skill OR movement skill OR fundamental motor skill OR fundamental movement skill OR coordination OR motor competence OR motor development). To combine search terms Boolean operators (AND/OR) were used. The Boolean phrase “AND” was used between groups and the phrase “OR” was used within groups. Both authors checked the initial results and discussed the outcomes. Studies published between January 2000 to December 2022 were included.

Study selection

After searching the databases, first, duplicate studies across databases were identified and excluded by one of the authors (P.K.) Next, two authors (P.K., J.H.) independently screened titles and abstracts of the remaining studies and divided them into two groups: yes or no. Initial consensus was reached in 91% of the screened studies, general agreement was achieved through discussion for the last 9%. Eligible studies selected from the first screening were retrieved and read in full by two authors (P.K., J.H). Additional studies were included based on reference tracking of the included studies.

Data extraction

From all included studies, the following data were extracted by two authors (P.K., J.H.): author, year and country, study design and setting, professional involved in the intervention delivery, training of the intervention professional, total sample size at baseline (boys and girls), age of the study sample (in years), intervention and control group (boys and girls), intervention length (in months), intervention name, intervention volume (duration x number of sessions per week), intervention focus (which FMS, deliberate practice and/or deliberate play), intervention content (specified content), control group information, motor skill assessment, primary outcome (post intervention and after retention), other measurements performed, and secondary outcome (post intervention and after retention). The effect size of the intervention on the primary outcome was registered. If not provided in the study, effect sizes were determined by calculating Cohen's d.[33]

Assessment of methodological quality and risk of bias

The methodological quality of the included studies was assessed by two authors (P.K., J.H.) using a 10-item quality assessment checklist adapted from the Consolidated Standards of Reporting Trials (CONSORT) statement,[34] and used in previous reviews of similar areas.[35,31] The checklist consisted of the following questions listed: (i) Were the key baseline characteristics reported separately for each group? (ii) Was the randomisation procedure clearly described and adequately carried out? (iii) Did the study report the sources and details of FMS assessment and did the instruments have acceptable reliability for the specific age group? (iv) Did the study report dropouts (in numbers and reasons) for participants who did not complete the intervention? (v) Has the process of concealing treatment group identity from outcome assessors, after their treatment assignment through randomisation, to minimise the occurrence of biased assessments been done properly? (vi) Did the study protocol contain a retention test more than 6 months after the pretest? (vii) Is the intention-to treat analysis properly performed in the study? (viii) Are potential confounders be taken in account when analysing the results? (ix) Have the outcomes of the study been presented in detail? (x) Is there a power calculation reported? Each item was scored positive (1) (i.e., criterion was met; low risk of bias) or negative (0) (i.e., criterion was not met; high risk of bias) by both authors independently. If a specific item could not be determined, the item was also considered as potentially high risk when reporting results. In cases of disagreement, consensus was reached by discussion. All positive scores were accumulated. A study was classified as of high methodological quality when it scored ≥5 points for a controlled trial and ≥6 points for a randomised controlled trial, lower scores were classified as studies of low methodological quality.[35] Next to the methodological quality assessment of each included study, the risk of bias of all included studies was assessed and accumulated. Criteria ii, iv, v, vii, and viii were regarded as the most significant items in which bias could have an impact on results. The scoring procedure was identical as the methodology assessment. Differences in assessments were resolved via discussion or by consulting a third author.

RESULTS

The process of identifying relevant studies is shown in the PRISMA flow diagram (see Figure 6.1). The initial search identified 2242 studies. After removing duplicates (n=9), 2184 articles were excluded based on title and abstract. The remaining 49 articles met the inclusion criteria and were assessed for eligibility based on the full texts of these studies. This resulted in the exclusion of another 33 studies. Reference tracking was performed which resulted in including one more study. Two studies have been excluded because the author(s) used an identical sample in the study. In total, 16 studies were included in this review.

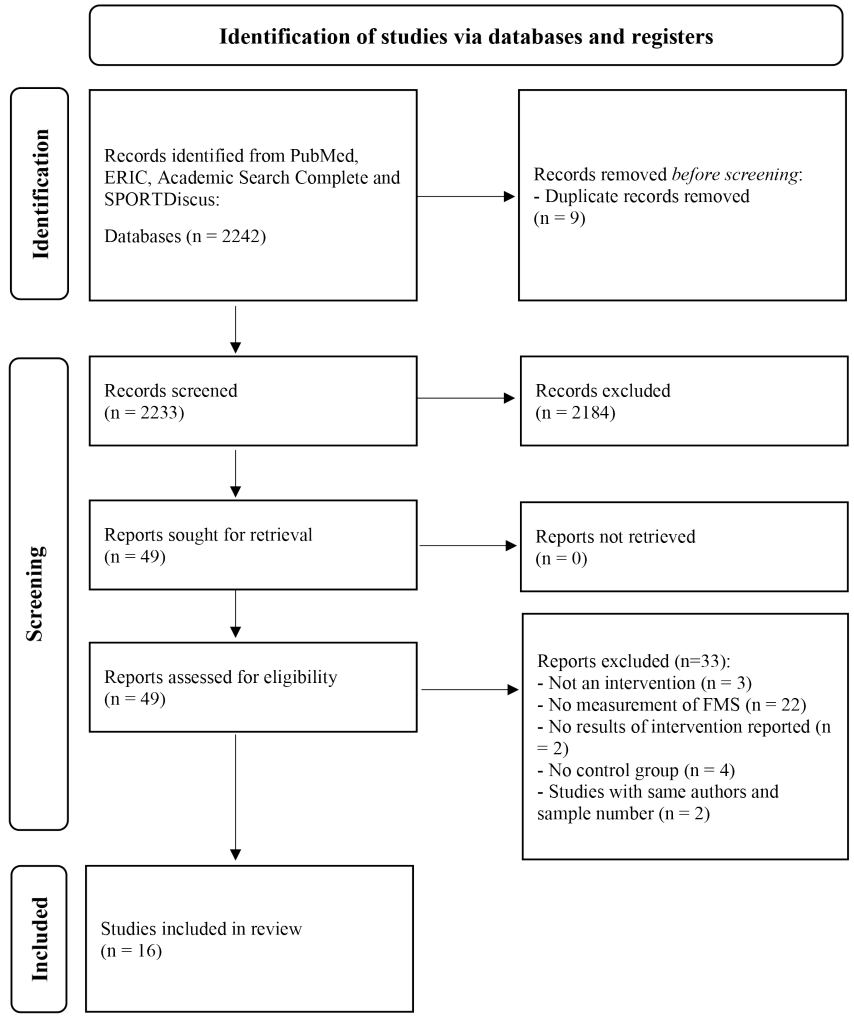

Figure 6.1. PRISMA flow diagram.

Table 6.1. Study characteristics of the 16 included studies.

Reference (author, year, country)	Design	Setting	Professional	Training profess-sional	Total sample	Age	Int. / Con. group	Int. length	Int. name	Int. volume per week	Int. focus	Int. content	Control group information	FMS assess-ment	Primary outcomes	Other measurements	Secondary outcomes
Aivazidis et al., 2019,[36] Greece	RCT	Kinder garten	- PE teachers - School teachers	- 1 day training session - weekly evaluation	n = 140 60 boys 80 girls	to 6-year-old (M=5.1 SD±0.2)	INT n = 74: 30 boys 44 girls CON n = 66: 30 boys 36 girls	8-months	The Walk	- PE sessions (4x p/w, 45-50 min) - recess (5x p/w 15 min)) - walking (1x p/w, 30 min) total: 355 min/w	FMS skills: - object control - locomotor - stability Deliberate practice (PE) Deliberate play (recess)	- PE Lessons: gross motor activities, traditional games, music activities - recess: chases, games with balls, hoops, ropes, e.d.	Received no additional practice	KTK* Product orientated	Post-test: INT > CON (P < .001) for all KTK items d = 3.45	PA: Omron HJ-720IT-E2 piezoelectric pedometers	Post-test: INT > CON (P < .001)
Bardid et al., 2016,[37] Belgium	CT	Sports club Local council School Day care centre	- Sport leaders - School teachers - Care-givers	- 1 day training session - supervision	n = 992 511 boys 481 girls	3-to 8-year-old (M=5.6 SD±1.4)	INT n = 523: 277 boys 246 girls CON n = 469: 234 boys 235 girls	6-months	Multimove for Kids	- Motor skill session (1x p/w, 60 min) total: 60 min/w	FMS skills: - object control - locomotor - stability Deliberate practice	running, climbing, swinging, gliding, rotating, jumping, catching and throwing, pushing and pulling, lifting and carrying, hitting, kicking, dribbling.	Received no additional practice	TGMD-2 Process orientated	Post-test INT > CON (p < .001) for both locomotor and object control skills d = 0.43	x	x
Brian et al., 2017,[38] USA	RCT	School	Class-room teacher	- 6-hour training session - supervision	n = 122 55 boys 67 girls	2-to 7-year-old (M=4.7 SD±2.2)	INT n = 63: 23 boys 40 girls CON n = 59: 32 boys 27girls	2-months	T-SKIP	- PE sessions (2x p/w, 30 min) total: 60 min/w	FMS skills: - object control Deliberate practice	No information provided in article	Received no additional practice	TGMD-2 Object control subscale Process orientated	Post-test INT > CON (p < .001) for object control skills d = 0.59	x	x
Donath et al., 2015,[39] Switzerland	RCT	Kinder garten	Experienced, certified, exercise instructor	No training reported	n = 41 24 boys 17 girls	3-to 5-year-old (M=4.6 SD±1)	INT n = 22: 12 boys 10 girls CON: n=19: 12 boys 7 girls	1.5-months	x	- Motor skill sessions (2x p/w, 30 min) total: 60 min/w	FMS skills: - object control Deliberate practice	ball rolling, throwing and catching, rolling or throwing balls against or into a target, dribbling scoring goals with kicking or rolling	Received instructed and supervised training twice a week	TGMD-2 Object control subscale Process orientated	Post-test INT > CON (p < .001) for object control skills d = 0.77	x	x
Engel et al., 2021,[40] Australia	RCT	Childcare centre (outdoor)	- Exercise phys. researcher - fourth year students	No training reported	n = 66 36 boys 30 girls	3- to 5 year-old (M=4.0 SD±0.6	INT n=49: 26 boys 23 girls CON n= 17: 10 boys 7 girls	3- months	PLAYFun	- Motor skill session (3x p/w, 40 min) total: 120 min/w	FMS skills: - object control - locomotor - stability Deliberate practice and deliberate play	Games, such as bull-rush (run), Jump the River (jump), Hopscotch (hop) and free play	Usual preschool curriculum	TGMD-2 Process orientated	Post-test: INT > CON (p <.001) for object control skills d = 1.06 GMQ total score d = 0.83 Retention test INT = CON	PA: GT3X+ Actigraph accelerometers Anthropometry: height, weight, and waist circumference, calculated BMI	INT > CON for less sedentary behaviour

Table 6.1. Continued.

Reference (author, year, country)	Design	Setting	Professional	Training professsional	Total sample	Age	Int. / Con. group	Int. length	Int. name	Int. volume per week	Int. focus	Int. content	Control group information	FMS assessment	Primary outcomes	Other measurements	Secondary outcomes
Foulkes et al., 2017,[41] UK	RCT	Childcare centre	Childcare centre staff	No training provided	n = 162 86 boys 76 girls	3-to 5-year-old (M=4.6 SD±0.6)	INT n = 71: 33 boys 38 girls CON n = 91: 53 boys 38 girls	1.5-months	Active Play	- Motor skill session (1x p/w, 60 min) total: 60 min/w	FMS skills: - object control - locomotor - stability Deliberate practice	Not reported	Not reported	CMSP Process orientated	Post-test INT = CON Retention test INT = CON d = x	x	x
Jones et al., 2011,[42] Australia	RCT	Childcare centre	Childcare centre staff	4 times a 30-minute training session	n = 97 N boys/ girls: not specified	3-to 5-year-old (M=4.1 SD: Not reported)	INT n = 52 CON n = 45	6-months	Jump Start	- Motor skill session (3x p/w, 20 min) - Unstructured activities, after the structured session total: 120 min/w	FMS skills: - object control - locomotor - stability Deliberate practice (structured lesson) Deliberate play (recess)	- structured lesson focusses on running, catching, jumping kicking and hopping - recess opportunity to practice the skills learnt in the structured lessons	Received no additional practice	TGMD-2 Process orientated	Post-test INT > CON (p < .001) Total outcome d = 0.42	PA: MTI 7164 Actigraph accelerometers Anthropometry: calculated BMI based on Weight and height	PA (counts per minute): INT > CON Anthropometry: INT = CON
Jones et al., 2015,[43] Australia	RCT	Childcare centre	Childcare centre staff	2 times a 90-minute training session - weekly supervision	n = 150 n boys/ girls: not specified	3-to 5-year-old (M=4.0 SD±0.6)	INT n =77 CON n = 73	6-months	Jump Start	- Motor skill session (3x p/w 20 min) - Unstructured activities, after the structured session total: 60 min/w	FMS skills: - object control - locomotor - stability Deliberate practice (structured lesson) Deliberate play (recess)	- structured lesson focusses on running, catching, jumping kicking and hopping - recess offering an opportunity to practice the skills learnt in the structured lessons	Received no additional practice	TGMD-2 Process orientated	Post-test INT = CON Medium effect size of FMS d = 0.23	PA: GT3X+ Actigraph accelerometers	Post-test Medium ES of sedentary behaviour (d=0.42) small ES of time in light-intensity PA (d=0.39) and light-, moderate- and vigorous-intensity PA (d=0.23)
Krneta et al., 2015,[44] Servia	RCT	Kinder garten	Kinesiology professionals	No training reported	n = 68 68 boys	4-to 6-year-old (M=5.9 SD±0.6)	INT n = 37 CON n = 31	9-months	x	Motor skill session (2x p/w, 60 min) total: 60 min/w	FMS skills: - object control - locomotor - stability Deliberate practice	perceptual-motor activities, creative movements, rhythms and dances, stunts, tumbling, and apparatus activities, running, jumping, throwing, games	Received no additional practice	No validated MC assessment tool was described	Post-test INT > CON (p=.001) Total outcome d = 3.54	x	x

Table 6.1. Continued.

