DETERMINANTS OF A CHILD'S ACTUAL MOTOR COMPETENCE: A DEVELOPMENTAL PERSPECTIVE

ELINE COPPENS

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LIST OF ABBREVIATIONS

AMC	= Actual Motor Competence
PA	= Physical Activity
OSP	= Organized Sports Participation
FMS	= Fundamental Motor Skills
PMC	= Perceived Motor Competence
KTK4	= KörperkoordinationsTest für Kinder
MQ	= Motor Quotient
KTK3	= KörperkoordinationsTest für Kinder short form
KTK3+	= KörperkoordinationsTest für Kinder + eye-hand coordination task
ICC	= Intra Class Correlation
TGMD-2	= Test of Gross Motor Development – Second Edition
TGMD-3	= Test of Gross Motor Development – Third Edition
SPPC	= Self-Perception Profile for Children
PSCS	= Physical Self-Confidence Scale
EC	= Early Childhood
MC	= Middle Childhood
LC	= Late Childhood
HRF	= Health-Related Fitness
BMI	= Body Mass Index
ANT	= Achievement Goal Theory
SDT	= Self Determination Theory
MIGI	= Move It Groove It
WHO	= World Health Organization
MOT 4-6	= Motoriktest für Vier- bis Sechsjährige Kinder
M-ABC	= Movement Assessment Battery for Children
BB	= Balance Beam
MS	= Moving Sideways

JS	= Jumping Sideways
HH	= Hopping for Height
EUROFIT	= European Test of Physical Fitness
20m SR	= 20 meter Shuttle Run
SLJ	= Standing Long Jump
SAR	= Sit And Reach
LGCM	= Latent Growth Curve Models
LGCA	= Latent Growth Curve Analyses
ROC	= Rate Of Change
RMSEA	= Root Mean Square Error of Approximation
SRMR	= Standardized Root Mean squared Residual
CFI	= Comparative Fit Index
BIA	= Bioelectrical Impedance Analysis
DXA	= Dual-Energy X-ray Absorptiometry
FPAQ	= Flemish Physical Activity Questionnaire
BREQ	= Behavioral Regulation in Exercise Questionnaire
zBMI	= z-score van Body Mass Index
SD	= Standard Deviation
Min	= Minimum
Max	= Maximum
L	= Low
A	= Average
H	= High
EHC	= Eye-Hand Coordination
IOTF	= International Obesity Task Force
COSMIN	= COnsensus-based Standards for the selection of health Measurement INstruments
VIF	= Variation Inflation Factor
MDS	= Multidimensional Scaling
NASPE	= National Association for Sport and Physical Education

ENGLISH SUMMARY

Motor development is an important part of children's overall health, and is also related to physical, cognitive, emotional, and social aspects of development. The development of actual motor competence (AMC) is essential for daily life activities and is associated with many health-related outcomes. However, AMC and its development may be affected by a multitude of factors, emerging both within and outside the individual. The synergistic relationship between these factors results in distinct and sometimes divergent developmental pathways of AMC in children. Hence, the overall aim of this dissertation was to gain more insight into specific individual, environmental and task-related determinants of children's AMC and its development.

The first two studies of our original research (**STUDY 1 & 2**) focused on acquiring a (more) comprehensive knowledge on children's individual change in AMC across childhood. Through latent growth curve modeling, these longitudinal studies examined children's trajectory of change in AMC over developmental time. The corresponding results revealed a general significant positive change in AMC over time with substantial variability in AMC development. Additionally, younger children showed a greater improvement in AMC over time in both studies. **STUDY 1** showed that children's baseline weight status is inversely associated with their baseline AMC level. Moreover, children with a less optimal weight status (i.e., higher body mass index) seemed to be at greater risk to become less motor competent across developmental time. Interestingly, children's baseline physical fitness was only significantly associated with their AMC level at baseline, but not with its change over time. **STUDY 2** revealed that individual trajectories of change in AMC are positively influenced by organized sports participation (OSP). Children with less experience in OSP (i.e., being less years involved in OSP) showed more improvement in locomotor skills. Children spending more time in OSP displayed a more pronounced improvement in overall AMC over time. Children practicing more object control-oriented sports during the 6-year follow-up displayed a better advancement in AMC. Furthermore, **STUDY 2** also investigated the long-term effectiveness of the 'Multimove for Kids' program, a policy-based FMS intervention for 3- to 8-year-olds funded by the Flemish Government. While the intervention group

demonstrated higher AMC levels at post-measurement (i.e., 30 weeks after the start of the program), the control group caught up with the intervention group during the retention period of 6 years, finding no evidence of a long-term effect of the early-childhood FMS intervention. In subsequent years following the intervention, environmental factors such as (non-)engagement in OSP may have influenced the level of motor skills of both intervention and control children.

The third study (**STUDY 3**) of this dissertation focused on providing a deeper understanding of previously identified motor competence based profiles. In this respect, we examined how AMC and perceived motor competence (PMC) as well as OSP interact while using aligned AMC and PMC assessment tools. Cluster analyses demonstrated that the most optimal profiles are those with average to high levels of all three cluster variables as they combined a healthier weight status with elevated levels of autonomous motivation, while the opposite was true for children with low levels on all three cluster variables (i.e., AMC, PMC and OSP). Furthermore, the identified partially convergent profiles revealed that children with relatively low levels of AMC and PMC show the least favorable weight status, independent of their OSP level. This study also revealed that using aligned AMC and PMC assessment tools yields higher correlations between AMC and PMC when compared to previous studies on the topic that used non-aligned instruments.

In **STUDY 4**, we validated the widely used KTK3 when combined with an object control task (KTK3+) among typically developing Flemish children and adolescents aged between 6 and 19 years. In addition, reference values for both children and adolescents were provided, more specifically for boys and girls. Its adoption in both children and adolescents makes the KTK3+ a tool of high practical value, especially for the longitudinal follow-up of AMC since few AMC assessment tools have been developed for evaluating both target populations across developmental time.

Finally, in **STUDY 5**, we examined the predictive value of different OSP features (i.e., practicing a single sport vs. multiple sports, time spent in OSP and type of sports practiced across childhood) on children's AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports. More involvement in object control-oriented sports and spending more time in OSP across childhood were associated with higher AMC levels. In addition, multiple sports participation was associated with higher levels of both cardiorespiratory fitness and PMC compared to single sport participation. However, no predictive value of the different OSP features was found on children's autonomous motivation toward sports.

Altogether, our findings indicate that each child develops in its own ecological system, which is influenced by several individual, environmental and task-related determinants. In this respect, it is important to better support children's motor development by using a multi-component approach with attention for the individual child. Therefore, future movement programs or interventions should not only focus on increasing AMC but also PMC. That way, children might become more autonomously motivated toward OSP and participate more in organized sports, which might have a positive impact on their weight status. From a developmental perspective but also in view of promoting positive AMC and healthy trajectories, all children should be stimulated to participate in organized sports, preferably engaging in more than one sport and with attention given to object control skills.

DUTCH SUMMARY

Motorische ontwikkeling is een belangrijk onderdeel van de algemene ontwikkeling bij kinderen, en is ook gerelateerd aan andere aspecten van opgroeien, zoals fysieke, cognitieve, emotionele en sociale ontwikkeling. De ontwikkeling van werkelijke of actuele motorische competentie (AMC) is essentieel voor tal van activiteiten in het dagelijks leven en is tevens geassocieerd met vele gezondheidsgerelateerde uitkomsten. AMC en de ontwikkeling ervan kunnen echter worden belemmerd of bevorderd door een veelheid aan factoren, die hun oorsprong zowel binnen als buiten het individuele kind vinden. De synergetische relatie tussen deze factoren resulteert in verscheidene en soms uiteenlopende ontwikkelingstrajecten van AMC bij verschillende kinderen. Het globale doel van dit proefschrift was dan ook om meer inzicht te verkrijgen in enkele specifieke individuele, omgevings- en taakgerelateerde determinanten van kinderen hun AMC en de ontwikkeling daarvan.

De eerste twee longitudinale studies van ons originele onderzoek (STUDIE 1 & 2) richtten zich op het verwerven van een uitgebreidere kennis inzake de individuele verandering in AMC overheen de kindertijd. In beide studies werd gebruik gemaakt van latente groeicurve analyses omdat deze statistische benadering het individuele traject van elk kind inzake AMC in de loop van de ontwikkelingstijd modelleert. De bijhorende resultaten toonden een significante positieve verandering in AMC in de loop der tijd met een aanzienlijke variabiliteit in de ontwikkeling van AMC. Bovendien vertoonden jongere kinderen in beide studies een sterkere verbetering in AMC overheen de tijd. STUDIE 1 toonde aan dat de initiële gewichtsstatus van kinderen omgekeerd geassocieerd is met hun AMC aanvangsniveau. Bovendien bleken kinderen met een minder optimale gewichtsstatus (d.w.z. een hogere *body mass index*) een groter risico te lopen om minder motorisch competent te worden in de loop van de ontwikkeling. Interessant is dat het initiële niveau van fysieke fitheid van de kinderen alleen significant geassocieerd bleek met hun AMC aanvangsniveau, maar niet met de verandering ervan na verloop van tijd. STUDIE 2 onthulde dat individuele trajecten van verandering in AMC positief worden beïnvloed door georganiseerde sportparticipatie (OSP). Kinderen die minder ervaring hadden met OSP (d.w.z. minder jaren betrokken zijn) vertoonden een steilere positieve evolutie wat betreft

locomotorische vaardigheden. Kinderen die meer tijd doorbrachten in OSP vertoonden een meer uitgesproken verbetering overheen de tijd wat betreft AMC in zijn totaliteit. Kinderen die overwegend object controle georiënteerde sporten beoefenden tijdens de 6 jaar follow-up vertoonden een iets betere vooruitgang in AMC. Daarnaast onderzocht **STUDIE 2** ook de effectiviteit op lange termijn van het 'Multimove for Kids' programma, een interventie gefinancierd door de Vlaamse Overheid gericht op het verbeteren van de fundamentele motorische vaardigheden (FMS) bij kinderen van 3 tot 8 jaar. Hoewel de interventiegroep bij de tussentijdse meting (d.w.z. na de interventieperiode van 30 weken) hogere AMC niveaus liet zien, haalde de controlegroep de interventiegroep terug in tijdens de retentieperiode van 6 jaar, wat erop wijst dat de eerdere FMS-interventie geen effect had op lange termijn. In de jaren die volgden op de interventie kunnen omgevingsfactoren, zoals het (niet) deelnemen aan OSP, het niveau van motorische vaardigheden van zowel interventie- als controlekinderen hebben beïnvloed.

De derde studie (**STUDIE 3**) van dit proefschrift richtte zich op het verschaffen van een dieper inzicht in eerder geïdentificeerde profielen op vlak van motorische competentie. In dit verband onderzochten we hoe AMC, waargenomen motorische competentie (PMC), maar ook OSP op elkaar inwerken, waarbij gebruik werd gemaakt van op elkaar afgestemde AMC en PMC meetinstrumenten. Cluster analyses toonden aan dat de meest optimale profielen deze met gemiddelde tot hoge niveaus van alle drie de clustervariabelen zijn, omdat deze kinderen een gezondere gewichtsstatus combineerden met verhoogde niveaus van autonome motivatie, terwijl het tegenovergestelde waar was voor kinderen met lage niveaus op alle drie de clustervariabelen (d.w.z. AMC, PMC en OSP). Bovendien toonden de gedeeltelijk convergerende profielen aan dat kinderen met relatief lage niveaus van AMC en PMC de minst gunstige gewichtsstatus vertoonden, en dit onafhankelijk van hun OSP niveau. Deze studie toonde ook aan dat het gebruik van op elkaar afgestemde AMC en PMC meetinstrumenten tot hogere correlaties tussen AMC en PMC leidden in vergelijking met eerdere studies over dit onderwerp die meetinstrumenten gebruikten die niet op elkaar waren afgestemd.

In **STUDIE 4** hebben we de veelgebruikte KTK3 in combinatie met een oog-hand coördinatie taak gevalideerd bij typisch ontwikkelende Vlaamse kinderen en adolescenten tussen 6 en 19 jaar oud. Bovendien werden referentiewaarden voor zowel kinderen als adolescenten verstrekt, en dit specifiek voor jongens en meisjes. Het feit dat de KTK3+ testbatterij kan gebruikt worden bij zowel kinderen als adolescenten maakt het een instrument tot één van hoge praktische waarde, vooral voor de longitudinale follow-up van AMC aangezien er weinig AMC meetinstrumenten zijn ontwikkeld ter beoordeling van beide doelgroepen overheen de ontwikkelingstijd.

Tot slot onderzochten we in **STUDIE 5** in welke mate de verschillende OSP kenmerken (d.w.z. beoefening van één sport vs. meerdere sporten, gemiddelde hoeveelheid tijd doorgebracht in OSP gedurende de kindertijd en type sport beoefend gedurende de kindertijd) AMC, cardiorespiratoire fitheid, PMC en autonome motivatie voor sport bij kinderen voorspellen. Meer objectcontrole gerichte sporten beoefenen en gemiddeld meer tijd doorbrengen in OSP gedurende de kindertijd waren geassocieerd met hogere AMC niveaus. Bovendien was het beoefenen van meerdere sporten geassocieerd met hogere niveaus van cardiorespiratoire fitheid en PMC in vergelijking met het beoefenen van één sport. De verschillende onderzochte OSP kenmerken waren geen voorspellers van autonome motivatie van kinderen om te sporten.

Op basis van onze resultaten kan geconcludeerd worden dat elk individueel kind zich ontwikkelt in een eigen ecologisch systeem, dat wordt beïnvloed door verschillende individuele, omgevings- en taakgerelateerde determinanten. In dit opzicht is het belangrijk om de motorische ontwikkeling van kinderen beter te ondersteunen door gebruik te maken van een holistische aanpak met aandacht voor het individuele kind. Daarom zouden toekomstige bewegingsprogramma's of interventies zich niet alleen moeten richten op het verbeteren van AMC maar ook op andere gezondheidsgerelateerde uitkomsten zoals het versterken van de PMC. Op die manier kunnen kinderen meer autonoom gemotiveerd worden voor OSP en deelnemen aan OSP, wat mogelijks een positieve impact kan hebben op hun gewichtsstatus. Vanuit een ontwikkelingsperspectief maar ook in functie van de (latere) gezondheid gekoppeld aan AMC zouden alle kinderen gestimuleerd moeten worden om aan georganiseerde sport deel te nemen, waarbij er bij voorkeur meer dan één sport wordt beoefend en er voldoende aandacht voor objectcontrole vaardigheden is.

PART I: GENERAL INTRODUCTION

"At the present moment, each of us is a product of 'what we were like before', and each of us will change to become 'something different in the future'."

(Kathleen M. Haywood & Nancy Getchell, 2019)

1 - BACKGROUND -

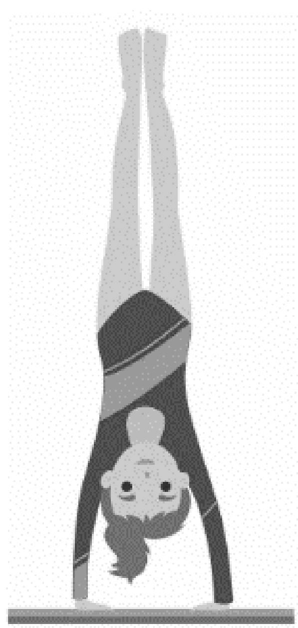
Imagine that your 7-year-old nephew invites three friends to celebrate his birthday. It is a beautiful day and he is really looking forward to spend time with his mates. Your nephew is totally in love with sports games. Therefore, you surprise him with a fantastic afternoon full of activities that he really enjoys. You all go to the public swimming pool by bike. After spending some pleasant time in the water, you all go back home riding your bike. Everybody is happy and the children decide to play a ball game, while you decorate the birthday cake.

Now, imagine the same story, but one child used a smaller bicycle than the other children because he is not used to cycling. As a result, he soon falls behind on the way to and from the public swimming pool. The same child does not feel safe in the water. He is hesitant and does not want to swim or play in the deeper part of the pool. He is also somewhat scared during the ball game: the ball is too hard for him and he often fails to catch it.

The situation described above clearly indicates that individual differences in motor competence exist. Each child develops differently and at different paces. Moreover, children arrive at the same point in development along very different pathways (Haywood & Getchell, 2019). As a specific but central aspect of children's general development, motor development is associated with physical, cognitive, emotional, and social development (Gallahue et al., 2012). Moreover, the development of motor skills is essential for daily life activities and it is a precursor for sustainable participation in physical activity (PA; Hulteen et al., 2018; Robinson et al., 2015; Stodden et al., 2008).

It is important to realize that motor skill development may be hindered or promoted by a multitude of factors both within and outside the individual child. Therefore, this dissertation focuses predominantly on <u>gaining more insight into the determinants of children's motor competence and its development</u>. In this respect, two developmental models are used as an overarching framework for the research conducted. The first one is Newell's constraints model (1986), which states that motor skills arise from interactions of characteristics specific to the individual (e.g., *the scared boy*), the environment in which the movement occurs (e.g., *the pool*), and the particular task(s) to be undertaken (e.g., *swimming or playing in the water*). The second one is the conceptual model of Stodden and colleagues (2008), which describes the potential role of motor competence in view of physical (in)activity, health-related fitness and weight status from a developmental perspective. Each of both pioneering models will be discussed at length.

In the first part of the present dissertation, an overview of the literature regarding actual motor competence (AMC) and its associations with other (health-)related factors is provided. Based on the identified existing gaps, the overall aims and specific research questions are described in relation to the original studies, which form the central part of this doctoral thesis. The third and final section of this presented work comprises a general and critical discussion of the original study results, followed by an overview of the implications for future research and practice.



2 - MOTOR DEVELOPMENT -

2.1 DEFINITION

Motor development can be defined as the continuous process of change in human motor behavior throughout the life span (Gallahue et al., 2012), the mechanisms underlying this continuous change and the factors affecting this change (Payne & Isaacs, 2016). It plays an important role in children's general health, and is also related to an individual's physical, cognitive, emotional, and social development (Gallahue et al., 2012). Across the 20th century, the theoretical approach to motor development research has shifted from a maturational perspective to an ecological perspective. The maturational perspective explains developmental change as a function of maturational processes, driven by genetics and heredity with little attention for potential environmental influences (Haywood & Getchell, 2019; Whitall et al., 2020). According to the ecological perspective, motor development is a lifelong process based upon the interactions between characteristics of the individual, his/her environment, and his/her reason(s) for conducting movement(s) (Haywood & Getchell, 2019). As stated by Whitall et al. (2020), "the mutuality forms a system that is ever-changing (i.e., dynamic), hence the ecological approach formed a critical component of the dynamical systems period". When studying (change in) motor development, using a model that reflects the continuously changing interactions between the individual, the environment and the task is helpful. In 1986, Karl Newell proposed such a model that is still being widely used today and provides a framework for organizing our knowledge regarding motor development (Haywood & Getchell, 2019; Rienhoff et al., 2016) and for designing developmentally appropriate movement activities (Gagen & Getchell, 2006). In the next section, Newell's model of constraints is introduced, which also serves as a central framework for this dissertation.

2.2 NEWELL'S MODEL OF CONSTRAINTS (1986)

In 1986, Karl Newell suggested that movements arise from the dynamic interactions of individual, environmental and task "constraints" (Newell, 1986; see Figure 1). A constraint is a characteristic (or determinant) that encourages the execution of some movement(s) (and/or changes therein) while discouraging others (Haywood & Getchell, 2019).

<u>Individual constraints</u> are a person's unique physical and mental/behavioral characteristics, and they are either structural or functional in nature. *Structural constraints* are individual constraints related to the individual's body structure (e.g., height, weight), which tend to change slowly with growth and aging. *Functional constraints* are individual constraints related to behavioral function (e.g., motivation, fear, attentional focus), which can change over a much shorter period of time. These constraints will vary across and within individuals, who must satisfy their unique organismic constraints when performing diverse motor skills.

<u>Environmental constraints</u> are characteristics that relate to the world around us. These constraints thus exist outside the body of the individual, and can be either physical (e.g., temperature, gravity) or sociocultural (e.g., the influence of significant others like family members, peers, coaches, inclusion of minorities in sports) in nature.

<u>Task constraints</u> also relate to extrinsic factors. They include the goals and rule structure of a particular movement or activity. These constraints substantially differ from functional constraints in that they specifically relate to the purpose of the motor task(s) at hand and any equipment that may be involved.

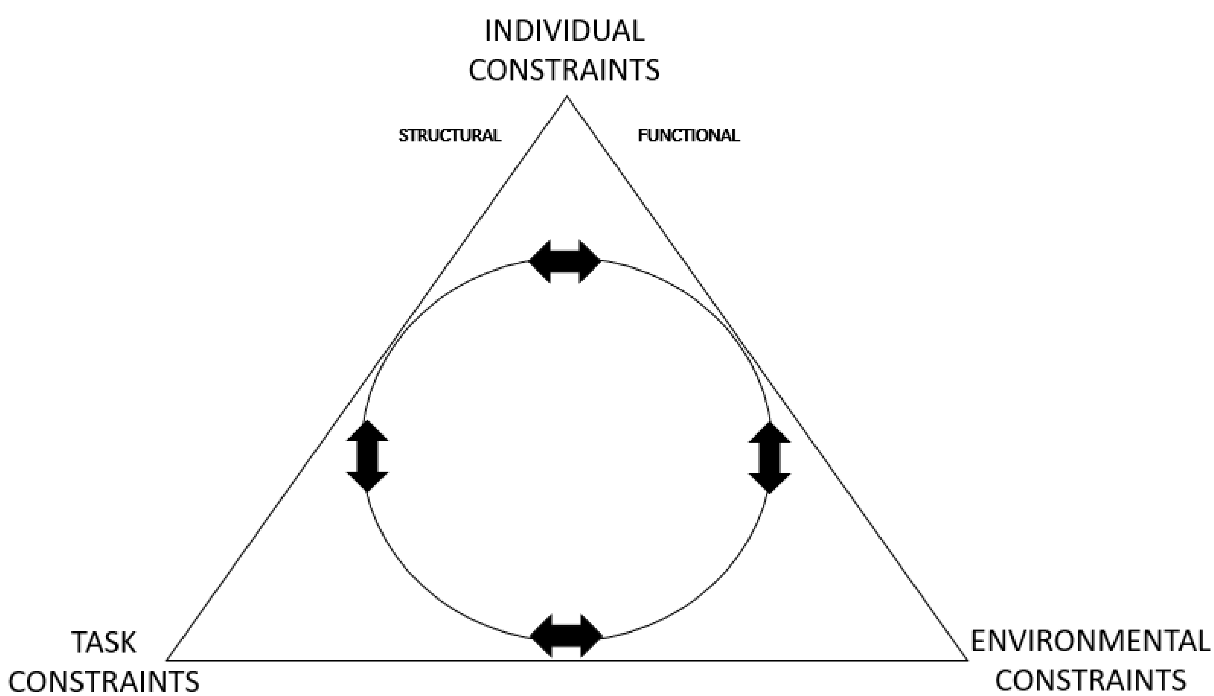


FIGURE 1 - Adapted from Newell's model of constraints (1986)

This ecological model of Newell (1986) allows us to look at the <u>individual</u> and the different systems that undergo age-related changes with regard to children's motor development. The triangulated model also emphasizes the influence of the context in which the individual moves or learns to move (i.e., environment) and what task(s) the individual undertakes. Changes at the individual constraints level will lead to changes in their interaction with both the environment and the task, subsequently changing the individual's range of movement options and the way in which motor actions are carried out (Haywood & Getchell, 2019).

Throughout this dissertation, Newell's constraints model (1986) will serve as a central framework to guide us in examining a set of selected determinants influencing AMC and its development across childhood, taking into account individual trajectories against group averages or predefined norms.

2.2.1 DEFINITION OF ACTUAL MOTOR COMPETENCE

AMC refers to a person's ability to perform a wide range of motor tasks, including the movement coordination and control underlying a particular motor outcome, that are necessary to manage everyday tasks (Robinson et al., 2015). These motor tasks include both gross and fine motor skills. Gross motor skills are required to stabilize and move the (larger part / multiple parts of the) body in any given environment, while fine motor skills refer to manual dexterity (e.g., writing, puzzling, playing the guitar; Henderson & Sugden, 1992). In the context of this dissertation, only gross motor skills will be taken into account.

In past literature, a huge array of terms has been used interchangeably to refer to AMC, including 'motor proficiency', 'motor performance', 'movement (skill) competence', 'motor ability', 'motor function', 'motor coordination' and 'fundamental movement / motor skills', amongst others (Robinson et al., 2015). Fundamental motor skills (FMS) can be defined as acquired basic movement patterns that do not occur naturally and are considered foundational for more complex physical and sports-related activities (Barnett, Stodden, et al., 2016; Hulteen et al., 2018). FMS can be divided into two or three movement categories, with Burton and Miller (1998) making a distinction between locomotor and object control skills. *Locomotor skills* are FMS that require fluid and coordinated movements of the body through space and involve skills such as running, jumping and hopping. *Object control skills*, in turn, involve the manipulation or handling of objects (e.g., a ball) and pertain to skills such as catching, kicking and shooting. Gallahue and Donnelly (2007) also distinguished a third movement category, namely the *stability skills*. These latter type of skills are required in view of the ability to sense a shift in the relationship of the body parts that alter one's balance as well as the ability to adjust rapidly and accurately for these changes with appropriate compensating movements (e.g., balancing, twisting; Gallahue & Donnelly, 2007). There is controversy in the literature whether stability is a skills set in itself or a representation of postural adjustment to environmental circumstances, underpinning FMS. However, in Newell's recent conceptualization of FMS, stability skills are considered as a separate FMS category next to locomotor skills and object control skills (Newell, 2020). These three movement categories of skills are frequently seen in people's daily life activities: for example, when coming down the stairs, walking around the supermarket or trying to throw a paper in the bin. We use our FMS for all of these everyday tasks. Moreover, the aforementioned skills become even more important when we want to participate in sports and other types of PA. Recently, Hulteen and colleagues (2018) suggested to use the term 'foundational movement skills' because it better reflects the wide variety of motor skills an individual should develop competency in to engage in physical activities for lifelong daily living, recreational or competitive purposes. Thus, foundational movement skills cover both traditionally noted FMS (i.e., locomotor skills, object control skills and stability skills) as well as other movement / motor skills important for a sustained PA engagement across the lifespan (e.g., cycling, skating, aquatic skills). These foundational skills can then be further adapted to more context-specific applications (e.g., mastering treading water would allow for the application to learn crawl in swimming).

In the context of this dissertation, AMC represents the degree of goal-directed human movement or proficient performance in various motor skills as well as its underlying mechanisms, such as motor control and coordination (Utesch & Bardid, 2019).

2.3 DEVELOPMENTAL CHANGE: GROUP vs. INDIVIDUAL LEVEL

As mentioned earlier, motor development refers to the continuous and age-related process of change in movement behavior as well as the interacting individual, environmental, and task-related constraints that drive these changes (Haywood & Getchell, 2019). Studying change in motor development at group level provides valuable information regarding age-related trends (Getchell et al., 2020). For example, identifying the average age at which distinct new levels in various motor skills are likely to occur or begin to decline (Getchell et al., 2020). Moreover, group outcomes and mean changes are generally also reported when investigating the effectiveness of motor skill interventions or activity programs.

Figure 2 shows a typical intervention study report, presenting the differences in a motor competence outcome measure between treatments (i.e., intervention vs. control group). It is clear from this figure that, based on the depicted mean values (and standard deviations), the intervention group significantly outperforms the control group both in boys and girls at the post test. While this is valuable information indicating a positive intervention effect, the graph only reports group's averages by sex but it does not take into account the individual progression or change over time within each individual child. In other words, we cannot conclude that the intervention was effective for every single individual. It is clear from the current literature that insight in the individual profile(s) of motor development is scarce, and at best implicitly present in most studies due to only reporting group means (and standard deviations).

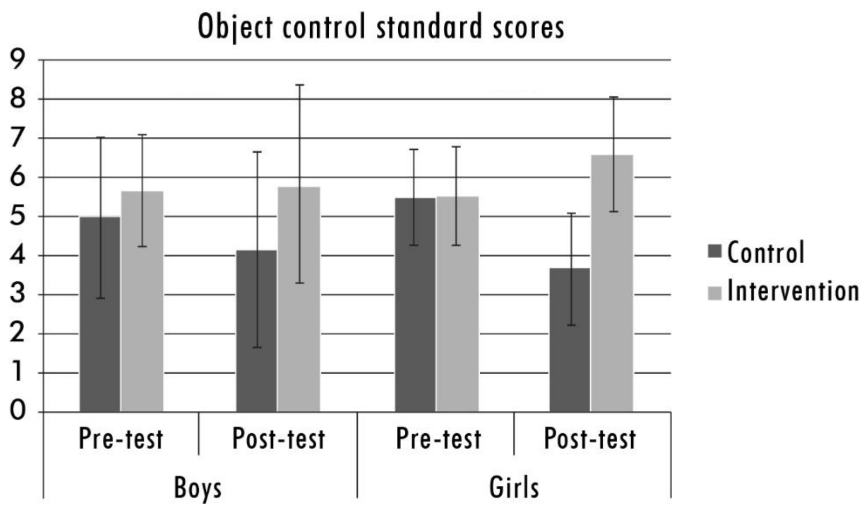


FIGURE 2 - A typical representation of intervention effectiveness at group level (Bardid et al., 2013)

As hypothesized by Stodden and colleagues (2008), children will demonstrate distinct and sometimes divergent developmental pathways of motor competence. Therefore, it is essential to move beyond group outcomes and to consider inter-individual variation within the population (Malina, 2014). When doing so, moving forward from more traditional statistics will be inevitable. Traditionally, repeated measures ANOVAs and multiple regression analyses are used to study change in motor development. Although these statistical approaches provide useful information on mean changes, they fail to describe individual development across the lifespan as they treat differences among individual subjects as error variance. However, this error variance may contain valuable information about change (Duncan & Duncan, 2009).