Reference (author, year, country)	Design	Setting	Professional	Training profess-sional	Total sample	Age	Int. / Con. group	Int. length	Int. name	Int. volume per week	Int. focus	Int. content	Control group information	FMS assess-ment	Primary outcomes	Other measurements	Secondary outcomes
Matvienko, 2010,[45] USA	RCT	Kinder garten	PE teacher	No training reported	n = 70 35 boys 35 girls	Not reported	INT n = 42 CON n = 28 ? boys/girls	1-month	Nutri active	- daily walk (15 min) - daily motor skill session (30 min) - daily non-structured active play (30 min) - daily classroom activities (30 min) total: 525 min/w	FMS skills: - object control - locomotor - stability Deliberate practice (structured lesson) Deliberate play (unstructured activity)	motor skills including throwing for distance, kicking for accuracy, and various rope-jumping steps. fitness-enhancing activities	Received no additional practice	No validated MC assessment tool was described	Post-test INT > CON (p=.001) Retention test INT > CON (p=.001) d = 0.85	Anthropometry: calculated BMI based on weight and height Body strength: push up, pull up and stranding long jump Endurance: Shuttle run	Post-test BMI: I NT = CON Pull Up: INT=CON Push Up: INT>CON Standing long jump: INT>CON Shuttle run INT=CON (p=.001)
Navarro-Patón et al., 2021[46] Spain	RCT	School	PE teachers	No training reported	n = 152 82 boys 70 girls	4- to 5 year-old (M=5.2 SD±0.54	INT n=76: 40 boys 36 girls CON n=76: 42 boys 34 girls	1.5-months	x	Motor skill session (1x p/w, 40 min) total: 40 min/w	FMS skills: - object control - stability Deliberate practice	Warm-up (5 min), three or four tasks related to the skill to be developed (manual dexterity, pointing and chatting or balance; 30 min) and a cool-down or goodbye activity (5 min).	Received no additional practice (regular program was given i.e., the body and body image, play and movement, daily activity, and personal care and health)	MABC-2 Product orientated	Post-test INT > CON for manual dexterity (p=<0.05) d = 0.30 for aiming and catching (p < 0.001) d = 0.84 for balance (p < 0.001) d = 0.61 total eight test score (p < 0.001) d = 0.88	x	x
Piek et al., 2013,[47] Australia	RCT	School	Classroom teachers	1 day training session	n = 511 257 boys 254 girls	4-to 6-year-old (M=5.4 SD±3.6)	INT and CON: no information provided	2.5-months	Animal Fun program	Not reported	FMS skills: - object control - locomotor - stability Deliberate practice	Trunk and lower limb static balance, dynamic balance, climbing, locomotion walking, jumping, hopping, skipping, throwing, catching, kicking	Not reported	BOT-2SF Product orientated MABC-2 Product orientated	Post-test: INT > CON (p=.001) d = -0.10	x	x
Robinson et al., 2017,[48] Australia	RCT	School	Motor development specialist	No training reported	n = 124 s (M age = 48.14 ± 6.62 months)	3-to 5-year-old (M=4.0 SD±0.6)	INT n = 81 CON n = 43 ? boys/girls	2-months	CHAMP	Motor skill session (2x p/w, 30 min) total: 60 min/w	FMS skills: - object control Deliberate practice	targeted six ball skills - throw, catch, strike off a tee, kick, dribble, and roll	Received no additional practice	TGMD-2 Object control subscale Process orientated	Post-test: INT > CON (p=.005) Retention test INT > CON (p=.005) d = 1.88	x	x

Table 6.1. Continued.

Reference (author, year, country)	Design	Setting	Professional	Training profess-sional	Total sample	Age	Int. / Con. group	Int. length	Int. name	Int. volume per week	Int. focus	Int. content	Control group information	FMS assess-ment	Primary outcomes	Other measurements	Secondary outcomes
Ruiz-Esteban, 2020,[49] Spain	CT	Childcare centre	Childcare centre staff	No training reported	n = 136 66 boys 70 girls	3-to 5-year-old (M=3.2 SD±0.3)	INT n = 28: 14 boys 14 girls CON n =106: 52 boys 56 girls	5-months	x	Motor skill session (2x p/w, 45 min) total: 90 min/w	FMS skills: - object control - locomotor - stability Deliberate practice	walking, running, jumping, rolling, sliding, galloping, leaping, striking, dribbling, kicking, throwing, and catching	Received no additional practice	MSCA Product orientated	Post-test: INT > CON (p=.001) for both leg and arm coord. d = 0.99	x	x
Tortella, 2016,[50] Italy	CT	Kinder garten	Childcare centre staff	No training reported	n = 110 63 boys 57 girls	5-to 6-year-old (M=5.6 SD±0.3)	INT n = 71: 41 boys 30 girls CON n = 39: 22 boys 17 girls	2.5-months	Primo Sport playground	- Motor skill session (1x p/w, 30 min - Unstructured activities session (1x p/w, 30 min) total: 60 min/w	FMS skills: - object control - locomotor - stability Deliberate practice (structured lesson) Deliberate play (unstructured activities)	- structured lessons focus on manual dexterity, mobility and balance - unstructured activities: free play at playground	No activities at the playground	Subscales of M-ABC KTK TMC Product orientated	Post-test: INT > CON (p=.001) d = -0.43	Test of Physical Fitness: Putting a Medicine Ball	Post-test: INT > CON (P < .001)
Toussaint, 2019,[51] the Netherlands	RCT	Childcare centre	Childcare centre staff	2 training session 1 coaching on the job session	n = not specified (Preschools N = 41)	2- to 4-year-old (M not reported)	n = not specified (Preschools INT n = 21 CON n = 20)	4-months	PLAYTOD	Not reported	FMS skills: - object control - locomotor - stability Deliberate play (unstructured activities)	zone 1: cycling, zone 2: obstacle course with jump, climb, crawl, walk, balance and turn. zone 3: experience sensory materials. zone 4: free play	Not reported	SOPLAY protocol Observation Process orientated	INT > CON based on observation d not reported	Physical activity observation	INT > CON based on observation

* KTK = Körper- Koordination Test für Kinder, TGMD-2 = Test of Gross Motor Development-2, SLJ = Standing Long Jump, TMR = Twelve Meter Run, CMSP = Children's Activity and Movement in Preschool Study Motor Skills Protocol, BOT-2SF = Bruininks–Oseretsky Test of Motor Proficiency-version 2 Short Form, MABC-2 = Movement Assessment Battery for Children-version 2, MSCA = McCarthy Children's Psychomotricity and Aptitude Scales, TMC = Test of Motor Competence, SOPLAY = System for Observing Play and Leisure Activity in Youth.

6

Study characteristics

Table 6.1 shows the characteristics of the 16 included studies. Despite the inclusion of studies from 2000 up till 2022, all studies were published between 2010 and 2022. Nine studies were conducted in Europe (studies: 36, 37, 39, 41, 44, 46, 49-51), five studies were conducted in Australia (studies: 40, 42, 43, 47, and 48), and two studies were conducted in the USA (studies 38 and 45). Thirteen studies conducted a randomised controlled trial (studies: 36, 38-48, and 51) and three studies a controlled trial (studies: 39, 49, and 50). The sample size of the studies varied from 41 children (study 39) up to 992 children (study 37). Ten studies had a sample size >n=100 children (studies: 36-38, 41, 43, 46-50). One study didn't report the number of included children in the study (study 51). The age range of the study samples varied between studies, with the most frequent age range between 3-and 5-year-old (studies: 39-43, 46, 48, and 49), two studies focused on 4-to 6-year-olds (studies 44 and 47), two studies on 5-to 6-year-olds (studies 36 and 50), and one study on 3-to 8-year olds (study 37), 2- to 7-year-old (study 38), and 2- to 4-year-old (study 51). One study didn't report the exact age of the included children (study 45).

Intervention setting

Most interventions took place in settings such as kindergarten (studies: 36, 39, 44, 45, and 50), childcare centre (studies: 40-43, 49, and 51) or school (studies: 38, 46, 47, and 48). Only one intervention had a community-based approach (e.g., sports club, local council, school, and day care centre) (study 37). There were no studies that focused on FMS development in the home setting. All interventions were conducted by professional staff of that setting. For example, in the school setting the teacher conducted the intervention. Specialised training for professional staff was offered in seven of the 16 studies prior to the interventions (studies: 36-28, 42, 43, 47, and 51). In one study no training was provided (study 41). The remaining eight studies didn't report about a professional training session prior to intervention delivery (studies: 49, 40, 44-46, 48-50) (see Table 6.1).

6

Interventions

In Table 6.1 the intervention length, volume per week, focus, and content of the interventions are reported. The length of the intervention period varied from one month (study 45) up to nine months (study 44) with an average length of four months. The volume per week (duration x number of sessions per week) was 60 minutes per week in most studies (studies: 37-39, 41, 43, 44, 48, and 50), except for six studies (studies: 36, 40, 42, 45, 46, and 49) which reported a volume of respectively 355, 120, 120, 525, 40, and 90 minutes per week. Two studies did not report the volume of the intervention per week (studies 47 and 51). If not specified in the selected studies, the deliberate practice and/or deliberate play intervention focus was deduced by terms as structured lessons and/or unstructured activities (e.g., recess or free play). In nine studies a deliberate practice programme was evaluated (studies: 37-39, 41, 44, 46-49). The intervention content of the deliberate practice programme focused on all FMS in five studies (studies: 37, 41, 44, 47, and 49). In four studies the deliberate practice programme focused solely on object control and/or stability skills (studies: 38, 39, 46, and 48). There was one study that consisted of a deliberate play condition to improve FMS (study 51). Six studies were based on a mix of deliberate practice and deliberate play conditions (studies: 36, 40, 42, 43, 45, and 50) with one or more structured activities and one or more supervised free play or unstructured activities per week. In all six studies, the programme consisted of activities to improve all FMS.

Motor skill assessment

The tools that were used to measure FMS can be divided into process- and product-orientated measurement tools. A process-orientated assessment evaluates how the skill is being performed while a product-orientated approach evaluates the outcome of a skill performance.[52] From the selected studies, eight interventions were evaluated with a process-oriented assessment whereas five studies used a product-orientated assessment. Of the eight studies that measured FMS with a process-orientated tool, the Test of Gross Motor Development-2 (TGMD-2)[53] was the most common one (studies: 37-40, 42, 43, and 48). One study used the System for Observing Play and Leisure Activity in Youth (SOPLAY)[54] (study 51), and one study used the Children's Activity and Movement in Preschool Study Motor Skills Protocol (CMSP)[55] (study 41). Five studies measured FMS with a product-orientated tool or a combination of tools: Bruininks–Oseretsky Test of Motor Proficiency-version 2 Short Form (BOT-2SF)[56] (study 47), McCarthy Children's Psychomotricity and Aptitude Scales (MSCA)[57] (study 49), Körper Koordination Test für Kinder (KTK)[58] (studies 36 and 50), Movement Assessment Battery for Children-version 2 (MABC-2)[59] (studies 46 and 47), and the Test of Motor Competence (TMC)[60] (study 50). In two studies motor competence assessments were used which were well described but lacked references to validation studies considering these assessment tools (studies 44 and 45). Six studies explicitly reported test-retest reliability scores ranging from moderate to high (r =.61–.94) (studies: 36, 37, 39, 41, 44, and 47). One study reported a "high" test-retest reliability score without reporting actual coefficient scores (study 46). Other studies did not report test-retest reliability scores.

6

Intervention effects

Fourteen studies reported a statistically significant positive effect of the intervention on children's FMS in the post-test (studies: 36-40, 42, 44-51), and two studies reported no statistically significant effect (studies 41 and 43). Four studies executed a retention test (studies 40, 41, 45, and 48). Two of these studies showed a statistically significant effect after retention (studies 45 and 48). In the other studies the effect was no longer statistically significant (study 40 and 41). Effect sizes ranged from small but negative (d=−0.43) to very strong (d =3.54) with 12 studies showing a positive effect size (studies: 36-40, 42, 46, 48, and 49).[33,35,31]

Next to FMS, seven studies reported a secondary outcome. Five studies reported secondary outcomes on PA, which all showed a statistically significant effect of the intervention on PA (studies 36, 40, 42, 43, and 51). Three studies measured children's body mass index (BMI). These studies showed no effect on BMI (studies 40, 42, and 45). Two studies showed a significant effect on physical fitness of the intervention (studies 45 and 50).

Quality assessment

Table 6.2 summarises the criteria and scoring of methodological quality and risk of bias of the 16 studies included in the review. Nine of the 16 studies (56%) had a high methodological quality with a total score ranging from 6 to 8 points on a 10-point scale (studies: 36, 37, 39-43, 46, and 48). The other seven studies had a low methodological quality with scores ranging from 1 to 4 points (studies: 38, 44, 45, 47, 49-51).

Risk of bias

Studying risk of bias shows that 29% of the included studies had some baseline imbalances due to the randomisation process, although bias related to controlling for potential confounders scored high (69%) and was of serious risk. The intention-to-treat analysis in most studies was well documented and relatively low of risk (38%), while the process of concealing treatment group identity from outcome assessors and the reporting of dropouts during the intervention scored high (69%).

6

Table 6.2. Criteria and scoring of methodological quality and risk of bias.

Reference (author, year, country)	i) Key baseline charac-teristics reported separately for each group	ii) Randomi--zation procedure clearly described	iii) Valid measure of FMS	iv) Dropout ≤20% for <6 months follow-up, ≤30% for ≥6 months follow-up	v) Assessor blinding	vi) Motor develop-ment assessed a min of 6 months after pre-test	vii) Intention-to-treat analysis	viii) Potential confoun-ders accounted for in analysis	ix) Summary outcomes presented+ treatment effect + precision	x) Power calcu-l--ation reported	Total score	Classified as high quality (≥5 for controlled trial and ≥6 for a randomized controlled trial)
Aivazidis et al., 2019,[36] Greece	1	1	1	0	0	1	1	1	1	0	7	High
Bardid et al., 2016,[37] Belgium	1	0	1	0	0	1	1	1	1	0	6	High
Brian et al., 2016,[38] USA	0	0	1	0	0	1	0	1	0	0	3	Low
Donath et al., 2015,[39] Switzerland	1	1	1	0	1	0	1	1	1	0	7	High
Engel et al., 2022,[40] Australia	1	1	1	1	1	0	1	0	1	1	8	High
Foulkes et al., 2017,[41] UK	1	1	1	0	0	1	1	0	1	0	6	High
Jones et al., 2011,[42] Australia	0	1	1	1	1	0	1	0	1	0	6	High
Jones et al., 2015,[43] Australia	1	1	1	0	1	1	0	0	1	0	6	High
Krneta et al., 2015,[44] Servia	1	0	0	0	0	1	1	0	1	0	4	Low
Matvienko, 2010,[45] USA	0	0	0	0	0	1	0	1	1	0	3	Low
Navarro-Patón et al.,[46] 2021, Spain	1	1	1	1	0	0	1	0	1	0	6	High

6

Table 6.2. Continued.