Figure 3 shows a typical representation of individual growth curves in motor competence and health-related fitness outcome measures. The thin lines visualize the individual variability in developmental change over time. It is clear from this figure that inter-individual variations do exist, which is further supported by Rodrigues and colleagues (2016), showing that the development of motor competence and physical fitness during childhood is noted by a high degree of inter-individual variation. While it is often assumed that all children naturally demonstrate improvements in their motor competence during childhood (Faigenbaum et al., 2011), it is clear from the study of Rodrigues and colleagues (2016) that this is not always just the case. Indeed, their research revealed that some children's competence levels increased over time whilst others' competence levels remained unchanged or even decreased. Although Rodrigues et al. (2016) used a test battery that mainly focused on components of physical fitness rather than motor competence, their research highlights the importance of gaining more insight in (promoting) individual trajectories in motor competence development. However, up to date, few studies have taken *individual change* in motor competence into account.

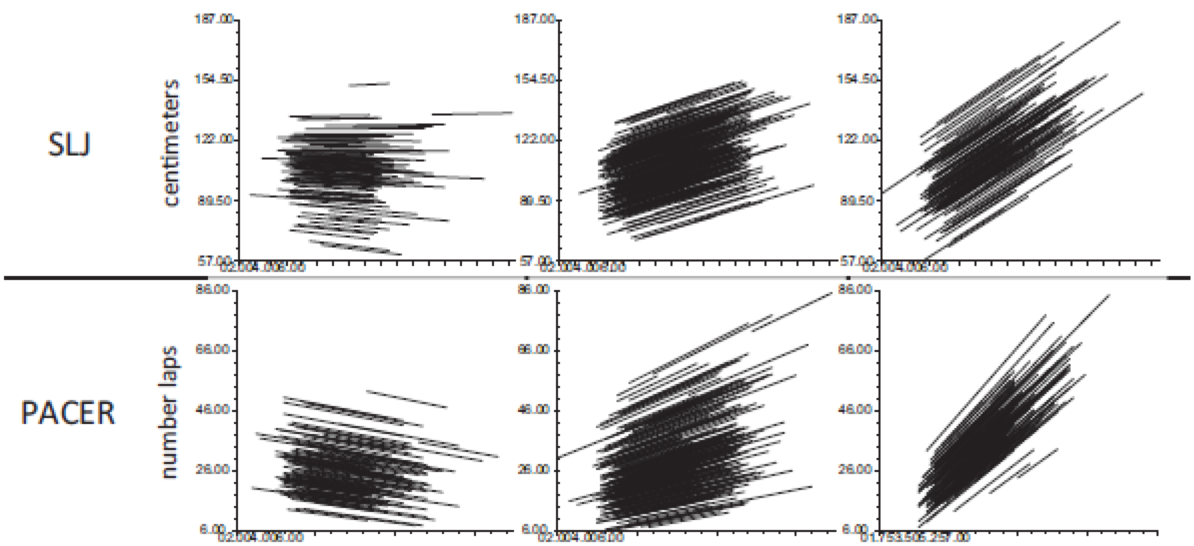


FIGURE 3 - A typical representation of individual growth curves (Rodrigues et al., 2016)

To understand change, both within and between individuals, there is a need for longitudinal studies enabling the assessment of how individuals' motor competence level changes across time and how these developmental changes differ between children, which are all growing up in a unique ecological system. One analytical technique that can be used to examine developmental change more closely at the individual level is latent growth curve modeling, which can be distinguished from more traditional methods for analyzing change over time (e.g., repeated measures ANOVAs). This approach affords the examination of both observed and latent variables, allowing to account for changes in individual differences that are not reflected in a group's mean or average effect and to separate true variance from measurement error (Kline, 2011; McArdle & Nesselroade, 2003). Using this more advanced statistical approach in future studies is paramount given the recent call for studies with multiple measurement points and the ability to extend latent growth curve models to fit an array of research questions (Pacewicz & Myers, 2021). In doing so, it is important to simultaneously consider all three types of the abovementioned constraints (i.e., individual, environmental and task constraints) as well as to carefully examine how these constraints interact with and influence each other over time (Haywood & Getchell, 2019).

3 - MOTOR COMPETENCE -

Motor competence, which is a concept within the context of motor development, can be subdivided into actual motor competence (AMC) and perceived motor competence (PMC). Each construct (i.e., AMC and PMC) is often used interchangeably with closely related terms and both of them have specific measurement methods. In the next section, clarification is provided regarding the used terminology in this dissertation and specific ways of assessments for both constructs are also described. Following, the conceptual model of Stodden and colleagues (2008), the association of motor competence with (health-)related factors will be discussed.

3.1 DEFINITION

3.1.1 DEFINITION OF PERCEIVED MOTOR COMPETENCE

PMC refers to the self-perception of one's AMC (Harter, 1999), and is often used interchangeably and/or simultaneously with terms as 'perceived sports competence', 'perceived athletic competence' and 'perceived physical confidence' in the literature. These perceptions are seen to arise from the experience one has with the environment and how these experiences are viewed by the individual (Estevan & Barnett, 2018). Shavelson and colleagues (1976) theorized a hierarchical model of the global self-concept, which was revised with empirical evidence by Marsh and Shavelson (1985). In this model, PMC is an underlying construct of physical self-perception, meaning that perceptions of behavior lead to perceptions in certain domains, and this contributes to a general self-concept (see Figure 4). In this multidimensional structure, physical self-perception is considered one of the four basic pillars of the global self-concept (Shavelson et al., 1976). In addition to this construct, academic self-perception, social self-perception, and emotional self-perception are also seen as basic pillars that shape one's self-concept in its entirety. Physical self-perception, in itself, can also be further broken down into four elements, namely perceived physical conditioning, perceived strength, perceived body attractiveness, and perceived sports/athletic competence (Fox & Corbin, 1989; Tenenbaum & Eklund, 2007). Perceived sports/athletic competence usually encompasses the self-perception of competence in sports and games (Barnett et al., 2015; Barnett, Vazou, et al., 2016). However, when mapping PMC in young children, it is important to use developmentally appropriate constructs (Estevan & Barnett, 2018). Therefore, perceived sports/athletic competence could be seen at a similar level-domain to PMC, as represented by the dashed line in Figure 4. PMC, in turn, is composed of the self-perception of the three FMS categories (i.e., locomotor skills, object control skills and stability skills) as well as self-perception in terms of active play / foundational skills such as cycling and skating (Barnett et al., 2015, 2017; Barnett, Vazou, et al., 2016).

In the context of this dissertation, PMC represents perceived sports/athletic competence, and thus refers to one's personal identification and interpretation of his/her AMC level (Estevan & Barnett, 2018). This is also in line with the terminology used in the recent systematic review and meta-analysis of De Meester and colleagues (2020).

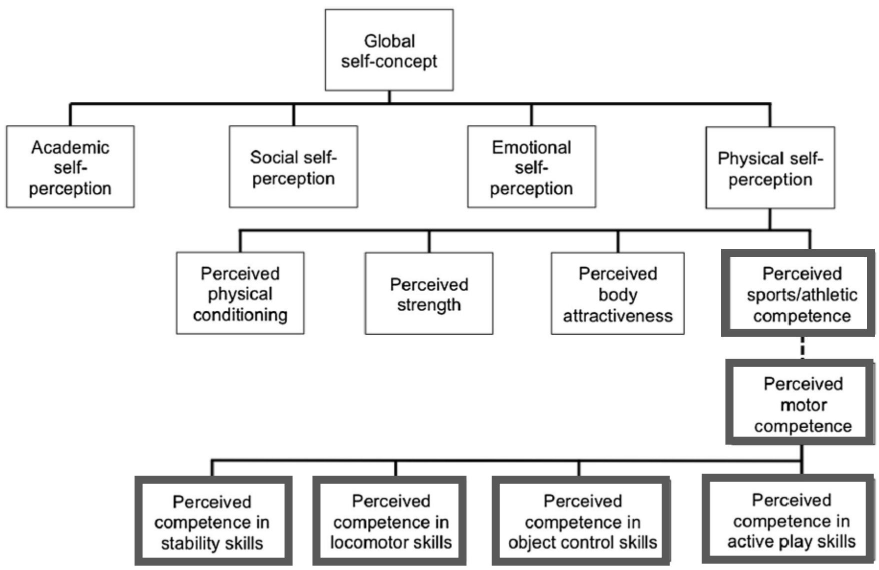


FIGURE 4 - Hierarchical model of the multidimensional structure of self-perception with perceived motor competence as the correspondent domain of perceived sports/athletic competence in children, with its operationalization in this dissertation being double framed (Adapted from Estevan & Barnett, 2018)

3.2 ASSESSMENT OF MOTOR COMPETENCE

Many different assessment tools are available to measure AMC and PMC in children and adolescents. These assessments can be categorized into objective and subjective methods. *Objective methods*, on the one hand, include motion capture devices and standardized test instruments to observe and evaluate an individual's movement behavior directly with minimal bias and measurement error. These methods provide a reasonably accurate estimate of one's AMC. *Subjective methods*, on the other hand, include self- and proxy-reports, which also allow the inclusion of contextual information. Self-reports focus on individual's PMC and can be used as an indicator or estimate of AMC (Bardid et al., 2019).

The main purposes for assessing children's motor competence are to evaluate motor competence levels, to identify developmental delays and to develop or evaluate interventions (Burton & Miller, 1998; Hulteen, Barnett, et al., 2020). In the context of this dissertation, the purpose of motor competence assessment was to evaluate individual levels of both AMC and PMC in typically developing children. Therefore, a combination of both objective (i.e., observations with standardized test instruments) and subjective (i.e., self-report tools) methods was used (see Figure 5).

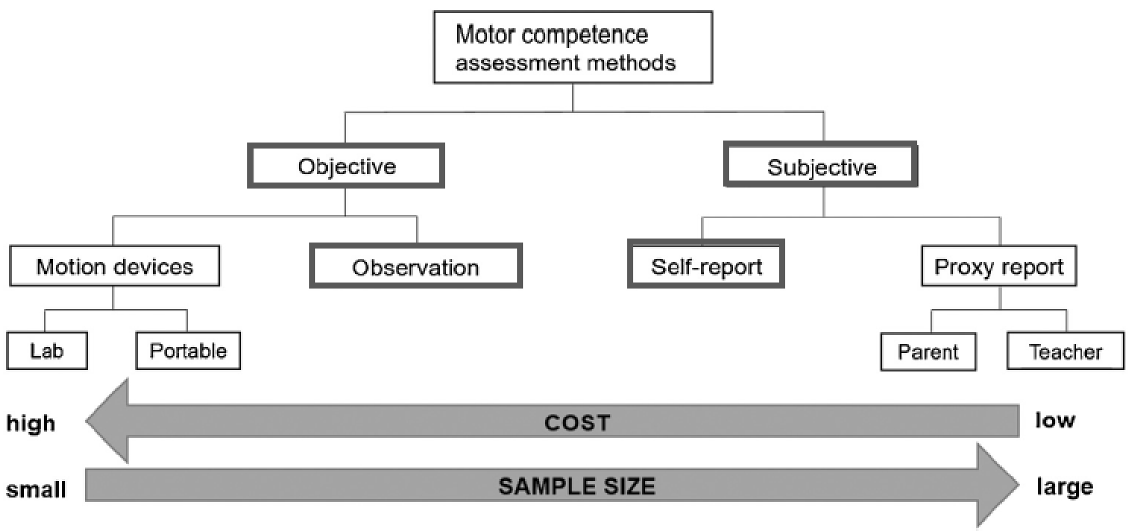


FIGURE 5 - Flow chart for selecting methods to assess motor competence among young people, with the selection of methods in this dissertation being double framed (Adapted from Bardid et al., 2019)

3.2.1 ASSESSMENT OF ACTUAL MOTOR COMPETENCE

The assessment of AMC is very popular and many AMC assessment tools exist, which is clear from different literature reviews on the topic that have been published over the past 15 years (Cools et al., 2009; Griffiths et al., 2018; Hulteen, Barnett, et al., 2020; Pill and Harvey, 2019; Scheuer et al., 2019;). Observation methods to assess AMC generally follow a standardized procedure in terms of guidelines and conditions, and they comprise product-oriented and/or process-oriented measures. Product-oriented assessments evaluate the outcome of movement/motor skills (e.g., how many times a child can perform jumps within a certain time frame) with no focus on how the movement is performed (Hulteen, True, et al., 2020; Logan et al., 2017). On the other hand, process-oriented assessments evaluate how a movement/motor skill is performed from a quality perspective (Logan et al., 2017), relying on a predefined list of technique related criteria that are either present or absent when a movement is performed (e.g., the presence or absence of reaching forward with the arm opposite to the lead foot in leaping; Hulteen, True, et al., 2020). While the focus on a (limited) set of tasks under standardized conditions may not provide a complete picture of children's AMC, as might be the case when observing children's AMC in a naturalistic condition, we focus on formal assessments within this dissertation as it allows using the assessment tool on a large scale in research (and practice). However, certain AMC assessments may not be able to adequately discriminate levels of proficiency in typically developing children (Logan et al., 2017). Therefore, the choice of assessment tool is crucial and depends on the purpose and the aim of the study (e.g., identifying developmental delay vs. evaluation of an intervention targeting AMC) but also on time, cost and effort (Bardid et al., 2019; Logan et al., 2017).

To measure AMC in the current dissertation, two product-oriented test batteries and one process-oriented test battery are used. Moreover, two of the original studies included in this doctoral thesis apply longitudinal research designs of which the baseline measurements were already performed before the start of my PhD trajectory. Therefore, using the same test batteries was necessary to allow longitudinal follow-up and analysis. In the next sections, the used AMC test batteries are discussed at length.

3.2.1.1 PRODUCT-ORIENTED ASSESSMENT

In the current dissertation, two product-oriented test batteries are used. The first product-oriented assessment tool that will be described is the widely used Körperkoordinationstest für Kinder (KTK4), which is a standardized normative product-oriented test battery for 5- to 15-year-old children with typical and atypical motor development (Kiphard & Schilling, 1974, 2007). The KTK4 test battery is considered a highly reliable instrument with excellent test-retest reliability for the total raw score (r = 0.97) as well as a very good inter-rater reliability (r > 0.85) and intra-rater reliability for the subtest raw scores (ICC = 0.80-0.96; Kiphard & Schilling, 1974, 2007). Content and construct validity have also been documented for the KTK4 (Kiphard & Schilling, 1974, 2007), and its convergent validity has been established through moderately strong correlations with other standardized assessment tools such as the Bruininks-Oseretsky Test of Motor Proficiency – 2nd Edition (Bruininks & Bruininks, 2005; Fransen, D'Hondt, et al., 2014), the Motoriktest für Vier- bis Sechsjährige Kinder (Bardid, Huyben, Deconinck, et al., 2016; Zimmer &Volkamer, 1987), and the Movement Assessment Battery for Children (Henderson & Sugden, 1992; Smits-Engelsman, 1998). The KTK4 is also considered a very useful motor test battery for longitudinal research because each test item is identical at any age (D'Hondt et al., 2013). The original KTK4 assessment tool includes four non-sport specific subtests (see Figure 6). All the tests integrate specific motor skills, such as balance and locomotion, but also rely on components of physical fitness and generic gross motor coordination. The first test is jumping sideways, where participants have to jump with their two feet together over a wooden slat for 15 seconds as many times as possible. For the second test, participants have to move sideways on a straight line for 20 seconds handling two wooden platforms to put down and step on to, making as many displacements as possible. The third test of the KTK4 is balancing backwards with three trials per balance beam, which is decreasing in width as the test progresses (6.0 cm - 4.5 cm - 3.0 cm). The fourth test is hopping for height on one leg over foam rectangles with consecutive steps of a 5 cm increase in height per added foam rectangle.

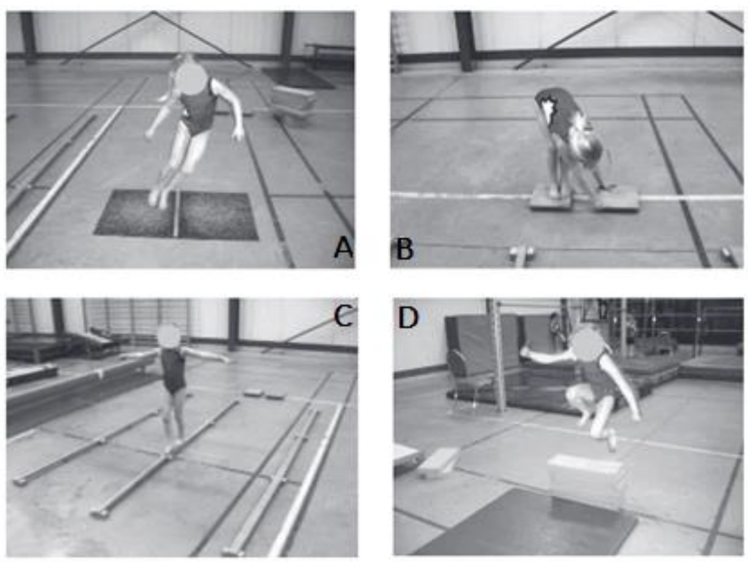


FIGURE 6 - The four test items of the KTK4: jumping sideways (A), moving sideways (B), balancing backwards (C), and hopping for height (D)

In more recent studies, the hopping for height test is often omitted from the original KTK4 test protocol due to time constraints and/or safety reasons, especially when applied in adolescents (Lovell et al., 2018; Mostaert et al., 2016; Pion et al., 2014; Pratorius & Milani, 2004). The resulting KTK short form (KTK3) has also been demonstrated to represent a valid assessment tool of AMC in itself, with a strong overall correlation between AMC scores of the three remaining tests (i.e., jumping sideways, moving sideways, balancing backwards) (r = 0.98; Novak et al., 2017). The raw scores of each subtest (i.e., four when using the KTK4 and three when using the KTK3) are first transformed into standardized scores based on the performance of the original reference sample (N = 1128; Kiphard & Schilling, 1974, 2007), and adjusted for age and sex. These standardized subtest scores are then summed and converted into a total motor quotient and a percentile rank. The test takes approximately 15-20 minutes to conduct. A weakness of both the KTK4 and the KTK3 is that only the moving sideways subtest requires a (limited) degree of object control skills. Nonetheless, object control is considered a fundamental aspect of AMC, in addition to stability and locomotor skills (Gallahue & Donnelly, 2007; Newell, 2020). In fact, these three main FMS categories should be addressed conjointly to evaluate AMC in a comprehensive manner. However, a recent review pointed out that it is better to enhance the measurement properties of existing assessments (Hulteen, Barnett, et al., 2020). Therefore, it seems desirable to add an already existing and explicit object control task to the KTK3 test protocol as opposed to creating another new assessment tool. In addition, the review by Hulteen, Barnett, et al. (2020) highlighted the importance of high-quality studies that explore both validity and reliability of results from AMC assessments. Secondly, there should be an intensified focus on investigating the measurement properties of tools developed specifically for evaluating older children's and adolescents' AMC levels (Hulteen, Barnett, et al., 2020).

This brings me to introducing the second product-oriented test battery applied in a number of studies included in this dissertation: the KTK3+ test battery, in which the KTK3 is supplemented with a catching and throwing task assessing one's eye-hand coordination, covering the three abovementioned main FMS categories (i.e., locomotion, object control and stability). The added eye-hand coordination task is a valid and reliable product-oriented test (Platvoet et al., 2018) that determines the level of controlling a tennis ball while conducting repetitive movements (i.e., left hand throw and right hand catch, followed by right hand throw and left hand catch, etc.) as frequently as possible in a time-constrained task of 30 seconds (Faber et al., 2014). The participants are free to use overhand and/or underhand techniques or a combination of both for throwing and catching. To this end, they have to stand 1 meter away from a wall, and throw the tennis ball at eye-level in a square (1 m^2) taped on that wall with the bottom side of the square being located 1 meter above the ground. Participants have to conduct this test item twice, with the number of successful ball catches across both trials resulting in a final test score. In addition, two studies revealed good test-retest reliability for all KTK3+ subtests (i.e., balancing backwards: ICC =0.80, moving sideways: ICC = 0.84, jumping sideways: ICC = 0.95, and eye-hand coordination task: ICC = 0.87 (Faber et al.2014; Platvoet et al., 2018). For a more exhaustive read concerning the KTK3+ test battery, I would like to refer to **STUDY 4** in chapter 3 of this doctoral thesis.

3.2.1.2 PROCESS-ORIENTED ASSESSMENT

The process-oriented test battery, which has been used for the original research presented in this dissertation was the Test of Gross Motor Development - second edition (TMGD-2; Ulrich, 2000), which is a revised version of the earlier TGMD (Ulrich & Sanford, 1985). The TGMD-2 is a process-oriented and norm-referenced test battery to measure AMC in 3- to 10-year-old children. In this respect, the test covers the developmentally sensitive age period in a child's gross movement skill development and includes qualitative aspects of movement behavior (Cools et al., 2009). It is considered a highly reliable assessment tool with excellent test-retest reliability ($r \geq 0.88$) and inter-rater reliability ($r > 0.98$) as well as good internal consistency (Cronbach's $\alpha = 0.85$ for locomotor subtests, 0.88 for object control subtests and 0.91 for the total score). Content, construct and concurrent validity have also been documented and found to be satisfying (Ulrich, 2000). The TGMD-2 includes six locomotor skills (i.e., run, gallop, hop, leap, horizontal jump and slide) and six object control skills (i.e., striking a stationary ball, stationary dribble, kick, catch, overhand throw and underhand roll), representing motor skills that are generally adopted in sports and games. It takes approximately 15 minutes to administer the test in one child. Children are given one familiarization trial and two test trials per skill. Each skill has between three to five technique related criteria or components, marked as either present (= 1) or absent (= 0), that need to be demonstrated for the skill to be performed proficiently. The awarded scores on the six locomotor skills and object control skills are then summed to create an overall score for each subtest (i.e., Locomotor Score Range: 0-48; Object control Score Range: 0-48). Raw scores from each subtest can be converted into standard scores (i.e., ranging from 1 to 20) using the standardized norms based on age (for the locomotor an object control subtest) and sex (for the object control subtest; Ulrich, 2000). These standardized scores can be combined to produce a gross motor quotient (i.e., ranging from 48-160) as well as a percentile rank. In addition, the overall FMS performance of each child can be categorized from very poor to very superior (Ulrich, 2000). Limitations of the TGMD-2 are its bias of some object control skills toward the American sports culture (i.e., strike and overarm throw both being highly related to baseball skills) and the absence of stability skills (Bardid, Huyben, Lenoir, et al., 2016; Cools et al., 2009). In addition, sufficient assessment training is required for assessors in order to correctly evaluate the motor skill patterns in relation to each of its components. Nonetheless, the TGMD-2 is the most widely used process-oriented assessment tool for AMC and has been used in different European countries (see Bolger et al., 2021 for a systematic review).

Recently, the TGMD-2 was revised, resulting in the TGMD-3 (Ulrich, 2019). In the TGMD-3, the object control subtest was renamed as the ball skill subtest, making it easier to understand for people outside the field of motor development. In addition some skills were removed (i.e., leap and underhand roll) while others were added or reinstated (i.e., skip, underhand throw and one-hand strike), resulting in six locomotor skills and seven ball skills to be assessed. While the TGMD-3 includes modified skill criteria and skill changes based on feedback from researchers and practitioners using the TGMD, we could not administer this revised version due to the longitudinal design of STUDY 2 (see Part II). That is, the TGMD-2 was used during the baseline measurement of the study in 2012.

3.2.2 ASSESSMENT OF PERCEIVED MOTOR COMPETENCE

A multitude of self-reported questionnaires has been developed to assess children's PMC and its subdomains. Some of these questionnaires evaluate PMC as a component of general self-esteem such as the Self-Perception Profile for Children (SPPC; Harter, 1985), whereas other questionnaires focus solely on PMC as is the case with the Physical Self-Confidence Scale (PSCS; McGrane et al., 2016). Moreover, some self-reported questionnaires explicitly ask children to compare themselves to other children. Examples of such questionnaires are the Pictorial Scale of Perceived Competence and Social Acceptance (Harter & Pike, 1984), and the athletic competence subscale of the SPPC (Harter, 1985), which is the same scale as the sport/athletic competence subscale of the Children's Physical Self-Perception Profile (Whitehead, 1995). Other questionnaires contain only statements about the individual itself and do not include a comparison with other children. Examples of such questionnaires are the Physical Self-Description Questionnaire (Marsh et al., 1994) and the PSCS (McGrane et al., 2016).

In the context of the present dissertation, two self-reported questionnaires are used as tools to assess PMC. The first one is the sport/athletic competence subscale of the Dutch version of the SPPC (Harter, 2012). Using this questionnaire is in line with previous (Belgian) studies, making it easier to compare the findings between studies (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016; Estevan & Barnett, 2018). Moreover, Estevan and Barnett (2018) stated that perceived sport/athletic competence could be seen at a similar level to PMC, which was also shown in Figure 4. The athletic competence subscale of the SPPC measures children's self-perceptions of their athletic ability and their ability to learn sports-related skills. The SPPC is validated in 8- to 13-year-old children and the internal consistency of the sport/athletic competence subscale is high, with a Cronbach's α ranging between 0.76 and 0.91 (Harter, 2012). The response categories for each of the six items of the SPPC's sport/athletic competence subscale consist of a four-choice structured alternative format to minimize socially desirable responses (Lubans et al., 2011). The child is first asked to decide with which kind of child he/she identifies the most: the one(s) described in the first part of the sentence or the one(s) described in the second part of the sentence (e.g., *"Some children do very well at all kinds of sports BUT other children don't feel that they are very good when it comes to sports."*). Subsequently, the child has to decide whether the chosen description was "*really true*" or "*sort of true*" for him/her personally. Accordingly, each item was scored from 1 (i.e., lowest level of PMC) to 4 (i.e., highest level of PMC). Tenenbaum and colleagues (2012) stated that special care should be taken to explain the response scale because this non-standard response format has been shown to be possibly confusing, particularly for children (Eiser et al., 1995). Therefore, when we used this questionnaire, detailed instructions at the outset were given to the participants.

The second self-reported questionnaire used to assess children's PMC in the original research of this doctoral thesis is an adapted version of the PSCS (McGrane et al., 2016). These authors actually developed a method for measuring PMC that was fully aligned to a method for measuring AMC, namely the TGMD-2 (Ulrich, 2000), which would facilitate future research into the relationship between children's AMC and PMC. Therefore, this PMC assessment was chosen in the context of this dissertation, since using aligned AMC and PMC assessment tools is hypothesized to result in a stronger association between these two constructs (Estevan & Barnett, 2018). The PSCS is suitable for self-assessment in children aged 12-14 years. The original PSCS contains 15 items for which participants rate their perceived self-confidence in performing a number of specific motor skills on a 10-point Likert scale, ranging from "*being not confident at all*" (= 1) to "*being very confident*" (= 10). These items are thus perfectly aligned with the locomotor and object control skills assessed in the eponymous subtests of the TGMD-2 (N = 12; Ulrich, 2000) as well as the stability skills assessed in the Victorian Fundamental Movement Skills Test (N = 3; Walkley et al., 1996). The PSCS's test-retest reliability is considered excellent with a Cronbach's α of 0.92 for all skills together, a Cronbach's α of 0.88 for locomotion and 0.92 for object control. Each individual skill achieved an ICC ranging between 0.63 and 0.94 (McGrane et al., 2016). Content validity and concurrent validity are also good, with the McGrane scale achieving a strong correlation with the Physical Self-Perception Profile (r = 0.72; Fox and Corbin, 1989; McGrane et al., 2016). Following experts' advice, and since the aim of this dissertation was to measure PMC rather than self-confidence, the question stem of the items was altered from "*how confident are you at performing*" to "*how well can you perform*"(Estevan & Barnett, 2018). The participants now only have to award themselves a score ranging from one to ten for each skill, so it is no longer self-confidence that is being measured, but PMC. On this 10-point scale, a score of 1 means that the participant believes that he/she cannot perform this skill well at all, whereas a score of 10 means that the participant thinks he/she can perform the skill at hand very well.