Reference (author, year, country)	i) Key baseline charac-teristics reported separately for each group	ii) Randomi-zation procedure clearly described	iii) Valid measure of FMS	iv) Dropout ≤20% for <6 months follow-up, ≤30% for ≥6 months follow-up	v) Assessor blinding	vi) Motor develop-ment assessed a min of 6 months after pre-test	vii) Intention-to-treat analysis	viii) Potential confoun-ders accounted for in analysis	ix) Summary outcomes presented+ treatment effect + precision	x) Power calcu-l-ation reported	Total score	Classified as high quality (≥5 for controlled trial and ≥6 for a randomized controlled trial)
Piek et al., 2013,[47] Australia	0	0	1	0	0	1	1	0	1	0	4	Low
Robinson et al., 2017,[48] Australia	1	1	1	1	1	0	1	0	1	0	7	High
Ruiz-Esteban, 2020,[49] Spain	1	1	1	0	0	0	0	0	1	0	4	Low
Tortella, 2016,[50] Italy	0	0	1	0	0	0	0	0	0	0	1	Low
Toussaint, 2019,[51] The Netherlands	0	1	0	1	0	0	0	0	1	0	3	Low
Risk of bias (%)	**28%**	**28%**	**19%**	**69%**	**69%**	**50%**	**38%**	**69%**	**13%**	**94%**		

6

DISCUSSION

This systematic review examined literature published between January 2000 and December 2022 on FMS interventions in young children (2–5 years). In the majority of the included studies, beneficial effects were found of general FMS interventions mainly focusing on object control skills, combined with either locomotion or stability. This suggests that significant increases in FMS proficiency can be achieved through an intervention. This is in line with previous reviews.[23-25,27,31,61,62] However, there were differences between the intervention studies. Interventions that consisted of a combination of deliberate practice and deliberate play or solely of deliberate practice seem to be more effective than only deliberate play. Deliberate practice is beneficial because of the provision of immediate feedback, time for problem-solving and evaluation, and opportunities for repeated performance to refine behaviour,[63] whereas a deliberate play setting can be characterised by flexibility and enjoyment.[64] A combination of deliberate practice and deliberate play seems effective[65] although at young age varied practice with a focus on deliberate play, fun, and enjoyment should be a bigger part of an intervention than structured and effortful training. Examples of combining deliberate practice and deliberate play in our selected high-quality studies were activities like ball rolling, throwing, and catching, against or into a target, dribbling scoring goals with kicking or rolling during the structured part of the lesson and later (or during recess) offering an opportunity to practice these skills on the playground. Also, a great variety in activities like music activities, traditional games, climbing, swinging, gliding, rotating, jumping, pushing and pulling, lifting and carrying were more often found in the more effective interventions. Weekly volumes ranged from 40 to 525 minutes per week, with the number of sessions ranging from 1 to 5 times a week, and intervention lengths varying from 1 to 9 months. However, for gaining significant results, a minimum of three sessions a week for 30–45 minutes per session is recommended from the high-quality studies. Also, longer intervention lengths (≥6 months) seem to generate better results compared with interventions shorter in length (<2 months). Similar findings were found in previous studies[23,24] however in this review a tendency was noticed with more, slightly shorter intervention sessions (three or four times a week for 30 minutes) being more effective than one (longer) session a week. However, inconsistency in reported intervention characteristics, for example, according to the F.I.T.T (Frequency, Intensity, Type, and Time) principle of exercise prescription[66] makes it difficult to extract the ideal dose–response relationship for the best intervention programme. Professionals (e.g., childcare centre staff, PE teachers, classroom teachers) delivered the interventions in almost all studies. According to Tompsett et al. (2017)[10] specialist-led interventions, taught in conjunction with at-home practice and parent involvement, appeared to be more efficacious in enhancing FMS proficiency than school PE alone. Although one study had a community-based approach (e.g., sports club, local council, school, and daycare centre) remarkably in our studies no parents were involved.

6

Methodological quality of the included studies

Since only nine of the 16 studies were of high methodological quality, caution is required when interpreting individual study results. Well-described study designs and well-described intervention programmes are essential for the assessment of RCT's. The CONSORT guidelines were presented in 2010 to improve the reporting of RCT's. However, some studies have been conducted before the guideline was published and thus may have influenced the quality and bias evaluation due to missing information. A lack of high methodological quality studies was also found in previous reviews.[25,27,31] More high quality research is needed, with more heterogeneous samples, that explore directly which determinants moderate an intervention's efficacy in young children.[35] Regarding the study design, 81% of the included studies were RCT's which is positive, given the fact that a RCT study is the desirable research design to gain objective results. This review revealed that only four studies performed a retention test after the post-test. One of the desired outcomes when conducting an intervention is a long-term effect on FMS proficiency. A research design including a retention test is needed to reveal those long-term effects on FMS proficiency. Another notable aspect of the included studies is the alignment of FMS measurement tools used to evaluate the interventions. In this review 10 different assessment tools were used (i.e., process-, product-orientated, and/or observations). According to Palmer et al. (2021)[52] and Tompsett et al. (2017)[10] the type of assessment used should be taken in consideration when interpreting the results of the evaluated studies, since product- and process-oriented tools assess different elements of FMS. In line with differences between type of assessment used, most severe lagging behind on FMS can be found in intervention studies[67,68] that used process oriented measurements (e.g., opposite leg in front position during overarm throw), while better results are presented in intervention studies which directed their attention towards product-oriented measures (e.g., the amount of positive hits when throwing at a target).[12]

Strengths and limitations of this review

This systematic review has certain strengths. It used a sensitive search strategy to ensure all relevant studies were captured. In addition, a proper review methodology, including full paper assessment and methodological evaluation of the studies was done in an independent standardised way. Furthermore, a unique in-depth-analysis of the intervention elements (e.g., intervention length, volume, focus, and content) was performed to explain possible causes of intervention results. There are a few limitations of this review. Although this review was comprehensive (e.g., no countries were excluded), only studies published in English were included and publication bias related to selective reporting of only positive associations may be possible. Additionally, most studies were conducted in well developed countries, where sedentary lifestyles are rather common among young children and where overweight and obesity rates in children are also high.[69] Pooling intervention data and outcomes from existing studies across the world would provide an insight on the global prevalence and trends of motor development. The partially inadequate description of the studies according to the CONSORT guidelines influenced the risk of bias. A detailed study protocol regarding the randomisation process, reporting of dropouts and controlling for potential confounders would have been beneficial. Regarding the lack of assessor blinding, it should be noted that it is difficult to blind PE teachers, childcare centre staff in relation with participants when a FMS intervention is given. Either way, lack of assessor blinding may have led to bias in the outcome of assessment results, particularly those of a subjective nature. In the included studies there was a limited amount of information on demographic, biological, environmental, social, and psychological confounders that might have influenced the effects of the FMS interventions on young children's FMS. For example, information regarding the type and amount of leisure PA (e.g., playground activity, sport club activities, community programmes) the participants displayed before, and during, the intervention was limited. This information could be valuable for group assignment, but also for looking at confounding. Five studies reported changes in PA levels as a result of the intervention provided. One study (study 43) mentioned increased levels of moderate to vigorous PA, however this was not statistically substantiated. Once PA is objectively measured and becomes a more consistent outcome it will be possible to explore the relationship between mastery in FMS and higher levels of PA participation.[70-72] PA may also act as a confounder for the intervention outcome.[24] One study (study 36) reported that the study population was not allowed to perform activities outside of the intervention programme. Another study (study 40) reported that during the intervention the control population was asked to refrain from any changes in their daily physical and sportive activities during the intervention. Some studies reported no changes in the daily routines of the control group. There was one study which suggested that sport club activities of participants in the control group during the summer could have influenced the results of the control group. However, none of the included studies reported to use physical activity assessment tools such as accelerometers of parental report to check for activities outside the FMS intervention. In future studies, it is recommended to assess and report potential confounders of effects on FMS. Furthermore, no distinction is made in intervention effects between boys and girls because the included studies did not report differences between boys and girls. However, there is growing body of evidence indicating that FMS are better performed by boys than girls in manipulative skills.[73,74] On the other hand, girls are performing better in balancing and locomotor tasks compared with boys.[62] Iivonen and Sääkslahti (2014)[62] suggested in their review that gender differences in motor skills at a young age (2–6 years) are likely to be influenced by environmental rather than biological factors. Therefore, it seems advisable when aiming at FMS improvement to strive for a multi-disciplinary approach including environmental aspects.

Recommendations

Based on this review several recommendations can be done for practitioners improving FMS at young age. First, incorporating all FMS (locomotor-, object control-, and balance skills) with a great variety of activities provided in a practice and play setting is recommended. Second, results indicate that longer interventions (6 months) divided into weekly volumes of at least three relative short sessions of 30–45 minutes training generate better results. Third, implementing a proper motor assessment is useful to objectively determine the results of the intervention. To be able to compare interventions, future studies should provide more information on the content of the interventions. Intervention characteristics such as deliberate practice and deliberate play should be specified since this can be of influence in the outcomings of the intervention programme for young children.[64] Also, general F.I.T.T. principles should be well documented since this can give direction for setting up new interventions and to improve translation of evidence into practice. Besides the specifications of the intervention there is need for alignment on the exact goal of the intervention and the type of assessments used to measure FMS improvement on the short- and, even more important, on the long-term.[75] For measuring the long-term effects, future effect studies of FMS interventions should incorporate a retention test to investigate if the results found are sustainable. Information on potential confounders is also required. Besides the alignment between intervention goal and type of assessment there is also a need for more international agreement regarding the implementation of FMS assessment tools.[69] In 2016, Malina and colleagues stated that studies are largely based on youth in economically better-off, developed countries in the Western culture context.[76] Reaching movement proficiency can be difficult when there is a lack of opportunities for (non-) organised play or when participating in sports is culturally less tolerated. According to Lopes and colleagues (2021)[69] an international field-based assessment tool of FMS would ensure comparability between populations with respect to socio-cultural diversity. Finally, the included high-quality studies reported training sessions for the professionals that delivered the interventions ranging from either a 1-day workshop or a series of brief workshops. It is however remarkable to notice that eight of the included studies did not report any information regarding the content of the training for the professionals. There seems to be no clear consensus about the skills and competences a professional needs to effectively improve young children's FMS levels through interventions. Most likely to have effect, and therefore recommended based on the results of this review, professionals should be trained prior, and coached during, the interventions to gain maximal intervention results.

CONCLUSION

Although effective FMS intervention for young children exists, results from this population should be interpreted with caution because of limited data, variance in research design, and lack of retention. Intervention elements which seem to lead to significant results are characterised by incorporating all FMS with a variety of activities provided in a combination of deliberate practice and deliberate play delivered by trained professionals.

REFERENCES

1. Hesketh, K.R., O'Malley, C., Paes, V.M., Moore, H., Summerbell, C., Ong, K.K., . . . Van Sluijs, E.M. (2017). Determinants of change in physical activity in children 0–6 years of age: A systematic review of quantitative literature. *Sports Medicine, 47*(7), 1349-1374.
2. Robinson, L.E., Stodden, D.F., Barnett, L.M., Lopes, V.P., Logan, S.W., Rodrigues, L.P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273-1284.
3. Tremblay, M.S., Kho, M.E., Tricco, A.C., & Duggan, M. (2010). Process description and evaluation of canadian physical activity guidelines development. *International Journal of Behavioral Nutrition and Physical Activity, 7*(1), 1-16.
4. Gentier, I., D'Hondt, E., Shultz, S., Deforche, B., Augustijn, M., Hoorne, S., . . . Lenoir, M. (2013). Fine and gross motor skills differ between healthy-weight and obese children. *Research in Developmental Disabilities, 34*(11), 4043-4051.
5. Cattuzzo, M.T., dos Santos Henrique, R., Ré, A.H.N., de Oliveira, I.S., Melo, B.M., de Sousa Moura, M., . . . Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *Journal of Science and Medicine in Sport, 19*(2), 123-129.
6. Barnett, L.M., Van Beurden, E., Morgan, P.J., Brooks, L.O., & Beard, J.R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health, 44*(3), 252-259.
7. Lopes, V.P., Rodrigues, L.P., Maia, J.A., & Malina, R.M. (2011). Motor coordination as predictor of physical activity in childhood. *Scandinavian Journal of Medicine & Science in Sports, 21*(5), 663-669.
8. Stodden, D.F., Goodway, J.D., Langendorfer, S.J., Roberton, M.A., Rudisill, M.E., Garcia, C., & Garcia, L.E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306.
9. Barnett, L.M., Salmon, J., & Hesketh, K.D. (2016). More active pre-school children have better motor competence at school starting age: An observational cohort study. *BMC Public Health, 16*(1), 1-8.
10. Tompsett, C., Sanders, R., Taylor, C., & Cobley, S. (2017). Pedagogical approaches to and effects of fundamental movement skill interventions on health outcomes: A systematic review. *Sports Medicine, 47*(9), 1795-1819.
11. Goodway, J.D., Ozmun, J.C., & Gallahue, D.L. (2019). *Understanding motor development: Infants, children, adolescents, adults.* Jones & Bartlett Learning.
12. Bös, K., Worth, A., Heel, J., Opper, E., Romahn, N., Tittlbach, S., . . . Woll, A. (2004). Testmanual des motorik-moduls im rahmen des kinder-und jugendgesundheitssurveys des robert koch instituts. *Haltung Und Bewegung, 24*, 6-41.
13. Hardy, L.L., Reinten-Reynolds, T., Espinel, P., Zask, A., & Okely, A.D. (2012). Prevalence and correlates of low fundamental movement skill competency in children. *Pediatrics, 130*(2), e390-e398.
14. Huotari, P., Heikinaro-Johansson, P., Watt, A., & Jaakkola, T. (2018). Fundamental movement skills in adolescents: Secular trends from 2003 to 2010 and associations with physical activity and BMI. *Scandinavian Journal of Medicine & Science in Sports, 28*(3), 1121-1129.
15. Roth, K., Ruf, K., Obinger, M., Mauer, S., Ahnert, J., Schneider, W., . . . Hebestreit, H. (2010). Is there a secular decline in motor skills in preschool children? *Scandinavian Journal of Medicine & Science in Sports, 20*(4), 670-678.

16. Tester, G., Ackland, T.R., & Houghton, L. (2014). A 30-year journey of monitoring fitness and skill outcomes in physical education: Lessons learned and a focus on the future. *Advances in Physical Education, 2014.*
17. Vandorpe, B., Vandendriessche, J., Lefèvre, J., Pion, J., Vaeyens, R., Matthys, S., . . . Lenoir, M. (2011). The körperkoordinationstest für kinder: Reference values and suitability for 6–12-year-old children in flanders. *Scandinavian Journal of Medicine & Science in Sports, 21*(3), 378-388.
18. Kambas, A., Michalopoulou, M., Fatouros, I.G., Christoforidis, C., Manthou, E., Giannakidou, D., . . . Gourgoulis, V. (2012). The relationship between motor proficiency and pedometer-determined physical activity in young children. *Pediatric Exercise Science, 24*(1), 34-44.
19. Slykerman, S., Ridgers, N.D., Stevenson, C., & Barnett, L.M. (2016). How important is young children's actual and perceived movement skill competence to their physical activity? *Journal of Science and Medicine in Sport, 19*(6), 488-492.
20. Williams, H.G., Pfeiffer, K.A., O'neill, J.R., Dowda, M., McIver, K.L., Brown, W.H., & Pate, R.R. (2008). Motor skill performance and physical activity in preschool children. *Obesity, 16*(6), 1421-1426.
21. Jaakkola, T., & Washington, T. (2013). The relationship between fundamental movement skills and self-reported physical activity during finnish junior high school. *Physical Education and Sport Pedagogy, 18*(5), 492-505.
22. Lima, R.A., Pfeiffer, K., Larsen, L.R., Bugge, A., Moller, N. C., Anderson, L.B., & Stodden, D.F. (2017). Physical activity and motor competence present a positive reciprocal longitudinal relationship across childhood and early adolescence. *Journal of Physical Activity and Health, 14*(6), 440-447.
23. Van Capelle, A., Broderick, C.R., van Doorn, N., Ward, R.E., & Parmenter, B.J. (2017). Interventions to improve fundamental motor skills in pre-school aged children: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport, 20*(7), 658-666.
24. Engel, A.C., Broderick, C.R., van Doorn, N., Hardy, L.L., & Parmenter, B.J. (2018). Exploring the relationship between fundamental motor skill interventions and physical activity levels in children: A systematic review and meta-analysis. *Sports Medicine, 48*(8), 1845-1857.
25. Wick, K., Leeger-Aschmann, C.S., Monn, N.D., Radtke, T., Ott, L.V., Rebholz, C.E., . . . Puder, J.J. (2017). Interventions to promote fundamental movement skills in childcare and kindergarten: A systematic review and meta-analysis. *Sports Medicine, 47*(10), 2045-2068.
26. Logan, S.W., Robinson, L.E., Wilson, A.E., & Lucas, W.A. (2011). Getting the fundamentals of movement: a meta-analysis of the effectiveness of motor skill interventions in childrencch_1307 305.. 315.
27. Riethmuller, A., Jones, R., & Okely, A. (2010). Efficacy of interventions to improve motor development in young children: A systematic review of controlled trials. *Journal of Science and Medicine in Sport,* 12, e83.
28. Güllich, A., Faß, L., Gies, C., & Wald, V. (2020). On the empirical substantiation of the definition of "Deliberate practice"(ericsson et al., 1993) and "Deliberate play"(côté et al., 2007) in youth athletes. *Journal of Expertise, 3*(1), 1-19.
29. Bailey, R., Collins, D., Ford, P., MacNamara, Á, Toms, M., & Pearce, G. (2010). Participant development in sport: An academic review. *Sports Coach UK, 4*, 1-134.
30. Engel, A. (2019). Improving Fundamental Motor Skills in a Preschool Setting (Doctoral dissertation, UNSW Sydney).
31. Veldman, S.L., Jones, R.A., & Okely, A.D. (2016). Efficacy of gross motor skill interventions in young children: An updated systematic review. *BMJ Open Sport & Exercise Medicine, 2*(1), e000067.
32. Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., ... & Moher, D. (2021). Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement. *Journal of clinical epidemiology*, *134*, 103-112.
33. Hox, J.J., Moerbeek, M., & Van de Schoot, R. (2017). *Multilevel analysis: Techniques and applications.* Routledge.
34. Moher, D., Hopewell, S., Schulz, K.F., Montori, V., Gøtzsche, P.C., Devereaux, P.J., ... & Altman, D.G. (2012). CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *International journal of surgery*, *10*(1), 28-55.
35. Van Sluijs, E.M., & Kriemler, S. (2016). Reflections on physical activity intervention research in young people–dos, don'ts, and critical thoughts. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 1-6.
36. Aivazidis, D., Venetsanou, F., Aggeloussis, N., Gourgoulis, V., & Kambas, A. (2019). Enhancing motor competence and physical activity in kindergarten. *Journal of Physical Activity and Health, 16*(3), 184-190.
37. Bardid, F., Lenoir, M., Huyben, F., De Martelaer, K., Seghers, J., Goodway, J.D., & Deconinck, F.J. (2017). The effectiveness of a community-based fundamental motor skill intervention in children aged 3–8 years: Results of the "Multimove for kids" project. *Journal of Science and Medicine in Sport, 20*(2), 184-189.
38. Brian, A., Goodway, J.D., Logan, J.A., & Sutherland, S. (2017). SKIPing with head start teachers: Influence of T-SKIP on object-control skills. *Research Quarterly for Exercise and Sport, 88*(4), 479-491.
39. Donath, L., Faude, O., Hagmann, S., Roth, R., & Zahner, L. (2015). Fundamental movement skills in preschoolers: A randomized controlled trial targeting object control proficiency. *Child: Care, Health and Development, 41*(6), 1179-1187.
40. Engel, A., Broderick, C., van Doorn, N., Hardy, L., Ward, R., Kwai, N., & Parmenter, B. (2021). Effect of a Fundamental Motor Skills Intervention on Fundamental Motor Skill and Physical Activity in a Preschool Setting: A Cluster Randomized Controlled Trial. *Pediatric Exercise Science*, *34*(2), 57-66.
41. Foulkes, J.D., Knowles, Z., Fairclough, S.J., Stratton, G., O'Dwyer, M., Ridgers, N.D., & Foweather, L. (2017). Effect of a 6-week active play intervention on fundamental movement skill competence of preschool children: A cluster randomized controlled trial. *Perceptual and Motor Skills, 124*(2), 393-412.
42. Jones, R.A., Okely, A.D., Hinkley, T., Batterham, M., & Burke, C. (2016). Promoting gross motor skills and physical activity in childcare: A translational randomized controlled trial. *Journal of Science and Medicine in Sport, 19*(9), 744-749.
43. Jones, R.A., Riethmuller, A., Hesketh, K., Trezise, J., Batterham, M., & Okely, A.D. (2011). Promoting fundamental movement skill development and physical activity in early childhood settings: A cluster randomized controlled trial. *Pediatric Exercise Science, 23*(4), 600-615.
44. Krneta, Ž, Casals, C., Bala, G., Madić, D., Pavlović, S., & Drid, P. (2015). Can kinesiological activities change» pure «motor development in preschool children during one school year? *Collegium Antropologicum, 39*(Supplement 1), 35-40.
45. Matvienko, O., & Ahrabi-Fard, I. (2010). The effects of a 4-week after-school program on motor skills and fitness of kindergarten and first-grade students. *American Journal of Health Promotion, 24*(5), 299-303.
46. Navarro-Patón, R., Brito-Ballester, J., Villa, S.P., Anaya, V., & Mecías-Calvo, M. (2021). Changes in Motor Competence after a Brief Physical Education Intervention Program in 4 and 5-Year-Old Preschool Children. *International Journal of Environmental Research and Public Health*, *18*(9), 4988.
47. Piek, J.P., McLaren, S., Kane, R., Jensen, L., Dender, A., Roberts, C., . . . Straker, L. (2013). Does the animal fun

program improve motor performance in children aged 4–6 years? *Human Movement Science, 32*(5), 1086-1096.

48. Robinson, L.E., Veldman, S.L., Palmer, K.K., & Okely, A.D. (2017). A ball skills intervention in preschoolers: The CHAMP randomized controlled trial. *Medicine and Science in Sports and Exercise, 49*(11), 2234-2239.
49. Ruiz-Esteban, C., Terry Andrés, J., Méndez, I., & Morales, Á. (2020). Analysis of motor intervention program on the development of gross motor skills in preschoolers. *International Journal of Environmental Research and Public Health, 17*(13), 4891.
50. Tortella, P., Haga, M., Loras, H., Sigmundsson, H., & Fumagalli, G. (2016). Motor skill development in italian preschool children induced by structured activities in a specific playground. *PLoS One, 11*(7), e0160244.
51. Toussaint, N., Streppel, M.T., Mul, S., Fukkink, R.G., Weijs, P.J., & Janssen, M. (2020). The effects of the PLAYTOD program on children's physical activity at preschool playgrounds in a deprived urban area: A randomized controlled trial. *International Journal of Environmental Research and Public Health, 17*(1), 329.
52. Palmer, K.K., Stodden, D.F., Ulrich, D.A., & Robinson, L.E. (2021). Using process-and product-oriented measures to evaluate changes in motor skills across an intervention. *Measurement in Physical Education and Exercise Science,* 1-10.
53. Ulrich, D.A. (2000). Test of Gross Motor Development Examiner's Manual. Austin. TX:Pro-ED.
54. McKenzie, T.L. (2002). System for observing play and leisure activity in youth (SOPLAY). *Retrieved August, 1*, 2006.
55. Williams, H.G., Pfeiffer, K.A., Dowda, M., Jeter, C., Jones, S., & Pate, R.R. (2009). A field-based testing protocol for assessing gross motor skills in preschool children: The children's activity and movement in preschool study motor skills protocol. *Measurement in Physical Education and Exercise Science, 13*(3), 151-165.
56. Simons, J. (2008). Bruininks oseretsky test of motor proficiency, version 2. *Bruininks Oseretsky Test of Motor Proficiency, Version 2*, 1-43.
57. McCarthy, D. (1972). *McCarthy scales of children's abilities (MSCA).* Psychological Corporation.
58. Kiphard, E.J., & Schilling, F. (2007). *Körperkoordinationstest für kinder: KTK*. Beltz-Test.
59. Henderson, S.E., Sugden, D.A., & Barnett, A.L. (2007). Movement assessment battery for children Harcourt Assessment London.
60. Sigmundsson, H., Lorås, H., & Haga, M. (2016). Assessment of motor competence across the life span: Aspects of reliability and validity of a new test battery. *SAGE Open, 6*(1), 2158244016633273.
61. Eddy, L.H., Wood, M.L., Shire, K.A., Bingham, D.D., Bonnick, E., Creaser, A., . . . Hill, L.J. (2019). A systematic review of randomized and case-controlled trials investigating the effectiveness of school-based motor skill interventions in 3-to 12-year-old children. *Child: Care, Health and Development, 45*(6), 773-790.
62. Iivonen, S., & Sääkslahti, A.K. (2014). Preschool children's fundamental motor skills: A review of significant determinants. *Early Child Development and Care, 184*(7), 1107-1126.
63. Anders Ericsson, K. (2008). Deliberate practice and acquisition of expert performance: A general overview. *Academic Emergency Medicine, 15*(11), 988-994.
64. Pesce, C., Masci, I., Marchetti, R., Vazou, S., Sääkslahti, A., & Tomporowski, P.D. (2016). Deliberate play and preparation jointly benefit motor and cognitive development: Mediated and moderated effects. *Frontiers in Psychology, 7*, 349.
65. Baker, J., & Côté, J. (2006). Shifting training requirements during athlete development: Deliberate practice, deliberate play and other sport involvement in the acquisition of sport expertise. *Essential Processes for Attaining Peak Performance, 1*, 92-109.
66. American College of Sports Medicine. (2012). *ACSM's resource manual for guidelines for exercise testing and prescription.* Lippincott Williams & Wilkins.
67. van Beurden, E., Barnett, L.M., Zask, A., Dietrich, U.C., Brooks, L.O., & Beard, J. (2003). Can we skill and activate children through primary school physical education lessons?"Move it Groove it"—a collaborative health promotion intervention. *Preventive medicine, 36*(4), 493-501.
68. Ré, A.H., Logan, S.W., Cattuzzo, M.T., Henrique, R.S., Tudela, M.C., & Stodden, D.F. (2018). Comparison of motor competence levels on two assessments across childhood. *Journal of sports sciences, 36*(1), 1-6.
69. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., . . . Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*(1), 18.
70. Cliff, D.P., Okely, A.D., Smith, L.M., & McKeen, K. (2009). Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science, 21*(4), 436-449.
71. Graham, M., Azevedo, L., Wright, M., & Innerd, A.L. (2021). The effectiveness of fundamental movement skill interventions on moderate to vigorous physical activity levels in 5-to 11-year-old children: A systematic review and meta-analysis. *Sports Medicine*,1-24.
72. Jones, D., Innerd, A., Giles, E.L., & Azevedo, L.B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of Sport and Health Science, 9*(6), 542-552.
73. Bardid, F., Huyben, F., Lenoir, M., Seghers, J., De Martelaer, K., Goodway, J.D., & Deconinck, F.J. (2016). Assessing fundamental motor skills in belgian children aged 3–8 years highlights differences to US reference sample. *Acta Paediatrica, 105*(6), e281-e290.
74. Bolger, L.E., Bolger, L.A., O'Neill, C., Coughlan, E., O'Brien, W., Lacey, S., & Burns, C. (2018). Age and sex differences in fundamental movement skills among a cohort of irish school children. *Journal of Motor Learning and Development, 6*(1), 81-100.
75. Logan, S.W., Ross, S.M., Chee, K., Stodden, D.F., & Robinson, L.E. (2018). Fundamental motor skills: A systematic review of terminology. *Journal of Sports Sciences, 36*(7), 781-796.
76. Malina, R.M., Cumming, S.P., & e Silva, M.J.C. (2016). Physical activity and movement proficiency: The need for a biocultural approach. *Pediatric Exercise Science, 28*(2), 233-239.