For the purpose of this dissertation, four items were added to this PSCS questionnaire, resulting in the adapted version of the PSCS. These four additional items were fully aligned with the aforementioned KTK4 subtests (i.e., jumping sideways, moving sideways, balancing backwards, hopping for height). To estimate the reliability of these four additional items, a test-retest procedure was performed. To this end, 64 children between 9 and 11 years of age completed these questions twice in similar conditions, with a 19-day interval in between, showing a moderate degree of test-retest reliability with an ICC of 0.78 and a 95% confidence interval ranging from 0.66 to 0.86 (F = 8.181, p < 0.001). Each participant's PMC subscore (ranging from 1 to 10) was determined by calculating the average score of the four items that were aligned with the four KTK4 subtests. A disadvantage of using the recent PSCS and the adapted version thereof is that it has not yet been used and tested as much as the SPPC (Harter, 2012), warranting further research into its psychometric properties.

3.3 ALIGNMENT BETWEEN ACTUAL AND PERCEIVED MOTOR COMPETENCE ASSESSMENT

The relationship between AMC and PMC has been investigated extensively over the last decades, which is clear from the recently published systematic review and meta-analysis of De Meester and colleagues (2020), including data from 69 studies. This meta-analysis supported a positive relationship between AMC and PMC in a sample of children, adolescents and young adults (until 24 years of age). However, the strength of the AMC-PMC association may depend on how both constructs are operationalized. Therefore, it was suggested to identify AMC and PMC in a similar way (e.g., walking backwards on a beam and the perception of walking backwards on a beam) in order to gain more insight into how children's perceptions of AMC correspond to their AMC (Barnett et al., 2015; Estevan & Barnett, 2018). Using aligned assessment tools could result in a stronger relationship between both constructs. Surprisingly, this hypothesis could not be verified by the meta-analysis of De Meester et al. (2020). Since most of the studies in their meta-analysis using aligned instruments were conducted in young children, and due to the level of cognitive maturation in this population (Harter, 1999), this could have impacted the findings (De Meester et al., 2020). As such, De Meester et al. (2020) suggested that future research regarding the alignment between measurement instruments and its potential impact on the strength of the relationship between AMC and PMC is needed in older age groups.

Investigating the association between children's AMC and PMC is of great interest because it is theorized that children with a higher PMC level will be more motivated to be physically active and, thus, further develop their AMC (De Meester, 2017; Harter, 1999; Stodden et al., 2008). Moreover, research shows that high and aligned levels (= convergent profiles) of actual and perceived motor competence are key to engaging children in PA and sport (Babic et al., 2014; Bardid, De Meester et al., 2016; Barnett, Lai, et al., 2016; Estevan & Barnett, 2018; Robinson et al., 2015), demonstrating the importance of AMC and PMC in promoting PA among children and adolescents (Stodden et al., 2008). In Belgium, one of the overarching curriculum goals for physical education relates to 'self-concept and social functioning' (i.e., Students will be able to assess and appreciate their own effort and that of others). Since PMC is a subcategory of global self-concept (see introduction p. 13), the above curriculum goal can be evaluated by measuring both AMC and PMC, with a strong correlation between both constructs indicating the ability to correctly assess one's own performance. Therefore, it is important that both constructs are measured in a similar manner.

The first model indicating this important relation and constant interaction between AMC and PMC was the conceptual model designed by Stodden and colleagues (2008), which brings me to introducing this well-known developmental model.

3.4 STODDEN AND COLLEAGUES' CONCEPTUAL MODEL ON MOTOR COMPETENCE (2008)

The development of AMC is an important influencing factor in the movement and PA behavior of young people. Moreover, developing competence in FMS is key for children as it allows for more complex context-specific skills to be developed. This idea is supported by several motor development models, such as the hierarchical model (Seefeldt, 1980), the mountain(s) of motor development (Clark & Metcalfe, 2002) and the triangulated hourglass model (Gallahue et al., 2012). All three of these models state that FMS must be taught early on, since individuals with a stronger base will have a greater repertoire of motor skills to apply, showing that the development of AMC is an important underlying mechanism of sustainable PA engagement (Barnett et al., 2009a; Holfelder and Schott, 2014; Lopes et al., 2011; Lubans et al., 2010). In 2008, a more holistic model was proposed by Stodden and colleagues. They developed a conceptual model that demonstrated the reciprocal relationships between AMC, PA, PMC and health-related physical fitness from a developmental perspective (see Figure 7). In their model, Stodden and colleagues (2008) approached these relationships at three time points in children's development: the preschool period or early childhood (i.e., 2 to 5 years, EC on Figure 7), the period in primary school or middle childhood (i.e., 6 to 8 years, MC on Figure 7) and the transition to secondary school or late childhood (i.e., 9 to 12 years, LC on Figure 7).

The authors hypothesized that the reciprocal relationship between AMC and PA will become stronger and more important as a child grows older. In addition to the strength of the relationship, the direction of the relationship will also evolve over developmental time according to these authors (Stodden et al., 2008). In early childhood, it is primarily PA that influences AMC development, with more PA during this period leading to higher AMC levels. However, from middle childhood onwards, AMC itself will drive PA levels. Children will then become more or less physically active depending on their degree or level of AMC (Stodden et al., 2008).

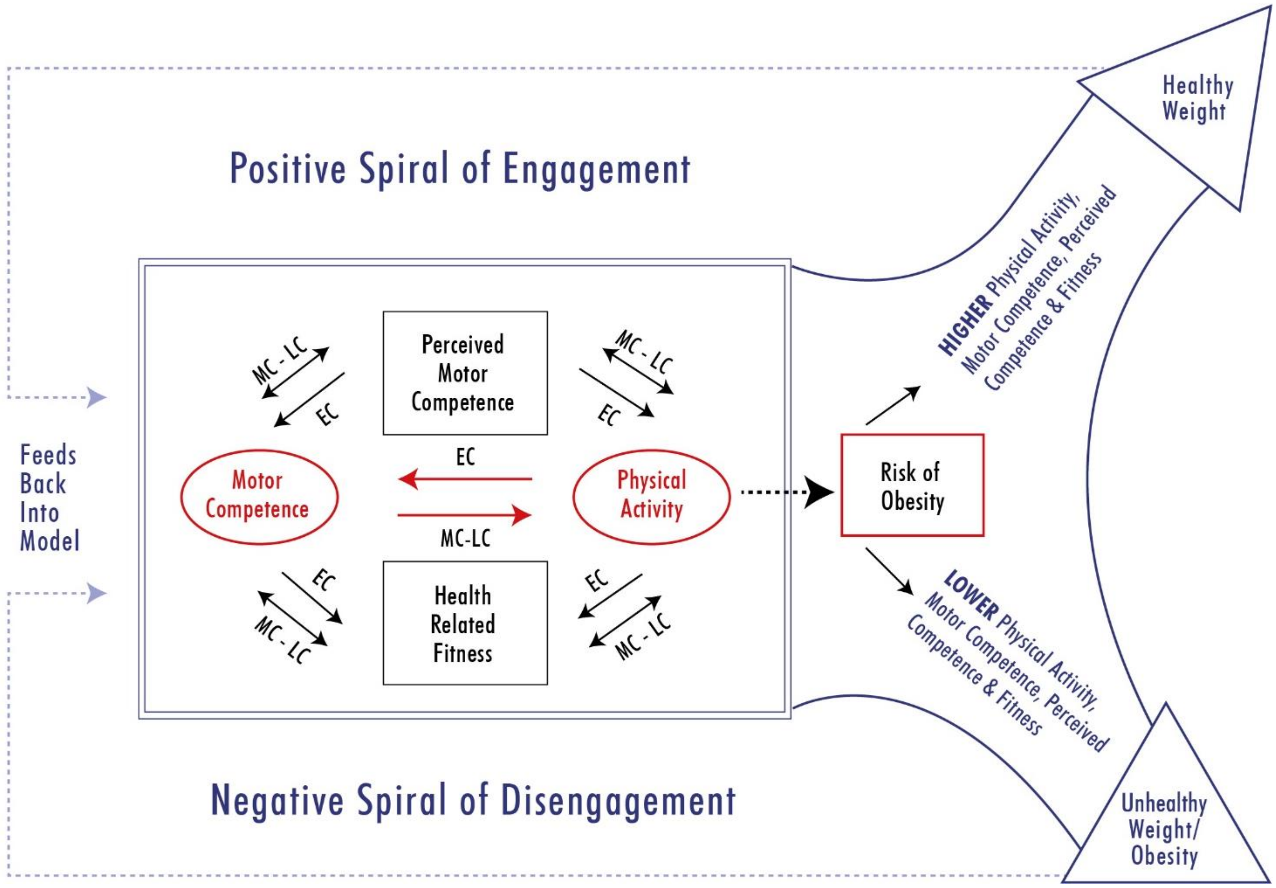


FIGURE 7 - The conceptual model with developmental mechanisms influencing physical activity trajectories of children. EC = early childhood, MC = middle childhood, LC = late childhood (Adopted from Stodden et al., 2008)

As mentioned above, the conceptual model by Stodden et al. (2008) is also the first model indicating that AMC is in constant interaction with PMC across developmental time. Moreover, this PMC as well as health-related physical fitness are hypothesized to be mediating factors for the reciprocal and central relationship between AMC and PA. The model suggests a ‘positive spiral of engagement’ in which children with better actual motor skills will feel more competent than their lower skilled peers. Therefore, these children are more likely to engage in PA leading to higher levels of health-related fitness, which will in turn reduce the risk of developing an unhealthy weight status. In contrast, children with poorer motor skills are at risk of a ‘negative spiral of (dis)engagement’. Due to their lower AMC levels, chances are higher that they will also feel less competent than their more skilled peers. Therefore, these children might be less motivated to engage in physical activities, which in turn may lead to lower health-related physical fitness and the development of an unhealthy weight status.

The conceptual model of Stodden et al. (2008) emphasizes the importance of understanding the mechanisms underlying these spirals of (dis)engagement so that the 'negative spiral' can be avoided and the 'positive spiral' can be encouraged in view of children's health

Previous research provided empirical support for most of the relationships being hypothesized in this conceptual model (De Meester, 2017; Robinson et al., 2015). It is well documented that AMC is associated with a range of health-related factors and is considered utmost important in developing an active lifestyle (Cattuzzo et al., 2016; Robinson et al., 2015). Apart from displaying a positive relationship between AMC and PA (Hulteen et al., 2018; Utesch et al., 2019), PMC (De Meester et al., 2020), health-related fitness (Cattuzzo et al., 2016; Utesch et al., 2019), and an inverse relationship between AMC and weight status (Cattuzzo et al., 2016; D'Hondt et al., 2011) across childhood and adolescence, AMC has also been associated with psychosocial well-being (Skinner & Piek, 2001) and cognitive skills (van der Fels et al., 2015). However, in order to understand motor development, we should not only take into account the individual and his/her characteristics. From an ecological point of view, motor development is also influenced by factors that do not originate within the individual, like environmental constraints and task constraints. Do you remember the boy being scared of the ball and the deeper water, and riding on a smaller bicycle? That situation clearly indicates that motor skill development may be hindered (or promoted) by a multitude of intrinsic and extrinsic factors, thus both within and outside of the individual child. Indeed, the boy in the example would have had a totally different experience if he could have watched a movie or play a board game with his friends (i.e., task constraint). Perhaps he would also have been less afraid in the water if he had a swimming pool in the backyard or when his parents took him to the swimming pool more often (i.e., environmental constraint). Therefore, this dissertation focuses predominantly on gaining more insight into some specific individual, environmental and task-related constraints or determinants of children's motor competence and its development. In doing so, the conceptual model of Stodden et al. (2008) will be combined with Newell's model of constraints (1986) in order to provide a clear overview of the determinants under investigation in this doctoral thesis (see Figure 8).

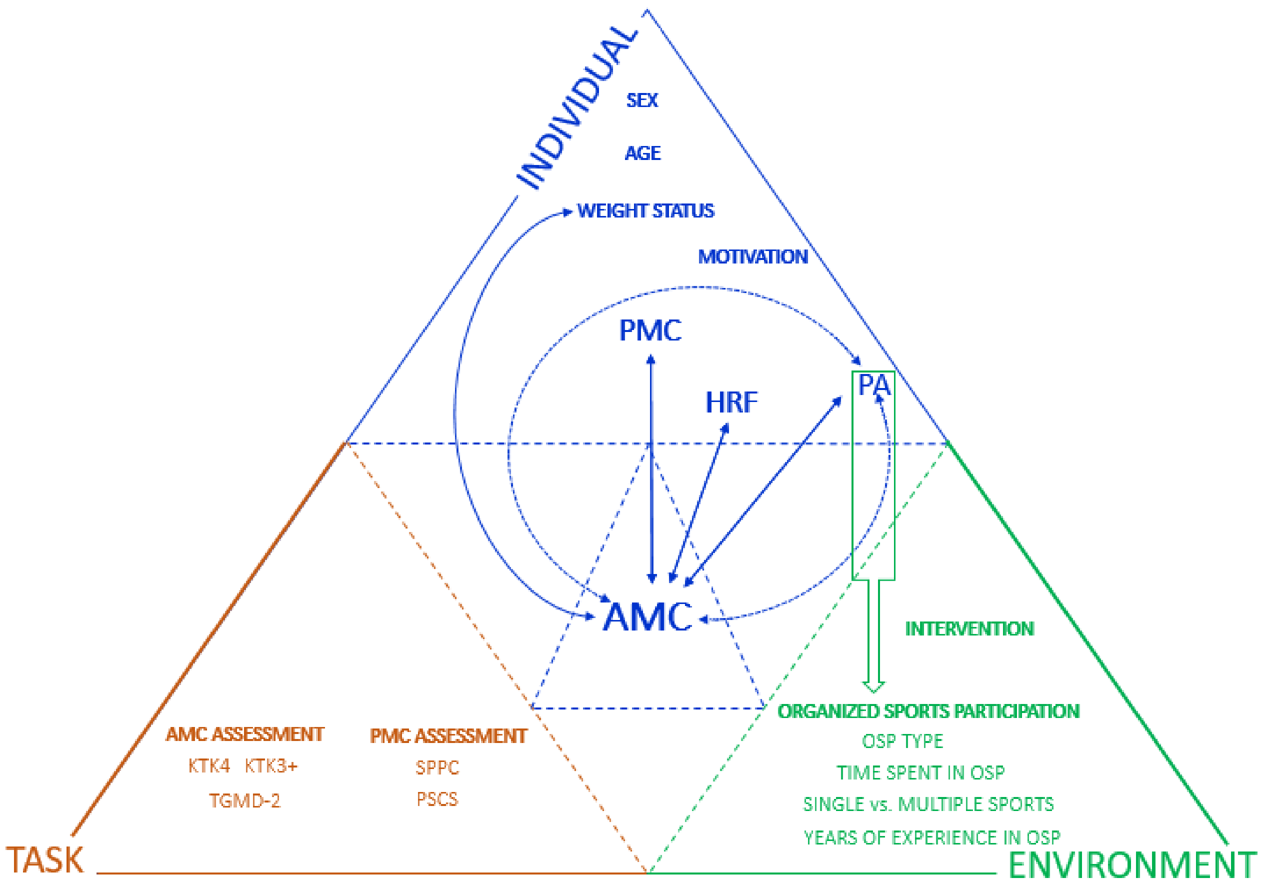


FIGURE 8 - Visual representation of individual, environmental and task-related determinants affecting a child's AMC and its development as being part of this dissertation, based on combining the constraints model of Newell (1986) with the conceptual model of Stodden et al. (2008). The blue arrows represent the reciprocal relationships between the constructs as hypothesized in the original conceptual model of Stodden et al. (2008). The green frame around PA indicates the relationship between PA and organized sports participation.
(AMC: actual motor competence; PMC: perceived motor competence; HRF: health-related fitness, PA: physical activity; KTK4: KörperkoordinationsTest für Kinder; KTK3+: KörperkoordinationsTest für Kinder + eye-hand coordination task; TGMD-2: Test of Gross Motor Development – Second Edition; SPPC: Self-Perception Profile for Children; PSCS: Physical Self-Confidence Scale; OSP: organized sports participation)

3.5 DETERMINANTS AFFECTING MOTOR COMPETENCE AND ITS DEVELOPMENT

In the next section, empirical evidence will be presented regarding each of the determinants that were investigated in the context of this dissertation (see Figure 8). It should be noted that these determinants influence and are influenced by motor competence. However, the focus is on AMC and its development, as the main outcome measure of interest.