Chapter 7

Epilogue

This dissertation describes the dynamics of motor competence (MC) development from early childhood (EC) to middle childhood (MCD). Being motor competent in early childhood creates a window of opportunity for taking part in physical activities later in childhood and adulthood. However, there is a worrying trend in MC development during childhood.[1,2] This trend shows that, last decades, children struggle more with executing fundamental movement skills (e.g., hopping, dribbling, balancing, throwing and catching) and that general motor fitness levels of children are decreasing.[3,4] A delay in MC development during childhood has a negative impact on the general health status later in life.[5,6,7] Therefore, it is important to support young children to develop their MC. The main research question of this dissertation was:

> How can motor competence be promoted as efficient and effective as possible in early childhood by sport professionals?

To answer this main research question, four sub-questions have been formulated. These sub-questions have been answered in the various chapters of this dissertation. Since there is a lack of insight into how MC develops during early childhood, the first question was: how does MC development proceed from early to middle childhood? (**Chapter 2)**. After we had obtained insight into how MC is developing in early childhood, we have focused on answering the next question: how can children's MC development in early childhood be characterized based on biological, personal and socio-demographic determinants? (**Chapters 3 and 4**). In order to clarify the dynamics of determinants associated with MC development, the follow-up question was: how can children with an undesirable MC development during the transition from early to middle childhood be identified? (**Chapter 5**). The last sub-question was: what is the effectiveness of fundamental movement skills interventions in young children? (**Chapter 6**). By answering these sub-questions sport professionals have information on *how* to promote motor competence in early childhood (EC)-aged children and *on whom to focus*.

How does MC development proceed from early to middle childhood?

Chapter 2 presents a longitudinal study that describes different desirable and undesirable patterns of MC development from early to middle childhood. Data were collected in three consecutive years, between February 2020 (timepoint 0) and May 2022 (timepoint 2). A total of 1128 typically developing Dutch children (50.2% male) between 4 and 6 years old at baseline (M = 5.35 ± 0.69 years) participated in this study. MC was measured with the Athletic Skills Track and converted into motor quotient (MQ) scores. Proceeding of MC development was analysed by examining changes in MQ categories (categories ranging from 1 to 5) between the three different timepoints. A total of 11 different developmental patterns were found. When grouping the different patterns, five undesirable patterns of MC development were found between T0 and T2 among 18.2% of the children.

The patterns of motor development of the other children showed a normal or fluctuating course over time.

How can children's MC development in early childhood be characterized based on biological, personal and socio-demographic determinants?

In chapter 3 we assessed the differences in actual motor competence (AMC), perceived motor competence (PMC) and enjoyment of physical activity (PA) among 1708 children aged 4-6 years old with different weight status. Results of this study showed that there were no significant differences in AMC and PMC between children of different sex, ages (4, 5 and 6 years), and weight status. MC development could not be characterized based on PMC or enjoyment of physical activities. However, there was a significant two-way interaction effect for enjoyment of physical activity and weight status. Children with obesity more often experienced less enjoyment during PA than children with another weight status.

In the next chapter (4) we looked at social and physical environmental factors associated with MC. In this chapter we explored the association between parenting practices, characteristics of the home environment, parental perceptions of the direct living environment and the odds for low versus high MC in a sample of 612 4- to 6-year-old children. Results showed that several characteristics of the social and physical home environment and direct living environment were associated with MC disparities during early childhood: the presence of a garden at home and having access to sports facilities in the direct living environment decreased the likelihood of children being classified as having a low MC. Moreover, stronger parental active transportation routines and more discouraging physical activity parenting practices resulted in lower odds of having a low MC. In addition, girls were more at risk for having a low MC. In conclusion, both parenting practices and parental physical activity-involved behaviour are relevant modifiable factors related to children's MC.

How can children with an undesirable MC development during the transition from early to middle childhood be identified?

After getting more insight in children's MC development, our next challenge was to characterize children whose MC development is lagging behind. Therefore, in chapter 5, the relation between biological, personal and socio-demographic determinants and an undesirable course of MC development during the transition from EC to MCD has been examined. AMC, PMC, physical activity enjoyment, weight status and organized sports participation of 721 children aged 4-6 years old were measured at two points in time, separated by a two-year interval. Overweight, obesity and lack of organized sports participation were associated with lower MQ scores over time. In other words, excessive body weight and lack of sports participation from early childhood increase the risk of an undesirable MC development over time.

What is the effectiveness of fundamental movement skills interventions in young children?

After getting more insight in children's MC development from EC to MCD and identifying profiles of children with an undesirable MC development, in chapter 6 possible solutions are presented. A systematic review has been conducted to provide an overview of the effectiveness of fundamental movement skills interventions in young children (2–5 years) and to identify elements that determine the effectiveness of these interventions. Elements that influence the effectiveness are: the type of fundamental movement skills and the variety of activities provided; the combination of deliberate practice and deliberate play; the intervention length; the intervention volume, and the training program provided for the professional involved in delivering the intervention. In summary, implementing an intervention with varied fundamental movement skills for at least 3 to 4 times a week for a relatively short duration (30 minutes per session) seems to be the most effective to stimulate MC development. Also, combining deliberate practice and deliberate play will increase the likelihood for children to enhance MC development. Finally, education (training and coaching) for sport professionals who deliver the intervention is essential.

7.1 MAIN CONCLUSION

In sum, the goal of this dissertation was to increase our insight into the way MC can be promoted as efficient and effective as possible in early childhood by sport professionals. Chapter 2 showed that MC development from early to middle childhood proceeds with variation. The majority of the children had a stable 'normal' or increasing 'high' development of MC over time. However, a concerning level of 18.2% of the young children showed an undesirable pattern (i.e., a negative course of motor development over time and a 'low' MQ score during the final measurement) of MC development as they grow older. Chapters 3 and 4 showed that characteristics of the social and physical home environment and direct living environment were associated with MC disparities during early childhood. Both parenting practices and parental PA-involved behaviours were relevant modifiable factors. For example, stronger parental active transportation routines and PA parental practices decreased the odds of a lower MC. Also, the presence of a home garden decreased the likelihood of children being classified as low motor competent. With regard to gender differences, girls showed lower levels of MC compared to boys. Special attention should also be paid to obese children as they experience less enjoyment of PA compared with normal weighted peers (chapter 3). Excessive body weight is also a risk factor associated with an undesirable MC development, just like lack of sports participation (chapter 5). Intervention strategies (chapter 6) incorporating all fundamental movement skills with a great variety of activities for at least 3 to 4 times a week seem to be most effective to stimulate MC development. Methodological and didactical aspects like deliberate practice and play should be implemented together with training and coaching sessions for sport professionals to increase the effectiveness of the interventions. With respect to the efficiency of promoting MC development, policy makers and sport professionals should pay more attention on early childhood and especially focus on those children at risk for a delay in MC development. So, overweighted children and children not participating in organized sports should be given more attention by sport professionals. Additionally, the effectiveness of MC interventions can be increased by making use of the home environment, childcare context and school context of young children. Sport professionals can act as connectors between parents, school, and sports clubs.

7.2 THEORETICAL CONSIDERATIONS

In order to support or change children's MC development, sport professionals should intervene as early as possible, on children at risk, and in the contexts where young children spent a significant part of their time, e.g., the home environment, childcare context and school context of young children. Also, attention should be given to modifiable determinants in these contexts to support children to develop their MC. According to Bronfenbrenner's ecological systems theory[8] the environment in which children grow up influences their MC development. This theory, depicted in figure 7.1, places the individual in the middle, surrounded by the different system levels (e.g., the micro-, meso-, exo-, macro and chronosystem) and the associated factors the individual is influenced by.

The first level, close to the core of the model, the microsystem, contains the most direct determinants that influence the individual, such as the parents, siblings, neighbours and friends. The second level, the mesosystem, aggregates two or more microsystems, such as child-home, child-school, and school-home relations. In addition, the different levels are interrelated and also influence each other. The further from the core, the more abstract the influences become. Therefore, in this dissertation the focus was on modifiable determinants in the microsystem and, to a lesser extent, in the mesosystem. Based on systematic reviews and meta-analyses,[10,11,12] several biological, personal and socio-demographic determinants have been found to be related to children's MC: age (increasing), weight status (healthy), sex (male), socioeconomic background (higher), and the home environment. Additionally, PA, physical education (PE) and sports participation are also associated with MC. Based on this dissertation determinants such as enjoyment of physical activities and parental practices on MC should also be included in the model. Our study results show that parenting style (e.g., active behaviour by parents) and physical home environment (e.g., the presence of a back garden) affect MC development in a positive way. When looking at the macrosystem one can imagine that the sports culture and governmental policies with guidelines regarding PA and PE at schools may also affect MC development for boys and girls.

On playgrounds in the Netherlands, boys are more active than girls and boys usually practice more object-control skills (e.g., soccer) while girls tend to practice more locomotor related games or gymnastic related skills.[13] Finally, the chronosystem includes events in the past (or future) which affect MC development. The increased usage of screens and social media, for example, has a tremendous influence on the amount of time children spend playing outdoors[14] and on their motor development.[15,16,17] But also, the COVID-19 pandemic may have affected MC development.[18]

When looking more in depth to the micro- and mesosystem level of Bronfenbrenner's ecological approach[8] the model of Robinson and colleagues can be used.[19] In their revised conceptual model, the relationship between MC, PA, and weight status is depicted. Health-related fitness (HRF) and perceived motor competence (PMC) are suggested as mediating variables in the model. Based on the findings of this dissertation, PMC is not a mediating variable EC-aged children. However, it should be considered to add enjoyment of PA to this model. Although in our study, enjoyment scores have not been significant in distinguishing children with low (versus high) MC development, it was associated with overweight and it remains an important characteristic for maintaining physically active and, thus, stimulating MC in early childhood.[20] Especially during EC, being physically active is foundational for developing MC. Participating in organized sports may also prevent a delay in MC development. In addition, our systematic review revealed that an intervention programme with a certain length, frequency, volume and content can effectively improve MC development.

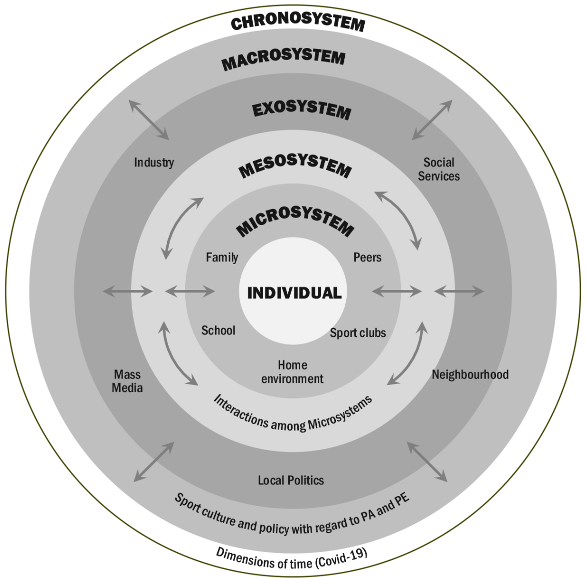

Figure 7.1. Visualization of multiple factors from Bronfenbrenner's ecological model,[9] specified for motor competence development in early childhood. *PA* Physical Activity, *PE* Physical Education.

7.3 METHODOLOGICAL CONSIDERATIONS

In this dissertation several choices have been made with regard to our study protocol. The assessments have been aligned to the young study population. We believed this was fundamental for gaining useful data. On the other hand, gathering data among such a young study population also has some limitations.

For assessing MC, the Athletic Skills Track has been used. The ecological validity of this assessment tool is high[21] which suggests that the test-performance truly reflect the child's motor performance in real life. We are convinced that testing MC by an obstacle course, which consists of a series of detached FMS, closely mimics how those FMS appear in real life. This idea is also in line with how we consider motor competence nowadays. Motor coordination and motor control (e.g., coupling, spatial orientation, and balance ability) are crucial in determining motor competence.[1,5,19,22] However, this assessment tool lacks the measurement of object-control skills as one of the main three FMS categories. Recent literature has also shown differences of object-control skills between boys and girls, even in early childhood[23]. From our study results we are not able to evaluate these object-control skills and accompanied differences, which we consider as a limitation.

Another challenge in our data collection was the COVID-19 pandemic that took place during the Start (V)aardig project. This was a challenging period with temporarily lockdowns of schools and sports clubs, risk of drop-outs due to illness of the children, parents, and research staff and lack of student participation for supervising measurements. In literature, studies are not consistent yet about the consequences of being refrained from PE lessons, organized sports and/or being able to outdoor active play during the pandemic.[18,24,25] For our study the consequences were that we had to spread out the measurements. Our goal was to conduct the assessments in February and March of 2020, 2021 and 2022. However, because of the COVID-19 lockdowns the assessments have been conducted from February till May of each year. How the pandemic has affected the long-term MC development within our study population remains unclear.

Furthermore, doing research with a relatively young study population remains challenging.[26,27] First of all, challenges related to the developmental phase of our population, but also challenges to create involvement from parents in a population with a lot of cultural and socio-economic differences, and policy makers such as a school board, PE teachers and sport professionals. We therefore have chosen to test enjoyment of PA and PMC by using pictorial scales instead of using interview techniques or questionnaires. Less time-consuming test protocols helped to maintain concentration during a PE test lesson. Additionally, before the start of our project, we organized sessions for professionals to create support and involvement.

7.4 RECOMMENDATIONS FOR PRACTICE

Developing MC, as part of developing physical literacy (PL), may occur in different contexts such as PE classes, youth sport programs and/or other settings such as at the home environment and playgrounds.[28] These different contexts all focus on other aspects of PL, have different goals and attract different children. For example, the sport context is more focused on the development of physical competence for athletic competition, while PE tends to emphasize other PL components like knowledge and skills acquisition and their applications.[29] So, in order to facilitate and promote physical literacy and MC development, parents, sport professionals and PE teachers should work together. Parents should be aware of their function as a role model with regard to being physically active, facilitate active transport routines and provide environmental opportunities for their children. Sport professionals should offer lessons and activities which meet the guidelines for effective MC development. PE teachers are responsible for developing a meaningful PE curriculum with high-quality lessons in and outside the walls of the gymnasium. By incorporating PA on the school playground, during school breaks and even in the classroom, a stimulating environment is created for an active start from early childhood.

There's also a responsibility for universities of applied sciences that educate the future sport professionals by embedding the knowledge and understanding with respect to young children's MC development in their curricula. Attention should be given towards recognizing the differences in young children's motor development and by providing the right interventions for those children at risk for a delayed development. Educating students will generate better equipped future professionals.

The outcomes of this dissertation ask for a change in governmental policy. For example, our outcomes show that there is an urge for qualified sport professionals (e.g. PE teachers) from 1st grade children on primary schools. However, there is a shortage of qualified PE teachers in the Netherlands and PE lessons for early childhood children are mostly provided by group teachers. In 2021, only 44% of the PE lessons were (partly) given by or with supervision of a qualified PE teacher.[30] Specialized sport professionals and PE teachers are important for an early detection of children at risk and offering them the right intervention.

In line with a change in policy, local authorities should prioritize sport stimulation from EC by creating sufficient playgrounds especially in neighbourhoods lacking these facilities. Also sport clubs should be well equipped providing affordable programs for EC-aged children stimulating a wide range of fundamental movement skills. The guidelines extracted from chapter 6 advise an activity programme with a frequency of 3 to 4 times a week. Meeting these guidelines can be challenging for parents. Creating an infrastructure offering activities at the contexts where children spent a lot of time, like school or daycare, will help meeting these guidelines.

Finally, within the Dutch health and sports infrastructure, a dialogue should be initiated about who is responsible for the early detection of children at risk for an undesirable MC development. Beside the parents, a lot of specialists (e.g., PE teachers, group teachers, community sport coaches, youth health care professionals) are involved in this age group, but there seems to be a lack of identification, communication and joint policy to actually help children.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

As the lifestyles of the current generation of children and adolescents are substantially different from previous generations, there is a continuous need for the study of the correlates and determinants of MC.[1] Bronfenbrenner's chronosystem,[8] for example, showed that dimensions of time (e.g. Covid-19 pandemic) force researchers to continue their work. Future research should investigate other determinants that may influence MC development. For example, a study recently published by Remmers et al. (2024)[31] unravelled in which (social) contexts throughout the day, PA of young children takes place. How these outcomes are associated with MC development and other determinants needs to be further explored. Also, there is a need for more longitudinal research to get more grip on the transition from early- to middle childhood and how this interacts with the proficiency barrier mentioned before. Longitudinal research can provide answers about what happens with motor development of children not reaching the proficiency barrier.

Also, an 18-week intervention programme has been developed based on the outcomes of our systematic review. This intervention has been enrolled in a sport- and school context. To date, results of the pre-, post- and retention test using the AST and Test of Gross Motor Development-3 seem promising. In addition, in order to acquire more insight into the short- and long-term effects of the intervention, these need to be scaled up in a broader spectrum of organized sports.

This dissertation aimed to enhance our understanding of how sport professionals can efficiently and effectively promote motor competence (MC) in early childhood. MC development varies from early to middle childhood, with most children showing stable or increasing MC, but 18.2% displaying undesirable patterns. Social and physical home environments, including parenting practices and the presence of a garden, significantly influence MC disparities. Obesity and lack of sports participation are risk factors for poor MC development, particularly in girls. Effective interventions involve all FMS related activities practiced for 3 to 4 times a week, focusing on at-risk children. We should develop a sense of urgency for sport professionals to work together with home, childcare, and school environments to positively influence MC development of young children.

REFERENCES

1. Lopes, L., Santos, R., Coelho-e-Silva, M., Draper, C., Mota, J., Jidovtseff, B., Clark, C., Schmidt, M., Morgan, P., & Duncan, M. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health, 18*(1), 18.
2. Mombarg, R., De Bruijn, A., Smits, I., Hemker, B. T., Hartman, E., Bosker, R. J., & Timmermans, A. C. (2023). Development of fundamental motor skills between 2006 and 2016 in Dutch primary school children. *Physical Education and Sport Pedagogy, 28*(6), 583–600.
3. Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., Wadsworth, D., Rudisill, M., & Stodden, D. (2019). Motor competence levels and developmental delay in early childhood: A multicenter cross-sectional study conducted in the USA. *Sports Medicine, 49*(10), 1609–1618.
4. Sugihara, T., Kondo, M., Mori, S., & Yoshida, I. (2006). Chronological change in preschool children's motor ability development in Japan from the 1960s to the 2000s. *International Journal of Sport and Health Science, 4*, 49–56.
5. Barnett, L. M., Webster, E. K., Hulteen, R. M., De Meester, A., Valentini, N. C., Lenoir, M., Pesce, C., Getchell, N., Lopes, V. P., & Robinson, L. E. (2022). Through the looking glass: A systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Medicine, 52*(4), 875–920.
6. Vandoni, M., Marin, L., Cavallo, C., Gatti, A., Grazi, R., Albanese, I., Taranto, S., Silvestri, D., Di Carlo, E., & Patanè, P. (2024). Poor Motor Competence Affects Functional Capacities and Healthcare in Children and Adolescents with Obesity. *Sports, 12*(2), 44.
7. Zacks, B., Confroy, K., Frino, S., & Skelton, J. A. (2021). Delayed motor skills associated with pediatric obesity. *Obesity Research & Clinical Practice, 15*(1), 1–9.
8. Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard university press.
9. Davis, B., & Francis, K. (2023). "Ecological Systems Theory" in *Discourses on Learning in Education*. https://learningdiscourses.com.
10. Barnett, L. M., Lai, S. K., Veldman, S. L., Hardy, L. L., Cliff, D. P., Morgan, P. J., Zask, A., Lubans, D. R., Shultz, S. P., & Ridgers, N. D. (2016). Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. *Sports Medicine, 46*, 1663–1688.
11. Flores, F. S., Rodrigues, L. P., Copetti, F., Lopes, F., & Cordovil, R. (2019). Affordances for motor skill development in home, school, and sport environments: A narrative review. *Perceptual and Motor Skills, 126*(3), 366–388.
12. Lorås, H. (2020). The effects of physical education on motor competence in children and adolescents: a systematic review and meta-analysis. *Sports, 8*(6), 88.
13. Helleman, G., Nio, I., & de Vries, S. I. (2023). Playing outdoors: What do children do, where and with whom? *Journal of Childhood, Education & Society, 4*(3), 322–337.
14. Clements, R. (2004). An investigation of the status of outdoor play. *Contemporary Issues in Early Childhood, 5*(1), 68–80.
15. Felix, E., Silva, V., Caetano, M., Ribeiro, M. V., Fidalgo, T. M., Rosa Neto, F., Sanchez, Z. M., Surkan, P. J., Martins, S. S., & Caetano, S. C. (2020). Excessive screen media use in preschoolers is associated with poor motor skills. *Cyberpsychology, Behavior, and Social Networking, 23*(6), 418–425.
16. Martzog, P., & Suggate, S. P. (2022). Screen media are associated with fine motor skill development in preschool children. *Early Childhood Research Quarterly, 60*, 363–373.
17. Webster, E. K., Martin, C. K., & Staiano, A. E. (2019). Fundamental motor skills, screen-time, and physical activity in preschoolers. *Journal of Sport and Health Science, 8*(2), 114–121.
18. Carballo-Fazanes, A., Rodrigues, L. P., Silva, R., Lopes, V. P., & Abelairas-Gómez, C. (2022). The Developmental Trajectory of Motor Competence of Children That Lived the COVID-19 Confinement Period: A Four-Year Follow-Up Study in Portuguese Children. *Journal of Functional Morphology and Kinesiology, 7*(3), 64.
19. Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273–1284.
20. Monacis, D., Trecroci, A., Invernizzi, P. L., & Colella, D. (2022). Can Enjoyment and Physical Self-Perception Mediate the Relationship between BMI and Levels of Physical Activity? Preliminary Results from the Regional Observatory of Motor Development in Italy. *International Journal of Environmental Research and Public Health, 19*(19), 12567.
21. Hoeboer, J., Krijger-Hombergen, M., Savelsbergh, G., & De Vries, S. (2018). Reliability and concurrent validity of a motor skill competence test among 4-to 12-year old children. *Journal of Sports Sciences, 36*(14), 1607–1613.
22. Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*(4), 541–551.
23. Zheng, Y., Ye, W., Korivi, M., Liu, Y., & Hong, F. (2022). Gender differences in fundamental motor skills proficiency in children aged 3–6 years: a systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 19*(14), 8318.
24. Abe, T., Kitayuguchi, J., Fukushima, N., Kamada, M., Okada, S., Ueta, K., Tanaka, C., & Mutoh, Y. (2022). Fundamental movement skills in preschoolers before and during the COVID-19 pandemic in Japan: a serial cross-sectional study. *Environmental Health and Preventive Medicine, 27*, 26.
25. Den Uil, A. R., Van Doorn, H., Schweitzer, M., Janssen, M., Scholte, R. H., & Busch, V. (2023). The effects of the COVID-19 lockdowns on motor skill development of 6-and 7-year old children in the Netherlands: a longitudinal study. *BMC Public Health, 23*(1),1871.
26. Nagy, Á V., Wilhelm, M., Domokos, M., Győri, F., & Berki, T. (2023). Assessment Tools Measuring Fundamental Movement Skills of Primary School Children: A Narrative Review in Methodological Perspective. *Sports, 11*(9), 178.
27. Piek, J. P., Hands, B., & Licari, M. K. (2012). Assessment of motor functioning in the preschool period. *Neuropsychology Review, 22*, 402–413.
28. Liu, Y., & Chen, S. (2021). Physical literacy in children and adolescents: Definitions, assessments, and interventions. *European Physical Education Review, 27*(1), 96–112.
29. Ennis, C. D. (2015). Knowledge, transfer, and innovation in physical literacy curricula. *Journal of Sport and Health Science, 4*(2), 119–124.
30. Mulier Instituut, (2021). Bewegingsonderwijs en sport in het primair onderwijs 2021: 2-meting. Mulier Instituut sportonderzoek voor beleid en samenleving.
31. Remmers, T., Koolwijk, P., Fassaert, I., Nolles, J., De Groot, W., Vos, S. B., ... & Van Kann, D. H. H. (2024). Investigating young children's physical activity through time and place. *International journal of health geographics*, *23*(1), 12.

Appendices

Nederlandse samenvatting
Dankwoord
About the author
Publications

NEDERLANDSE SAMENVATTING

Jong geleerd is oud gedaan. Dat geldt ook voor bewegen. Als kinderen niet van jongs af aan goed leren bewegen en de juiste fundamentele motorische vaardigheden beheersen, dan is de kans minder groot dat ze een leven lang bewegen. Ook hangen de motorische vaardigheden samen met onze cognitieve en sociaal-emotionele ontwikkeling. Om goed te kunnen bewegen en aanverwante gedragingen te ervaren is motorische vaardigheid voorwaardelijk. Helaas gaat het niet goed met de motorische vaardigheden van kinderen. De laatste decennia laten een (wereldwijde) negatieve trend zien in de motorische ontwikkeling van kinderen, ook voor kinderen in de kleuterleeftijd (4 tot 6 jaar). Deze trend is ook in Nederland te zien en heeft gevolgen voor de gezondheid van kinderen. Zo halen steeds minder kinderen de aanbevolen beweegnorm voor een goede lichamelijke en mentale gezondheid, neemt het zitgedrag onder jonge kinderen toe, net als de schermtijd en social media gebruik. Ook heeft meer dan 1 op de 9 kinderen in de leeftijd van 4 tot 11 jaar overgewicht.

De ontwikkeling van de motorische vaardigheid verloopt via verschillende opeenvolgende fasen (van primaire reflexen kort na de geboorte tot uiteindelijk het uitvoeren van complexe sportactiviteiten op latere leeftijd). De ontwikkeling loopt niet lineair, maar met sprongen. Sommige kinderen slaan bepaalde mijlpalen over en bereiken de mijlpalen in een andere volgorde. Een cruciale fase in de motorische ontwikkeling is het beheersen van de zogenaamde fundamentele motorische vaardigheden. Dit zijn bijvoorbeeld verplaatsen (rennen, springen), balvaardigheden (gooien, vangen, slaan) en balanceren (stoeien, glijden). Literatuur wijst uit dat deze fase ligt rondom de kleuterleeftijd. Het beheersen van deze fundamentele motorische vaardigheden is belangrijk omdat deze de basis vormen voor complexere vaardigheden die nodig zijn voor deelname aan sport- en spelactiviteiten. Immers, een kind moet kunnen rennen om deel te nemen aan voetbal, of kunnen gooien om lid te kunnen worden van de handbalvereniging.

De interesse voor de ontwikkeling van motorische vaardigheden van jonge kinderen is de laatste 10 jaar toegenomen. Toch blijft een aantal vragen onbeantwoord. Zo is er nog relatief weinig bekend over de lange termijn ontwikkeling van de motorische vaardigheid van het jonge kind. Ook zijn de consequenties van het niet, of het niet op tijd, beheersen van de fundamentele motorische vaardigheden onduidelijk. Tevens zijn ook de kenmerken van kinderen bij wie de motorische vaardigheid achterloopt onbekend. Op wie moet je je richten en hoe kun je jonge kinderen met achterblijvende motorische vaardigheden het beste helpen? Daar gaat dit proefschrift over.