3.5.1 TASK DETERMINANTS

Newell (1986) suggested that motor skills and their development arise from the mutual interactions of the individual and his/her characteristics, the environment in which the movement occurs, and the specific task(s) to be undertaken. Changing one determinant will thus also affect others. In the context of this doctoral thesis, the task determinants were approached from a methodological point of view and, as such, represent the different assessment tools used to measure participants' AMC and PMC across the included studies. Accordingly, changing the assessment tool might influence the way the child responds. For example, a child that has to complete a questionnaire evaluating the child's self-perceptions of his/her AMC might reveal other perceptions when the questionnaire does include a comparison with other children (i.e., SPPC) as compared to using a questionnaire that does not include such a peer comparison (i.e., PSCS). In Figure 5, a distinction has been made between the objective measures for assessing AMC (i.e., the product-oriented KTK4 and KTK3+ as well as the process-oriented TGMD-2) and the subjective measures or self-reported questionnaires regarding PMC (i.e., SPPC, PSCS). In addition, it is also important to note that there is a large variation in measurement methods meaning that not all AMC assessment tools cover the broad spectrum of AMC, from overall motor coordination to FMS (Barnett, Lai, et al., 2016). A recent validity study revealed that the KTK4 and TGMD-2 indeed measure discrete aspects of AMC (Rudd et al., 2016). The same holds for PMC, where the available instruments are assessing different constructs of self-perception with the consequent error assumed (Estevan & Barnett, 2018).

While using a combination of both product-oriented and process-oriented assessment tools would offer more information about children's AMC (Fransen, D'Hondt, et al., 2014), it is interesting to note that few studies have used this approach. As one of the exceptions, Niemistö et al. (2020) combined the KTK4 and the TGMD-2. These authors confirmed that the KTK4 and TGMD-2 measure different aspects of AMC (i.e., gross motor coordination vs. FMS), which is important from the perspective of monitoring and promoting AMC for health outcomes (Hulteen, True, et al., 2020). Indeed, motor skill assessment allows for the informed development of interventions by identifying various skill deficiencies in movement execution and/or outcome, which highlights the need for continued research related to the use of process- and product-oriented assessments (Hulteen, True, et al., 2020). It is important to take into account that the chosen instrument or measurement tool might influence the assessment of AMC or PMC.

3.5.2 INDIVIDUAL DETERMINANTS

As stated earlier, individual determinants refer to one's unique physical and mental/behavioral characteristics, and they are either structural or functional in nature (Newell, 1986). First, empirical evidence regarding the structural determinants (i.e., sex, age, weight status, health-related fitness) of AMC that were part of this dissertation will be described in the following paragraphs. Next, three functional determinants under investigation (i.e., PMC, motivation toward sports, PA) will be specifically addressed.

3.5.2.1 STRUCTURAL DETERMINANTS

3.5.2.1.1 SEX

A substantial number of studies provided evidence for a strong association between AMC and sex across childhood. Moreover, at least four reviews have taken sex into account as an influencing determinant regarding children's level of AMC (Barnett, Lai, et al., 2016; Bolger et al., 2021; Iivonen and Sääkslahti, 2014; Lubans et al., 2010). Most of the previously conducted studies have reported sex differences in favor of boys although different results have been found across specific motor skill domains (e.g., FMS versus gross motor coordination), which was already mentioned when discussing the task constraints. The systematic review conducted by Barnett, Lai, et al., 2016), being based on 42 studies investigating sex as a potential determinant of AMC in children between 3 and 18 years of age, found strong evidence that being male was a positive correlate of object control skills and motor coordination although the effect was rather small. In that same review, no effect of sex on locomotor skills could be demonstrated, whilst inconclusive evidence for girls outperforming boys in stability measures was reported (Barnett, Lai, et al., 2016). A recently published systematic review by Bolger et al. (2021) examined the FMS levels of more than 21.000 children from all over the world, using the TGMD-2. They confirmed the sex differences in object control skill levels in favor of boys. In this latter review, boys also demonstrated a slightly higher total FMS score when compared to their female peers (Bolger et al., 2021). A potential explanation might be that boys generally tend to participate more in object control-oriented activities while girls tend to participate more in locomotor related activities (Bardid, Huyben, Lenoir, et al., 2016), indicating that boys and girls seem to have different preferences when it comes to (organized) sports participation, whether or not because of the environmental and social influence of family and peers (Hardy et al., 2010).

In general, prior research has not specifically investigated how a child's sex influences developmental change in motor competence over time. However, in the study of dos Santos et al. (2018) differences in the trajectory of change favoring girls were established, whilst the study of Rodrigues and colleagues (2016) found no sex-related differences in developmental pathways in AMC and health-related fitness. In light of these contrasting findings, there is clearly a need for more research into how boys and girls develop their motor competence levels over time.

3.5.2.1.2 AGE

The systematic review of Bolger et al. (2021) revealed that children's FMS levels tend to be higher among older children in comparison to their younger counterparts. This was in agreement with the systematic review of Barnett, Lai, et al.(2016) demonstrating that increasing age was the most consistent correlate of AMC. However, it is important to highlight that findings might differ according to how AMC is operationalized based on the AMC assessment tool being used. Not all test instruments cover the broad spectrum from general gross motor coordination to FMS (see task determinants), which was also evident from this review by Barnett, Lai, et al. (2016) showing that not all included studies found age (or sex) to be a positive correlate of AMC. In addition, the association between age and AMC might change across developmental time (Barnett, Lai, et al., 2016).

Moreover, when using standardized scores adjusted for children's age (and sex) in the analyses, the potential effects of age (and sex) should be leveled out. Besides, some instruments are criterion-referenced with a theoretical maximum, indicating that the instrument possibly encounters a ceiling effect, especially in older and more skilled children (Barnett, Lai, et al., 2016). Previous research revealed an average positive change in motor competence over time (Ahnert et al., 2009; dos Santos et al., 2018; Vandorpe et al., 2011). However, this assumption might not hold when taking into account individual developmental or age-related change rather than group mean changes. Indeed, Rodrigues and colleagues (2016) detected that not all children increased their AMC and health-related fitness over an extended period of time during childhood. Actually, many children (i.e., almost 25% of their study sample) showed negative trajectories of AMC and fitness over a 3 year timespan. This conclusion generally aligns with the assumption of Stodden and colleagues' conceptual model (2008) that children will demonstrate distinct and sometimes divergent developmental pathways of motor competence across childhood (Rodrigues et al., 2016). In light of the limited longitudinal evidence investigating individual change, there is a need for a more person-centered approach to gain more insight into children's AMC development.

3.5.2.1.3 WEIGHT STATUS

Several cross-sectional and longitudinal studies among children and adolescents have demonstrated that lower AMC levels are associated with an increased body mass index (BMI; kg/m²) (D'Hondt et al., 2014; Lopes et al., 2012; Martins et al., 2010) and it seems that this negative association between AMC and weight status strengthens with increasing age (Ommundsen et al., 2010). Moreover, the inverse relationship between AMC and weight status has also been confirmed in different reviews (Cattuzzo et al., 2016; Lubans et al., 2010). In contrast to these latter reviews, the one by Barnett, Lai, et al. (2016) did consider associations for weight status with different domains of gross motor competence (e.g., FMS versus gross motor coordination) and revealed differential associations depending on how AMC was operationalized. A higher BMI was not found to be associated with lower object control competence. However, children with a higher BMI displayed a lower level of stability and general motor coordination. Regarding locomotion, the evidence was inconclusive (Barnett, Lai, et al., 2016). Overall, these findings partly support Stodden and colleagues' (2008) notion of a 'negative spiral of (dis)engagement', where children with a less optimal weight status are at greater risk to end up becoming less motor competent over time, which in turn may lead to reduced PA participation and lower levels of health-related fitness.

When taking into account individual developmental changes or trajectories, Rodrigues and colleagues (2016) found that children's BMI level at baseline was associated with doubling the odds of being overweight or obese at the end of their 3-year longitudinal study. While the latter study mainly focused on components of fitness rather than AMC, children in the low rate of change group were several times more prone to become overweight or obese, independent of their BMI level at baseline. This kind of research highlights the need for more person-centered longitudinal studies to gain more comprehensive knowledge on whether and how children with low(er) levels of AMC (and physical fitness) in early childhood can redirect these negative trajectories over time into positive developmental trajectories with a view to a healthy later life.

3.5.2.1.4 HEALTH-RELATED FITNESS

AMC is associated with a range of health-related outcomes (Utesch et al., 2019), including health-related fitness. Health-related fitness can be defined as one's ability to perform daily activities with vigor and a demonstration of traits and capacities that are associated with PA (American College of Sports Medicine, 2014). It includes components such as cardiorespiratory fitness, musculoskeletal fitness (i.e., muscular strength and endurance) and flexibility (Caspersen & Christenson, 1985; Ortega et al., 2008), which are all critical to long-term health. According to the conceptual model of Stodden and colleagues (2008), AMC development will initially promote health-related fitness in early childhood. It was also postulated that, in middle and late childhood, health-related fitness would mediate the relationship between AMC and PA as increased levels of health-related fitness facilitate continued engagement in PA (Robinson et al., 2015). Although the evidence regarding this mediating role of health-related fitness is limited (Khodaverdi et al., 2016), a recently published meta-analysis revealed moderate-to-large positive associations between AMC and overall physical fitness from early childhood to early adulthood (Utesch et al., 2019), which is in line with previous systematic reviews on the topic (Cattuzzo et al., 2016; Lubans et al., 2010; Robinson et al., 2015). The meta-analysis of Utesch and colleagues (2019) also demonstrated that the association with AMC remained the same for cardiorespiratory and musculoskeletal fitness. However, more research is warranted to further understand the association between AMC and flexibility as there is currently limited evidence available on this particular relationship (Cattuzzo et al., 2016; Utesch et al., 2019). The latter study also indicated that more longitudinal studies are needed in order to better reflect the *developmental* perspective in the relationship between AMC and physical fitness.

It is important to note that AMC and physical fitness are separable yet interrelated. This is particularly apparent in the fact that some test items of (mainly product-oriented) AMC assessment tools require a certain fitness level to achieve a good level of performance or test score (Bardid, Huyben, Deconinck, De Martelaer, et al., 2016; Fransen, D'Hondt, et al., 2014). In addition, some tasks (e.g., standing broad jump) are used as either a physical fitness or an AMC measure (Utesch et al., 2019), which was also the case in the study of Rodrigues et al. (2016), proving the close relationship between these two constructs.

3.5.2.2 FUNCTIONAL DETERMINANTS

Functional determinants are individual constructs that determine behavior (e.g., motivation, fear, attentional focus). These determinants change over a much shorter period of times and can also drastically shape a person's active behavior (Haywood & Getchell, 2019). In the context of this dissertation, an individual functional determinant is a rather psychosocial or behavioral construct that might be influenced by peers, parents, coaches, teachers and other significant others.

3.5.2.2.1 PERCEIVED MOTOR COMPETENCE

In the conceptual model of Stodden and colleagues (2008), it is hypothesized that children with higher PMC will be more motivated to be physically active, and thus to further develop their AMC level. In this regard, the relationship between AMC and PMC is already extensively examined in literature, revealing divergent results. However, a recently published systematic review and meta-analysis including data from 69 studies, revealed that the relationship between AMC and PMC was positive in children, adolescents and young adults (until 24 years of age), but the strength was only low to moderate (De Meester et al., 2020). Moreover, the strength of the association between both motor competence constructs was not moderated by age, sex, developmental status or alignment between objective and subjective test instruments. Yet, most of the studies included in the meta-analysis of De Meester et al. (2020) only used a correlational approach to document the relationship between the two constructs at group level (i.e., for the total study sample and/or specific subsamples). However, this variable-centered approach does not provide insight into how differently AMC and PMC may be combined at the individual level (Bardid, De Meester, et al., 2016). Accordingly, to examine whether children with similar AMC levels may differ in the degree to which they perceive themselves as motor competent, a person-centered approach is needed. Indeed, previous studies using this latter approach revealed different profiles of children (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Weiss & Amorose, 2005), including some children with convergent levels of AMC and PMC (i.e., similar high(er) or low(er) levels of both AMC and PMC) and others with divergent levels of AMC and PMC (i.e., higher(er) levels of AMC and low(er) levels of PMC, or vice versa). However, a limitation of prior person-centered studies is the lack of alignment between AMC and PMC measures since the attributes to evaluate AMC via guided assessment and PMC via self-reported questionnaires are often not the same. This leaves us with the question whether the disparity in these measures may constitute one of the reasons for finding such divergent profiles or for finding low-to-moderate correlations between AMC and PMC.

3.5.2.2.2 MOTIVATION TOWARD SPORTS

Another individual functional constraint of interest is motivation, which can be defined as “that which influences the initiation, direction, magnitude, perseverance, continuation, and quality of goal-directed behavior” (Dweck & Elliott, 1983). In other words, it is the reason why people initiate and want to repeat a certain behavior, such as participating in organized sports. In literature, many definitions of the concept ‘motivation’ can be found, all referring to the reasons underlying human behavior (e.g., Dweck & Elliott, 1983; Guay et al., 2008).