Hoofddoel van dit proefschrift

Bij het schrijven van dit proefschrift stond de volgende vraag centraal: hoe kan de motorische vaardigheid van jonge kinderen zo efficiënt en effectief mogelijk gestimuleerd worden door sportprofessionals? Om deze vraag te kunnen beantwoorden is ook een aantal deelvragen geformuleerd.

Hoe verloopt de motorische vaardigheid van jonge kinderen?

In **hoofdstuk 2** van dit proefschrift laten we het verloop van de motorische ontwikkeling bij jonge kinderen zien tussen 4 en 8 jaar. In totaal hebben 1128 kinderen in de leeftijd van 4 tot 6 jaar afkomstig uit de regio's Haaglanden, Groningen en Eindhoven deelgenomen aan dit onderzoek. Met behulp van een gevalideerde en betrouwbare motoriektest, de Athletic Skills Track, werd de motorische vaardigheid score van de kinderen bepaald. Deze score, ook wel de motor quotiënt (MQ) score genoemd, werd gecategoriseerd op basis van leeftijds- en geslachtsgebonden referentiewaarden. Het verloop van de motorische vaardigheid werd geanalyseerd door de verandering in MQ-categorie (categorieën variërend van 1: een ernstig motorische achterstand tot 5: een uitstekende motorische vaardigheid) tussen de drie verschillende meetmomenten (2020, 2021 en 2022) in kaart te brengen. In totaal werden 11 verschillende patronen van ontwikkeling gevonden. Bij het clusteren van de verschillende patronen werden vijf zorgwekkende patronen van motorische ontwikkeling gevonden voor bijna 1 op de 5 kinderen (18,2%). Het verloop in motorische ontwikkeling van de andere kinderen vertoonden een normaal of fluctuerend verloop over de tijd. De uitkomsten van deze studie tonen aan dat er veel variatie is in het verloop van de motorische vaardigheid in de kleuterperiode. Een aanzienlijk deel van de kleuters in dit onderzoek laten een zorgwekkende ontwikkeling in motorische vaardigheid zien. Niet alle kleuters groeien dus zo maar over een achterstand heen. Dit benadrukt de noodzaak voor vroegtijdige signalering en tijdige en gerichte interventies.

Hoe kan de motorische vaardigheid van jonge kinderen worden gekarakteriseerd op basis van biologische, persoonlijke en sociaal-demografische kenmerken?

In **hoofdstuk 3** hebben we de verschillen in objectieve motorische vaardigheid, de ervaren motorische vaardigheid en plezierbeleving tijdens bewegen beoordeeld bij jonge kinderen met verschillende lichaamssamenstelling. In totaal zijn de gegevens geanalyseerd van 1708 kinderen in de leeftijd van 4 tot 6 jaar uit de regio's Haaglanden, Groningen en Eindhoven. Naast de eerder beschreven Athletic Skills Track is de Pictorial Scale of Perceived Movement Skill Competence for Young Children gebruikt om te bepalen hoe de kinderen hun motorische vaardigheid zelf inschatten. Beweegplezier van de kinderen werd gemeten met behulp van een visueel analoge schaal waarbij kinderen met behulp van smileys konden aangeven hoe leuk ze bepaalde sport- en spelactiviteiten vinden. Analyses werden uitgevoerd om de verschillende testscores te vergelijken op basis van geslacht, leeftijd (4, 5 en 6 jaar) en lichaamssamenstelling (normaal gewicht, overgewicht of ernstig overgewicht). De resultaten laten zien dat de objectieve motorische vaardigheid niet samenhangt met de ervaren motorische vaardigheid, het geslacht, de leeftijd of de lichaamssamenstelling van het kind. De uitkomsten laten echter wel zien dat kinderen met ernstig overgewicht minder beweegplezier ervaren vergeleken met kinderen van een normaal gewicht.

In **hoofdstuk 4** hebben we geïnventariseerd of de sociale en fysieke omgeving van kinderen verband houdt met de motorische vaardigheid van jonge kinderen. We onderzochten het verband tussen de opvoedpraktijken van de ouders, kenmerken van de thuisomgeving, de beleving van de ouders van de directe leefomgeving en de kans op een lage of hoge motorische vaardigheid van 612 kinderen van 4 tot 6 jaar oud. De motorische vaardigheid van kinderen werd gemeten via de Athletic Skills Track. Opvoedpraktijken van de ouders, kenmerken van de thuisomgeving en de beleving van de leefomgeving werden uitgevraagd in oudervragenlijsten. De resultaten van deze studie toonden aan dat verschillende kenmerken van de sociale en fysieke thuisomgeving en de directe leefomgeving samenhangen met verschillen in motorische vaardigheid: de aanwezigheid van een tuin bij het huis en toegang tot speelfaciliteiten in de directe leefomgeving verminderen de kans dat kinderen een lage motorische vaardigheid hebben. Bovendien leiden actieve transportgewoonten (lopen en fietsen door ouders) en stimulerende opvoedpraktijken met betrekking tot bewegen van ouders tot een lagere kans op een motorische achterstand. Aanvullend lopen meisjes meer risico op een lage motorische vaardigheid dan jongens. Als uitkomst van deze studie kan geconcludeerd worden dat zowel de opvoedpraktijken als het beweeggedrag van de ouders zelf belangrijke, veranderbare, factoren zijn die verband houden met verschillen in motorische vaardigheid van jonge kinderen.

Hoe kunnen kinderen met een zorgwekkende motorische ontwikkeling van de kleuterleeftijd naar de midden-kindertijd worden gekarakteriseerd?

Na meer inzicht te hebben verkregen in de motorische ontwikkeling van jonge kinderen en hun biologische, persoonlijke en sociaal-demografische kenmerken, was onze volgende uitdaging het karakteriseren van kinderen waarvan de motorische ontwikkeling achterblijft. Daarom is in **hoofdstuk 5** de relatie tussen biologische en persoonlijke determinanten, en een ongewenst verloop van de motorische ontwikkeling tijdens de overgang van de kleuterleeftijd naar de midden-kindertijd onderzocht. De objectieve en ervaren motorische vaardigheid, het beweegplezier, de lichaamssamenstelling en sportdeelname van 721 kinderen werd in kaart gebracht in 2020 en in 2022. (Ernstig) overgewicht en het niet deelnemen aan georganiseerde sport hangen samen met een lagere motorische vaardigheid over de tijd. Met andere woorden, deze twee factoren verhogen de kans op een zorgwekkende motorische ontwikkeling op latere leeftijd.

Wat is de effectiviteit van interventies gericht op verbeteren van de fundamentele motorische vaardigheden bij jonge kinderen?

Nu er meer inzicht is in het verloop van de motorische ontwikkeling in de kleuterperiode en in de kenmerken van kinderen bij wie dit minder gunstig verloopt, is het goed om te weten wat je als sportprofessional dan het beste kunt doen. In **hoofdstuk 6** wordt een aantal handvatten gepresenteerd. In dit hoofdstuk beschrijven we de resultaten van een systematische literatuurstudie naar de effectiviteit en werkzame elementen van beweeginterventies gericht op fundamentele motorische vaardigheden bij jonge kinderen (2-5 jaar). Elementen die de effectiviteit beïnvloeden, zijn: het implementeren van alle fundamentele motorische vaardigheden (verplaatsen, balvaardigheid en balans vaardigheden), de mate van variatie van de aangeboden activiteiten tijdens de interventie, het combineren van enerzijds gericht oefenen met anderzijds het creëren van een uitnodigende beweegsituatie, de duur en de frequentie van de interventie en, tot slot, de begeleiding/ coaching van de professional tijdens het aanbieden van een beweegprogramma voor jonge kinderen. We concluderen dat het aanbieden van een beweeginterventie met een gevarieerd aanbod van alle fundamentele motorische vaardigheden het meest effectief is om de motorische ontwikkeling te stimuleren. Ook zal een combinatie van gericht oefenen en uitnodigende beweegsituaties de motorische vaardigheid van jonge kinderen stimuleren. Tot slot is scholing voor professionals die de interventie aanbieden onmisbaar.

Conclusie van dit proefschrift

Samenvattend was het doel van dit proefschrift om inzicht te krijgen in hoe de motorische vaardigheid van jonge kinderen zo efficiënt en effectief mogelijk gestimuleerd kan worden door sportprofessionals. We hebben aangetoond dat de ontwikkeling van de motorische vaardigheid van jonge kinderen in Nederland varieert. Echter, ongeveer 1 op de 5 jonge kinderen laat een zorgwekkend motorische ontwikkeling zien. Vooral kleuters met (ernstig) overgewicht, die geen lid zijn van een sportvereniging, die geen achtertuin hebben, van wie de ouders bewegen niet stimuleren en zelf ook geen actief voorbeeldgedrag laten zien, hebben extra ondersteuning en stimulering nodig om het risico op een achterblijvende motorische ontwikkeling te verkleinen en de kans op een leven lang bewegen te vergroten. Sportprofessionals kunnen hiervoor korte, gevarieerde, beweegactiviteiten aanbieden, waarbij verschillende fundamentele motorische vaardigheden aan bod komen en gericht oefenen afgewisseld wordt met uitnodigende speel- en beweegsituaties. Tot slot mag scholing voor de professional die het beweegprogramma aanbiedt, niet ontbreken. Zo kunnen we bijdragen aan een leven lang bewegen van jonge kinderen.

&

&

DANKWOORD

Na anderhalf jaar in dienst van De Haagse Hogeschool kreeg ik in het najaar van 2019 de kans een promotieonderzoek te doen. Deze kans om mijzelf uit te dagen en te verdiepen in een interessant en relevant onderwerp heb ik met beide handen aangegrepen. Eén ding is zeker; promoveren doe je niet alleen! Omdat wetenschap niet met de dag komt, het lang kan duren voordat je een succes boekt, heb je mensen om je heen nodig. Mensen die je motiveren en het gevoel geven dat je op de goede weg bent en mensen die je ondersteunen met hun vaardigheden en expertise. Dankzij de samenwerking met en de steun van verschillende mensen, is dit proefschrift tot stand gekomen. Ik wil iedereen bedanken die bijgedragen heeft aan mijn proefschrift.

Allereerst mijn promotor **Geert Savelsbergh**. Onze bijeenkomsten op de VU heb ik als zeer waardevol en prettig ervaren. Dikwijls trapten we af met een degelijke analyse over de staat van het (inter-) nationale voetbal. Wat volgde was jouw typerende nuchtere kijk op onderzoek doen hetgeen mij ontzettend heeft geholpen om de juiste stappen te zetten tijdens mijn proces. Ik ben trots dat ik als een van jouw laatste PhD studenten mag promoveren. Hopelijk kunnen we de samenwerking voortzetten in de toekomst.

Sanne de Vries, mijn copromotor. Jouw vermogen om te schakelen tussen enerzijds projectoverkoepelende zaken en anderzijds de kleinste details van mijn onderzoek, zijn ongeëvenaard. Je hebt mij geholpen in mijn ontwikkeling bij het schrijven van artikelen en geleerd de juiste prioriteiten te stellen gedurende het proces. Jouw wijze van feedback geven heeft mij continu de energie en het vertrouwen gegeven om mijn promotieonderzoek tot een goed einde te brengen. Ondanks je drukke agenda gaf je mij steevast het gevoel er altijd te zijn om even te sparren of te reflecteren op de volgende stap. Hopelijk volgen er nog mooie projecten waar we samen aan kunnen werken.

Dat brengt mij bij mijn andere copromotor, **Remo Mombarg**. Jij hebt mij geleerd autonomie te pakken op mijn eigen PhD traject. Af en toe duizelde het me weleens door alle opties die je mij gaf, bijvoorbeeld over welke analyses ik allemaal kon doen. Maar altijd was er weer die geruststellende zin *"Pim, jij bepaalt de koers en ik zal je steunen"*. Ik waardeer je aanstekelijke humor en je gezonde portie relativeringsvermogen, dit maakte mijn promotieonderzoek tot een traject waar ik met plezier op terug kijk. Op naar nog meer mooie samenwerkingen tussen de Hanze en de Haagse.

Beste leden van de beoordelingscommissie, **prof.dr. J. Seghers**, **prof.dr. B. Steenbergen**, **dr. I. Estevan**, **dr. J.S. Gubbels**, **dr. E. Hartman** en **dr. G.J. van der Kamp**, hartelijk dank voor de tijd en bereidheid dit proefschrift kritisch te lezen en te beoordelen.

Het **Start (V)aardig consortium.** Dit proefschrift is voortgekomen uit een project met een consortium onderzoekers en kennispartners. Jullie expertise en ervaring, de talloze stuur- en projectgroep bijeenkomsten, hebben mij geholpen in mijn ontwikkeling als onderzoeker. Stuk voor stuk ontzettend fijne collega's! Fontys Hogeschool Eindhoven: **Dave Van Kann**, **Teun Remmers** en **Steven Vos.** De collega's van de Hanze Hogeschool Groningen: **Ingrid van Aart, Janco Nolles, Robert de Groot** en **Loes Mombarg.** Hogeschool Windesheim: **Mark de Greeff, Wytse Walinga** en **Nicolette Schipper- van Veldhoven.**

Annemarie de Witte (paranimf), wat een geweldige collega en bovenal fijn mens ben jij! Ik heb jou tijdens een van de heisessies met ons lectoraat omschreven als iemand die ogenschijnlijk complexe zaken doelgericht plat kan slaan tot een simpel pakketje. Met jouw pragmatische aanpak heb je mij op belangrijke momenten een zetje in de goede richting gegeven. Met name bij de totstandkoming van mijn eerste publicatie, maar ook bij de lay-out van dit proefschrift heb je mij veel werk uit handen genomen. **Joris Hoeboer** (paranimf), jij hebt aan de wieg gestaan van mijn promotietraject. Ik koester onze schrijfsessies op de hei die soms tot diep in de nacht doorgingen maar nooit verveelden, onze goede gesprekken over van alles en nog wat, de hardloopsessies tijdens congressen in binnen- en buitenland. We gaan vast nog mooie dingen doen samen.

De Haagse Hogeschool, die als organisatie veel in mij geïnvesteerd heeft. De HALO opleidingsmanager **Guy van der Meulen,** dank voor de vrijheid die je mij hebt gegeven in het doen van mijn promotieonderzoek naast mijn functie als hogeschooldocent. De combinatie van onderwijstaken samen met het doen van onderzoek was soms uitdagend, maar bovenal leuk! Mijn fijne collega's van **team HALO.** Dank voor jullie oprechte interesse! In het bijzonder wil ik mijn collega **Bente van Dijk** bedanken. In het Start (V)aardig project ben je begonnen als testleider in je 3e jaar als HALO student, gevolgd door je scriptie in jaar 4. Daarna een aanstelling als onderzoeksassistente binnen het lectoraat Gezonde Leefstijl in een Stimulerende Omgeving (GLSO) en na je Master, nu als gewaardeerde collega! We hebben wat afgereden tijdens de metingen op de basisscholen en sportverenigingen in Den Haag en Rotterdam. Soms vermoeiend wanneer we op zaterdagochtend naar Den Haag moesten voor weer een test- en meetmoment, soms stressvol om genoeg testleiders bij elkaar te verzamelen maar vaak was het ook erg gezellig. Je hebt ongeloofelijk veel talent en ik ben benieuwd naar wat de toekomst jou gaat brengen.

Mijn collega's van het **lectoraat GLSO**, dank voor jullie opbouwende feedback, het heeft mij doen realiseren hoeveel kwaliteit en expertise er in ons kenniscentrum aanwezig is. **Ester de Jonge**, dank voor je eindeloze geduld tijdens onze statistieksessies en je kritische vragen. Je hebt mij er echt doorheen geholpen. We hebben in menig koffietentje tussen Rotterdam en Utrecht onze laptops opengeklapt voor weer een SPSS of R sessie. Ik kijk er met heel veel plezier op terug.

&

Praktijkgericht onderzoek kan plaatsvinden onder andere door de inzet van het werkveld. Daarom wil ik alle professionals van de deelnemende basisscholen en sportverenigingen bedanken voor hun inzet en betrokkenheid. Fijn om een gezamenlijke passie voor het ontwikkelen van de beweegvaardigheid van het jonge kind te delen. **Chris Hazelebach**, een vakman met passie voor het jonge kind én opleiden. Dank voor de fijne en leerzame gesprekken die we hebben gehad bij het realiseren van de onderwijsmodule voor het jonge kind. Een andere component van praktijkgericht onderzoek zijn de studenten. Samen met een grote groep doortastende, onderzoekende en enthousiaste studenten van de HALO heeft dit onderzoek zo grootschalig kunnen plaatsvinden. En uiteraard alle kinderen en ouders die hebben geparticipeerd in het onderzoek. Voor de kinderen die beweegbaantjes hebben uitgevoerd, lastige keuzes moesten maken bij het aanwijzen van picto's en smileys, rond hebben gelopen met GPS en versnellingsmeters en dan nog de vragenlijsten voor de ouders. Complimenten hiervoor.

Eenieder die ik mogelijk vergeten ben, dank voor jullie bijdrage aan de studies waaraan we samen hard gewerkt hebben.

Lieve vrienden, familie en kennissen, dank jullie wel voor de getoonde interesse in mijn promotietraject. Dank ook voor jullie support. Promoveren is weliswaar werk maar in de privésfeer heeft een promotietraject misschien wel de grootste impact.

Natuurlijk is ook het fijne netwerk van vrienden belangrijk omdat jullie er eigenlijk altijd voor mij zijn. Fijn dat ik met jullie allemaal bevriend mag zijn. Ik zal de komende tijd weer wat meer tijd in jullie investeren. De '**Mannuh Mannuh**' uit Harmelen; ik waardeer jullie interesse. Ik vond het fijn om tijdens onze periodieke ronde tafel diners of weekendjes weg een update te geven over de status van mijn onderzoek.

Rob en **Anton**, ik koester onze waardevolle vriendschap. Alhoewel Groningen vanuit Vleuten een stuk rijden is, voelt het alsof jullie nooit ver weg zijn. Na dit promotietraject komt er meer tijd om leuke dingen te doen met z'n drieën en met de gezinnen erbij.

Mijn schoonfamilie. **Martin**, met jouw achtergrond en expertise in het onderwijs waardeer ik de familiebijeenkomsten waarin we af en toe afdwaalden in dialogen met als doel het onderwijs te verbeteren en waardevol onderzoek na te streven. **Ellie**, dat jij ons op tijd tot de orde riep wanneer we hierin teveel doordraafden. Jullie flexibiliteit bij het oppassen op onze kinderen wanneer ik op congres of aan het schrijven was.

&

Mijn ouders, **Ad en Dorien**. Zonder jullie onvoorwaardelijke steun had ik dit niet bereikt. Altijd geïnteresseerd, trots en steunend als dat nodig was. Een beter voorbeeld kan ik mij niet wensen om je kind de vrijheid te geven om zijn ambities na te jagen. Ik wist van jongs af aan dat ik 'iets met sport en bewegen wilde doen'. Dat traject startte op de MAVO en heeft na een lange reis geleid tot mijn titel als PhD. Dank jullie wel!

Marc, mijn broer, de meest intelligente van ons twee met altijd een brede interesse. Dank dat je mijn grote broer bent en altijd voor mij klaarstaat!

Mijn schatten van kinderen **Sepp en Lise**. Sepp, papa kan hard werken maar, tsjonge, jij werkt echt het hardst van de hele wereld, iedere dag weer. Lise, jij hebt zoveel talenten en ik ben zo nieuwsgierig naar waar jouw passie ligt.

Lieve, **Adinda**, de laatste woorden in mijn boekje zijn voor jou. Ik had het niet beter kunnen treffen. Het geduld dat jij hebt gehad de afgelopen jaren (en ook daarvoor) is indrukwekkend. Ten tijde van mijn metingen brak de corona pandemie uit. Samen vanuit huis werken met allebei een baan in het onderwijs, gecombineerd met onze uitdagende thuissituatie, was pittig. De manier waarop jij het gezin draaiende hebt gehouden wanneer ik een schrijfweek of cursus had, heeft mij ontzettend geholpen. Het achtergrondgeluid van het getik op mijn toetsenbord in de late avonden zal vast niet helemaal stoppen maar wel een stuk minder worden de komende tijd. Dank je wel, ik heb mij altijd gesteund gevoeld zowel in voor- als tegenspoed.

&

&

ABOUT THE AUTHOR

Pim Koolwijk was born on the 24th of January 1976 in Woerden, the Netherlands and grew up in Harmelen. In 1992 he graduated from secondary school (MAVO) followed by the HAVO in 1994. After four years of studying, in 1998, he received his Bachelor of Physical Education at the The Hague University of Applied Sciences. During this study he became fascinated with motor learning and exercise physiology within the context of sport and exercise. He therefore started the study Human Movement Sciences at the Vrije Universiteit in Amsterdam. After a minor sport psychology and a research internship at AFC Ajax he obtained his Master in 2003 with the specialization Sport.

After receiving his Master, he started to work as a physical education teacher in Bilthoven and as a human movement scientist in Amsterdam. His ambition of combining both specialties became reality in 2006 when starting to work as a sports scientist in professional soccer at FC Utrecht. In 2018 he left professional soccer and started working as a lecturer at The Hague University of Applied Sciences (THUAS). One year later he combined his work as a lecturer with doing research at the research group Healthy Lifestyle in a Supporting Environment at THUAS supervised by Dr. Sanne de Vries. After successfully submitting a grant application he started his PhD-research in September 2019. This dissertation is the result of his PhD-research.

PUBLICATIONS

As part of this dissertation

Koolwijk, P., De Jonge, E., Mombarg, R., Remmers, T., Van Kann, D., Van Aart, I., Savelsbergh G., De Vries, S. (2024). Changes in Motor Competence of 4–8-Year-Old Children: A Longitudinal Study. *International Journal of Environmental Research and Public Health, 21*(2):190.

Koolwijk, P., De Witte, A., Mombarg, R., Remmers, T., Kann, D. V., Aart, I. V., ... & De Vries, S. I. (2022). Differences in motor competence, enjoyment and weight status of young children (4-6 years). *Journal of Physical Education and Sport*, *22*(6), 1471-1479.

Van Kann, D. H. H., **Koolwijk, P.**, de Kok, T., Vos, S. B., De Vries, S. I., Mombarg, R., ... & Remmers, T. (2022). Applying an ecosystem approach to explore modifiable factors related to the risk for low motor competence in young children. *Journal of Science and Medicine in Sport*, *25*(11), 890-895.

Koolwijk, P., De Jonge, E., Mombarg, R., Remmers, T., Van Kann, D., Van Aart, I., ... & De Vries, S. (2024). Characteristics of Children with an Undesirable Motor Competence Development During the Transition from Early to Middle Childhood: Results of a 2-Year Longitudinal Study. *International Journal of Environmental Research and Public Health, 21*(11), 1460.

Koolwijk, P., Hoeboer, J., Mombarg, R., Savelsbergh, G. J. P., & De Vries, S. (2023). Fundamental movement skill interventions in young children: a systematic review. *International Journal of Sport and Exercise Psychology*, 1-23.

Other publications

Remmers, T**., Koolwijk, P**., Fassaert, I., Nolles, J., De Groot, W., Vos, S. B., ... & Van Kann, D. H. H. (2024). Investigating young children's physical activity through time and place. *International journal of health geographics*, *23*(1), 12.

Koolwijk, P., & De Vries, S. (2022). Breed motorisch opleiden. Richtlijnen voor het begeleiden van jonge kinderen. *Sportgericht, 2*(76), 2-5.

Koolwijk, P., Janssen, M., & De Vries, S. (2022). Kleuter in beweging!. *LO Magazine, 3*(110), 48-50.

Van Aart, I., Nolles, J., De Groot, W., Mombarg, R., **Koolwijk, P**., & Mombarg, L. (2022). Vijf keer succes met je kleuterles. *LO Magazine, 3*(110), 17-21.

Pim Koolwijk. (2019). Oefening baart kunst? *LO Magazine, 102*, 12-14.

Jaspers, A., & **Koolwijk, P**. (2016). Overbelastingsblessures in het voetbal. Preventie op meerdere fronten nodig. *Sportgericht, 5*(70), 8-11.

Koolwijk, P., & Bettonviel, A. (2015). Herstel in het topvoetbal. *Sportgericht, 3*(69), 41-44.

Koolwijk, P. (2014). Voetbalsport kan zich verder ontwikkelen'. 4th Seattle Sounders FC Sport Science Conference. *Sportgericht, 5*(68), 39-41.

Koolwijk, P. (2014). Prestatiebepalende eigenschappen in het voetbal. Wat zijn de implicaties voor het selectiebeleid? *Sportgericht, 2*(68), 34-37.

Albert Smit, Hanno van der Loo, Erik Hein, **Pim Koolwijk** & Gerard van der Poel. (2014). Bijblijven in Brussel en Utrecht. Twee symposia over sportwetenschap. *Sportgericht, 2*(68), 45-48.

Koolwijk, P. (2013). Vermoeidheid in het voetbal. *Sportgericht, 5*(67), 2-5.

Bettonviel, A., **Koolwijk, P.**, & Raymann, R. (2013). De relatie tussen slaap, voeding en herstel *Sportgericht, 3*(67), 18-20.

Armand Bettonviel, **Pim Koolwijk** & Wigert Thunnissen. (2012). Bicarbonaat effectief bij sprint(st)ers? *Sportgericht, 3*(66), 25-27.

Scientific conference proceedings

AIESEP World congress 2024 Finland – mini symposium**: Pim Koolwijk**, Lieke Wolfs, Jonas Leenhouts & Sanne de Vries. Bridging gaps in children's Motor Development and Physical Activity through Physical Educators.

AIESEP World congress 2024 Finland – oral presentation: **Pim Koolwijk**, Ester de Jonge, Remo Mombarg, Teun Remmers, Dave Van Kann, Ingrid van Aart, Geert Savelsbergh & Sanne de Vries. Characteristics of children with an undesirable motor competence development during the transition from early to middle childhood: results of a longitudinal study.

AIESEP World congress 2023 Chile – oral presentation: **Pim, P. Koolwijk**, Ester, A.L. de Jonge, Remo, R.M. Mombarg, Teun, T. Remmers, Dave, D.H.H. Van Kann, Ingrid, I. van Aart, Geert, G.J.P. Savelsbergh, Sanne, S.I. de Vries. Changes in Motor Competence of 4–8- year-old children: a longitudinal study.

Dag van het Sportonderzoek 2023 Groningen – oral presentation: **Pim Koolwijk**. Veranderingen in motorische vaardigheid bij 4-8-jarigen; een longitudinale studie.

AIESEP Specialist Seminar 2022 Italy – poster presentation: **Pim Koolwijk,** Joris Hoeboer, Remo Mombarg, Geert Savelsbergh, Sanne de Vries. Implementation of motor competence assessment outcomes into practical interventions for young children.

AIESEP Specialist Seminar 2022 Italy – poster presentation: Joris Hoeboer, Sanne de Vries**, Pim Koolwijk,** Geert Savelsbergh. Measuring motor competence with the athletic skills track in a primary school setting in the Netherlands.

Dag van de leraar LO 2022 Zwolle – oral presentation: **Pim Koolwijk**, Janco Nolles. Start(V) aardig: Het ontwerpen en uitvoeren van een 18-weekse interventie gericht op de motorische ontwikkeling van kleuters.

Dag van het Sportonderzoek 2022 Zwolle – oral presentation: **Pim Koolwijk**. Effectiviteit van een breed motorisch interventieprogramma op de beweegvaardigheid van jonge kinderen (4-7 jaar).

&

AIESEP World congress 2022 Australia – online presentation: **Pim Koolwijk**, Joris Hoeboer, Remo Mombarg, Geert Savelsbergh, and Sanne de Vries. Fundamental movement skill interventions in young children: a systematic review.

Dag van het Sportonderzoek 2020 Eindhoven – online presentation: **Pim Koolwijk.** Motor competence and motivation of children 4-6 years: a cross-sectional study.

Dag van het Sportonderzoek 2021 Nijmegen – oral presentation: **Pim Koolwijk.** Fundamental movement skill interventions in young children: a systematic review.

Awards

Nomination Pim Breebaart Research Award (2024)

Nomination for the best Applied Research Program; The Hague University of Applied Sciences

Nomination Populatie impactprijs (2024)

Nomination for most impactful project in the field of population health that is/has been carried out in the region of the LUMC

&