Multiple theories have conceptualized and examined motivation. In the field of motor development, commonly used motivational theories are the Achievement Goal Theory (AGT; Nicholls, 1989) and Self-Determination Theory (SDT; Deci & Ryan, 2000). The AGT describes the goals and attributions that individuals adopt in learning and the subsequent effect of these goals on approaches and engagement in learning environments. This theory is based on the belief that children are innately motivated to learn and explore their environment (Palmer et al., 2017). The SDT, however, conceptualizes motivation in a multidimensional way, driven by different types of regulation. The SDT also assumes that these regulations fall along a global continuum, indicating the degree of an individual’s self-determination (Howard, 2020). Yet, both the AGT and SDT agree that one’s likeliness to exhibit a certain behavior is related to his/her reasons to engage in this specific behavior and the (expected) feelings of competence he/she experiences while doing so.

According to the Self-Determination Theory, three types of motivation exist: amotivation, extrinsic motivation and intrinsic motivation (see Figure 9; Deci and Ryan, 2000; De Meester, 2017). **Amotivation** implies that any motivation or intention to perform a particular activity is absent (Deci & Ryan, 2000). This is the least self-determined type of functioning and occurs when people are convinced they lack the competence to successfully perform the task, or when they believe their participation in a task will not result in the desired outcome(s) (Deci & Ryan, 2000; Ryan et al., 2011). **Extrinsic motivation** arises when the performance of the activity serves a purpose that lies outside the activity itself. Extrinsic motivation is constituted by four separate regulators, which differ in the degree to which they are self-determined. External regulation means that the activity is carried out to gain appreciation or reward, or to avoid punishment or criticism, so external pressure is experienced. Introjected regulation implies that the individual performs an activity to avoid feelings of guilt, shame or fear, or to experience pride. In this case, pressure is experienced from within the person himself/herself. Regarding identified regulation, the individual is motivated to perform the activity because he/she understands the personal meaningfulness of the activity. Finally, integrated regulation, which is the most volitional form of extrinsic motivation, comes down to engagement in an activity because it is aligned with the general values and ideals one has in life (Aelterman et al., 2012; Deci & Ryan, 2000). These four regulators, ranging from external to integrated regulation, fall along a continuum of qualitatively different types of motivation namely controlled and autonomous motivation (Deci & Ryan, 2000

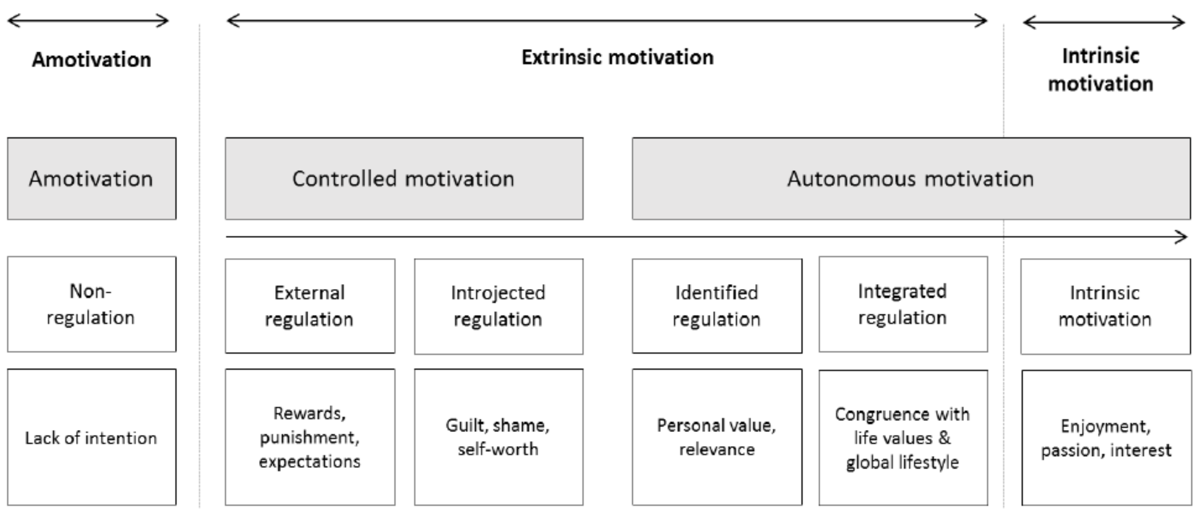


FIGURE 9 - The self-determination continuum with the types of motivation and regulation (Adopted from De Meester, 2017 who adapted the figure form Deci & Ryan, 2000)

Controlled motivation involves a sense of obligation to perform the activity, which is the case with external regulation and introjected regulation because the individual experiences pressure (Deci & Ryan, 2000). Contrary, ***autonomous motivation*** – the 'most optimal form' of motivation – refers to all forms of motivation in which the individual wants to carry out the activity himself/herself, without experiencing any pressure. It involves the regulation of behavior with the experiences of volition, psychological freedom, and reflective self-endorsement (Vansteenkiste et al., 2010). This includes identified and integrated regulation but also intrinsic motivation. **Intrinsic motivation** arises when an activity is carried out because it is satisfying in itself and perceived as enjoyable or interesting by the individual (Deci & Ryan, 2000; Teixeira et al., 2012).

In the context of my dissertation, the concept of motivation is approached from the perspective of the SDT (Deci & Ryan, 2000), which is in agreement with motivational studies in the field of motor development (e.g., studies of An De Meester, Farid Bardid, Isaac Estevan). Autonomous motivation for PA is associated with a variety of physical and mental health outcomes (i.e., effective performance, psychological well-being, healthy development; Teixeira et al., 2012). Autonomously motivated children participate in PA and sports, because they enjoy doing so or because they understand and endorse the personal relevance of participation (e.g., the health benefits; Teixeira et al., 2012). De Meester (2017) examined how children's motor competence relate to their autonomous motivation toward different types of physical activities. In her dissertation, she revealed that youngsters' AMC levels are positively related to their autonomous motivation toward sports. The correlations were significant, yet small ($0.20 \leq r \leq 0.22$). In addition, she found stronger correlations between youngsters' PMC and autonomous motivation toward sports ($0.34 \leq r \leq 0.35$), indicating that PMC might be a more decisive underlying factor of autonomous motivation than AMC. Indeed, previous studies using a person-centered approach revealed that children with relatively lower self-perceptions of their motor competence were less autonomously motivated toward sports than their peers with higher perceptions, irrespective of their AMC level (Bardid, De Meester, et al., 2016). In addition, De Meester, Maes, et al. (2016) found that adolescents with relatively high levels of AMC and PMC were more autonomously motivated toward physical education than those with relatively high levels of AMC but low levels of PMC and those with relatively low levels of both AMC and PMC. However, children with relatively low levels of AMC and high levels of PMC showed similar levels of autonomous motivation as their peers with high levels of both constructs. These studies thus suggest that higher levels of PMC could compensate for lower levels of AMC in terms of autonomous motivation toward sports (Bardid, De Meester, et al., 2016) and/or physical education (De Meester, Maes, et al., 2016).

3.5.2.2.3 PHYSICAL ACTIVITY

As mentioned earlier, Stodden and colleagues (2008) hypothesized a reciprocal relationship between AMC and PA. These authors postulated that PA is not only an influencing factor for AMC, but that - in middle and later childhood - AMC will in turn also influence PA. Since then, many studies examined this intriguing relationship between PA and AMC, which resulted in several systematic reviews (Holfelder & Schott, 2014; Jones et al., 2020; Logan et al., 2015; Lubans et al., 2010) and longitudinal studies (Barnett et al., 2009a; Lima et al., 2017 ;Lopes et al., 2011) on the topic, confirming a positive association between both constructs across childhood and adolescence although the strength of the relationship might vary depending on the studied populations. Indeed, the current (mainly cross-sectional) literature shows a positive correlation between AMC and PA throughout the different stages of childhood ($r \leq 0.55$; De Meester, 2017; Logan et al., 2015; Temple et al., 2016;). In addition, lower correlations were found in adolescence ($r \leq 0.35$; De Meester, 2017; Logan et al., 2015), which is in contrast with Stodden et al.'s (2008) hypothesis of a strengthening relationship between AMC and PA with increasing age. However, De Meester et al. (2018) indicated that having a high(er) level of AMC as a 6-to 12-year-old child was positively associated with reaching the daily target of 60 min of moderate-to-vigorous PA. Children with an above average AMC level were 2.46 times more likely to attain this World Health Organization (WHO) recommendation (2014) when compared to their less skilled peers (De Meester et al., 2018). This finding demonstrates the importance of targeting children's AMC from early childhood onwards to increase the likelihood of developing a sufficiently physically active lifestyle. Apart from age, the operationalization and assessment of PA across studies (e.g., objective measures like accelerometers versus subjective measures like questionnaires) might reveal different correlations with AMC. Likewise, when the intensity of PA is investigated, there is also evidence of differing associations with AMC. For example, previous studies investigating the association between light intensity PA and AMC did not find a relationship (Fisher et al., 2005; Williams et al., 2008; Wrotniak et al., 2006), whereas moderate-to-vigorous and vigorous PA are commonly associated with motor competence (Lubans et al., 2010; Barnett et al., 2011). Moreover, the way PA (e.g., organized sports participation vs. PA during free play at school) and AMC (e.g., overall AMC vs. only object control competence) are defined might also play a role. In this regard, the systematic review and meta-analysis from Barnett, Lai, et al. (2016) found PA to be a positive correlate of children's overall skill composite score and gross motor coordination, whilst no conclusive evidence was found for PA being a correlate of object control or locomotor skill competence each on its own. It is clear that more research is needed regarding the type of activities accounted for in relation to AMC development, which will be addressed in the next section.

3.5.3 ENVIRONMENTAL DETERMINANTS

From birth on, the capacity for intentional motor actions develops in close relation with other domains of human functioning like socio-communicative skills, psychological/emotional features, and cognition (Barnett, Stodden, et al., 2016; Bolger et al., 2021). Moreover, the development of an adequate level of AMC is imperative to be able to participate in games, sports and other types of movement activities that are typical during childhood (Gallahue et al., 2012). As a result, AMC is considered an important prerequisite toward sports participation (De Meester et al., 2014), as a specific form of PA, since it is a key factor in learning new motor skills and building the necessary proficiency for novel motor tasks. However, contrary to popular belief, the development of AMC does not occur spontaneously or purely by nature but needs targeted stimulation and formal instruction (Barnett, Stodden, et al., 2016).

3.5.3.1 MOTOR SKILL INTERVENTIONS

Despite the health benefits associated with AMC, many studies report low levels of AMC among today's children and youth (Bardid, Huyben, Lenoir et al., 2016; Bolger et al., 2021; Bryant et al., 2014; Kordi et al., 2012; O'Brien et al., 2016; Spessato et al., 2013; Vandorpe et al., 2011). Recent work has even signaled that children's AMC development is already delayed by the age of 3 years (Brian et al., 2019). In the latter study, where AMC was evaluated using the TGMD-2, more than 75% of 3- to 6-year-olds in the US scored below the 25th percentile, indicating they are at risk for (serious) developmental delays, while nearly 30% even scored below the 5th percentile. Moreover, lower levels of AMC have been associated with difficulties in academic performance (Lingam et al., 2010; Tseng et al., 2007), attention (Lingam et al., 2010; Tseng et al., 2007) as well as emotional aspects and social skills (Lingam et al., 2010; Skinner & Piek, 2001). The associations of AMC with these developmental areas serve as additional arguments for promoting AMC development in early childhood

Environmental stimulation in the form of practice opportunities enables young children to develop and master AMC. For this reason, numerous interventions have been implemented, which is clear from previous studies (Bardid et al., 2017; Van Beurden et al., 2003) as well as from reviews on the topic (Logan et al., 2012; Morgan & Barnett, 2013), in order to counter the secular decline in AMC and to have all children enjoy the lifelong benefits of an adequate AMC level. However, while most motor competence intervention studies provide evidence of short-term positive effects, studies investigating the long-term impact on children's (future) motor competence levels are scarce (Lai et al., 2014; Morgan & Barnett, 2013). As an exception, two studies investigated the long-term impact of a movement skill intervention, respectively three and six years later. Zask et al. (2012) aimed to determine whether intervention preschool children were still more skilled than the control group three years after the 'FunMoves' program. This game-based program focused on the 12 fundamental movement skills (i.e., six locomotor skills and six object control skills) The program consisted of 2 x 10 sessions with each session repeated twice a week. Each session included a warm up and cool down and about three short games, resulting in a session of approximately 25 minutes. The preschool staff received one day of training and were given the program notes and 30 laminated cards for each of the games to implement the program. The cards included instructions for setting up the materials, playing the game, adapting it to different age groups and skill levels, and giving verbal cues. In addition, the playground layout and access to the sports equipment during free play times were reviewed by project staff and adjustments were made to encourage more PA and facilitate access to the equipment. Health professionals held workshops for parents on teaching skills at home, and all preschool parents received written materials with ideas for fun games to play with children at home. Barnett et al. (2009b) evaluated the long-term impact of 'Move it Groove it' (MIGI) on adolescent motor skills and PA. MIGI was a one-year intervention with the aim of increasing motor skills and PA in young children. The intervention focused on supporting the teachers and a healthy school policy. In doing so, five strategies were used: project teams (a group of people including the principal, teachers, parents, future teachers and pupils), a buddy program (future physical education teachers go to schools to support general learning journeys to implement more PA in the daily routine and in the stimulation of the development of FMS), professional development for teachers (following sessions at regular intervals), a project website (all information regarding lesson plans, activities, planning, ...), and funding for the purchase of equipment. Four workshops were also given to teachers in the intervention schools. As these two studies found mixed results, more research investigating the long-term impact of motor competence interventions during childhood are needed. More specifically, these additional studies should more closely examine individual and environmental factors underlying children's AMC trajectories over time, especially in view of the secular decline in motor competence levels among youth (Roth et al., 2010; Vandorpe et al., 2011).

3.5.3.2 ORGANIZED SPORTS PARTICIPATION

Organized sports, which is a specific type of PA, can be defined as (usually competitive) sports that are played with a team or as an individual within a club setting (Eime et al., 2013). Participating in organized sports contributes to children's and adolescents' overall engagement in moderate-to-vigorous PA (Marques et al., 2016) and is accordingly associated with numerous health benefits (Crane & Temple, 2015). In addition, a recent cross-cultural study revealed the importance of organized sports participation (OSP) in such a club setting among children and adolescents in view of meeting the set PA guidelines (Kokko et al., 2019). While previous studies have shown that a worldwide increasing number of children and adolescents do not meet the WHO recommendations of at least 60 minutes of moderate-to-vigorous PA on a daily basis (Aubert et al., 2018), their OSP appears to be more stable over time (Guagliano et al., 2013; Telama et al., 2006). Moreover, participating in organized sports during early childhood was found to significantly increase the likelihood of continuation of OSP throughout (middle and late) childhood (Henrique et al., 2016), which may promote lifelong positive pathways of health-promoting behaviors.

In the context of this dissertation, OSP refers to children's sports participation in a club setting, which is a valuable and more controlled environment to let children and adolescents develop both psychosocial and motor skills, since it is an important leisure-time context (Goodway & Robinson, 2015).

3.5.3.2.1 ORGANIZED SPORTS PARTICIPATION IN FLANDERS

The concept of participating in organized sports is quite popular among children in Belgium, which is clear from the statistics collected by the governing body overarching all Flemish sports federations (Sport Vlaanderen, 2021). Since 2014, OSP numbers have been rising every year in every age group. In 2019, approximately 81% of all Flemish sports participants (i.e., children and adolescents) were involved in only one organized sport during the sports season (i.e., September – June) and about 19% combined two or more organized sports (i.e., 14% combined two sports, 5% combined three or more sports). In that same year, 51% of the children between 5 and 9 years of age participated in organized sports. In the next age group (i.e., 10-14 years), the prevalence of OSP was 58%. For the youngest children (i.e., 0-4 years), this participation rate was significantly lower (i.e., 10%), which makes sense since the sports offer in Flanders primarily focuses on (pre)school-aged children (i.e., starting from 3 years of age and up). However, participation rates in organized sports also seem to decline with increasing age, especially during adolescence (Brettschneider & Naul, 2007), which can also be confirmed by our Flemish data revealing that the OSP rate in 15- to 19-year-olds drops with almost 20% when compared to the 10- to 14-year-olds (see Figure 10).

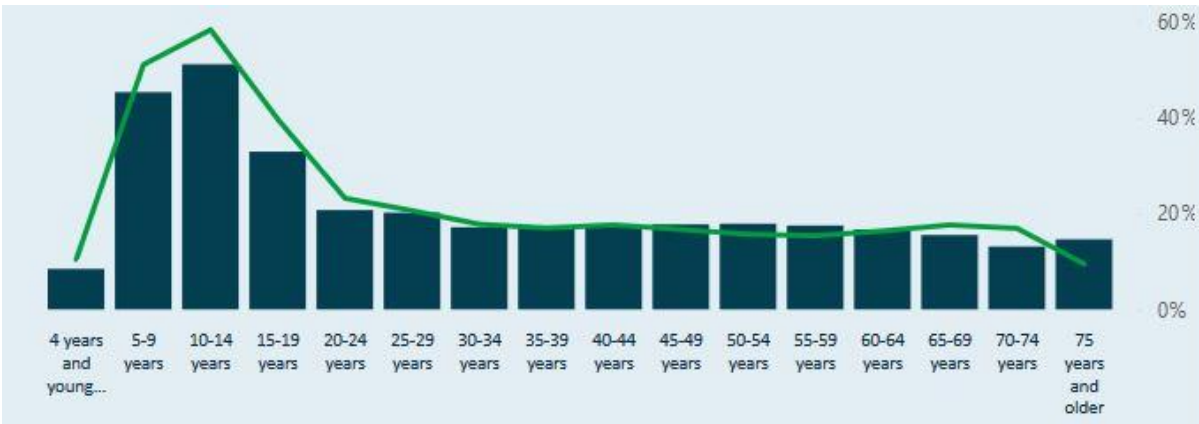


FIGURE 10 - Prevalence rates of organized sports participants in 2019 by age category in Flanders (Adopted from Sport Vlaanderen, 2021)

While a part of this dropout may reflect that children and youth are transferring between different sports, another part may reflect negative experiences in the organized sports setting (Crane & Temple, 2015). These authors reported five major groups of reason for dropout in their systematic review: lack of enjoyment, perceptions of competence, social pressures, competing priorities and physical factors like maturation and injuries. While investigating reasons for dropout of organized sports is not the focus of the current dissertation, it is important to know that participants' perceptions of sports/athletic competence (i.e., PMC) was one of the most reported factors associated with dropout (Crane & Temple, 2015). Thus, maintaining OSP throughout childhood may not only be achieved by improving children's AMC, but also by focusing on strengthening or reinforcing their levels of PMC and enjoyment in sports. This might be important in view of attaining the recommended PA levels and the associated health benefits (De Meester, 2017).

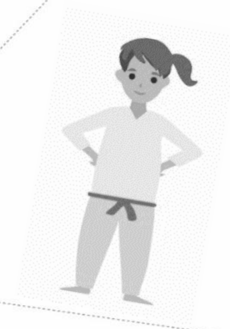
3.5.3.2.2 DIFFERENT FEATURES OF ORGANIZED SPORTS PARTICIPATION RELATED TO ACTUAL MOTOR COMPETENCE

To date, only three studies investigated the longitudinal association between children's AMC and (organized) sports participation (Fransen, Deprez, et al., 2014; Henrique et al., 2016; Vandorpe et al., 2012). Two of these studies demonstrated that spending more hours of participation in (organized) sports during the study period was associated with higher AMC levels (Fransen, Deprez, et al., 2014; Vandorpe et al., 2012). In addition, a cross-sectional study of Fransen et al. (2012) also revealed a positive association between spending more time in OSP and the child's current AMC level, an idea that was first introduced by Newell and Rosenbloom (1981) and later by the "Theory of Deliberate Practice" (Ericsson et al., 1993). Although the aforementioned studies indicate a positive effect of time spent in OSP on the level of AMC over time, it remains unclear whether other OSP features (e.g., type of sports, years of experience in sports) also show different associations with AMC and its development across childhood.

To the best of our knowledge, only one previous study investigated the relationship between type of organized sports and children's motor development (Barnett et al., 2013). These authors found that the association between AMC and OSP in early childhood (i.e., 3-6 years) differed according to the type of sports being practiced (i.e., swimming, dancing, gym). In this study, swimming was more associated with the level of locomotor skills than dancing and gymnastics. However, because only one study took the type of sports into account so far, no general conclusions can be drawn yet. Moreover, the sports that were compared in the study of Barnett and colleagues (2013) were predominantly locomotor-oriented sports. Therefore, future studies should investigate how the type of organized sports (i.e., locomotor-oriented vs. object control-oriented) in which children are involved influences their motor competence development and to what extent, which was also previously suggested by both Barnett, Lai, et al. (2016) and Henrique et al. (2016).

Another aspect of OSP involves the distinction between early specialization versus early sampling (i.e., combining multiple sports) as a pathway in youth sport participation (Côté & Vierimaa, 2014). Early specialization, which can be defined as the engagement in a single sport and involvement in competition before the age of 12 years (LaPrade et al., 2016), has sparked both positive and negative arguments. Success at junior level (Güllich & Emrich, 2014) and a higher focus on athletic achievement (Feeley et al., 2016) are arguments favoring early specialization. Negative arguments include experiencing less fun (Feeley et al., 2016), higher risk of injuries (Difiori et al., 2014), earlier dropout (Difiori et al., 2014), more psychological stress or burnout (Difiori et al., 2014) and more social isolation (Malina, 2010). When it comes to early sampling (i.e., combining multiple sports at the same time), previous research revealed that it leads to lower dropout rates and less mental problems (Côté et al., 2009). Moreover, early sampling is linked to a longer (organized) sports career and has positive implications for long-term sport involvement (Côté & Vierimaa, 2014). However, it remains unclear whether children who are involved in only one sport (i.e., single sport participants) perform better in terms of AMC when compared to children who are involved in multiple sports (i.e., multiple sports participants). A recent systematic review on the topic by Kliethermes et al. (2020) revealed that only seven studies addressed the effect of sport specialization on specific motor task performances (Beese et al., 2015; Buhrow et al., 2017; DiStefano et al., 2018; Fransen et al., 2012; Gorman et al., 2012; Miller et al., 2017; Peckham et al., 2018). In these studies, specialization was most commonly addressed by comparing single sport versus multiple sports athletes, with most of them showing no significant differences in task performance outcomes between both groups of participants. However, when differences were found, it was systematically in favor of the multiple sports participants (Kliethermes et al., 2020). For example, Fransen et al. (2012) compared physical fitness and gross motor coordination performances of 1162 boys aged 6-12 years, who participated in multiple versus single sports. In the age groups 6-8 years and 8-10 years, no differences were detected in the sit-and-reach test, push-ups, sit-ups, standing long jump and shuttle run performances as well as the total motor quotient for gross motor coordination. In contrast, 10- to 12-year-old multiple sports athletes performed better than the single sport athletes in push-ups, standing long jumps, agility shuttle run, endurance shuttle run and the overall motor coordination test. These findings indicate a more latent effect of multiple sports participation (Fransen et al., 2012). In 2021, Salin and colleagues published a paper revealing that 11- to 12-year-old boys practicing multiple sports reached overall higher fitness and AMC levels at baseline and follow-up (i.e., one year later). No such differences were found among girls when comparing both groups. Moreover, boys participating in multiple sports displayed a larger increase in AMC over time when compared to their peers participating in single sport. However, both the studies by Fransen et al. (2012) and Salin et al. (2021) did not include the (retrospective) training history for more than one year, assuming little or no change in children’s OSP over the years. While the literature suggests that OSP is important for developing both motor and psychosocial skills (Goodway & Robinson, 2015), a more fine-grained analysis is required to determine the significance of

OSP and its features that contribute most optimally to AMC and other physical and psychosocial factors, taking into account children's training history.



4 - RESEARCH OBJECTIVES AND OUTLINE OF THE DISSERTATION -

The general introduction of this dissertation revealed some important research gaps and shortcomings in the existing literature regarding (the assessment of) motor competence as well as the role of different determinants in view of children's AMC and its development. Therefore, the main goal of this dissertation was to address some of these shortcomings and provide recommendations for future research and practice.

The original research reported in PART II of the present doctoral thesis is a collection of five studies on the topic addressed. Although these articles each answer a distinct research question, they all contribute to the same overall objective, which is **gaining more insight into the determinants that influence children's AMC and its development** (see Figure 11, for a schematic overview).

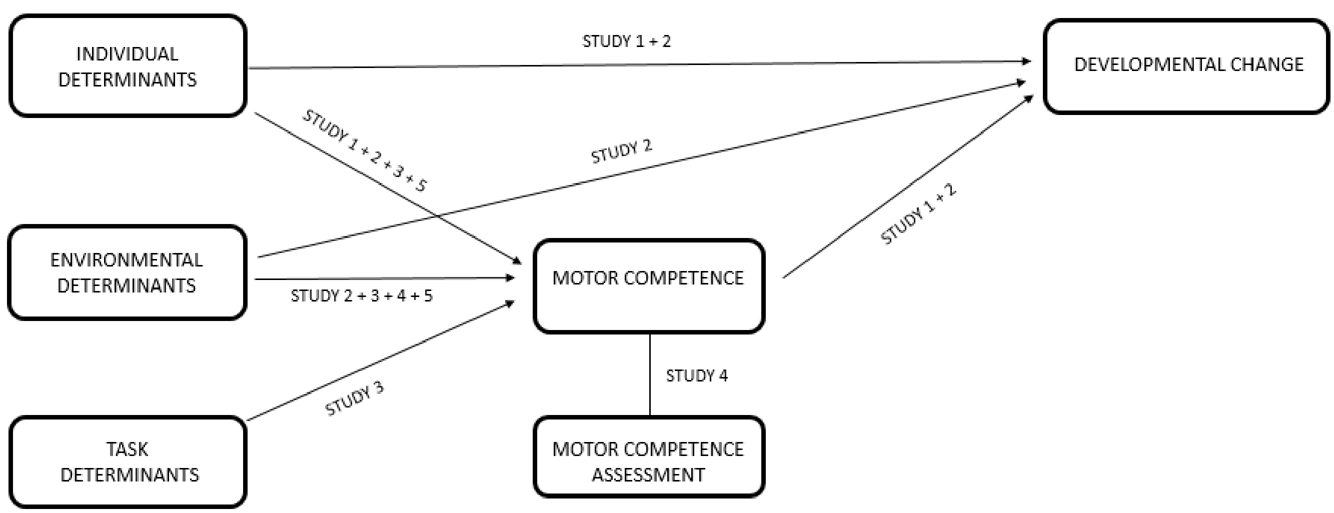


FIGURE 11 – Schematic overview of the PhD research project

The 1st CHAPTER of PART II will focus on **gaining more insight into children's individual change in AMC across childhood** as a high degree of inter-individual variation exists (Rodrigues et al., 2016; *the first objective*). Two longitudinal studies contribute to the realization of this aim, both using an approach that models each child's trajectory of change in AMC across time. In the first study, differences in developmental trajectories across children and the potential influence of five individual determinants (i.e., sex, age, baseline AMC, baseline weight status and baseline fitness) on this developmental change at the individual level over a 2-year timespan was considered (**STUDY 1**). The second study investigated to what extent two individual determinants (i.e., sex and age) as well as different environmental determinants (i.e., OSP features) are explanatory for children's AMC improvement over a period of six years (**STUDY 2**). Moreover, the long-term effectiveness of a FMS intervention was also examined in this second paper, while taking into account the potential influence of sex, age and different OSP features.

In CHAPTER 2, we applied a person-centered approach to provide **a better understanding of previously identified motor competence based profiles** *(the second objective)* by using aligned measures of AMC and PMC. As an environmental determinant, OSP was also incorporated in order to examine how AMC, PMC and OSP interact with each other (**STUDY 3**). Moreover, the newly identified profiles were compared in terms of children's weight status and autonomous motivation toward sports participation (i.e., a combination of both a structural and functional individual determinant).

In the 3rd CHAPTER, we attempted **to address some of the perceived shortcomings in literature concerning AMC assessment** *(the third objective).* It is clear that many different AMC assessment tools exist (Hulteen, Barnett, et al., 2020). However, the majority of studies focus on assessing AMC in (younger) children (Hulteen, Barnett, et al., 2020). As motor development is a lifespan process, the tools available to assess and track AMC should also be applicable beyond the childhood years. Moreover, covering the whole range of locomotor skills, object control skills and stability skills is important when assessing AMC in children, adolescents and young adults. In the context of the preceding arguments, we validated a widely used standardized normative and product-oriented test battery when combined with an object control task (**STUDY 4**). In addition, reference values for both children and adolescents (i.e., 6-19 years of age) were provided.

While previous studies confirm that OSP can vary between children (Fransen et al., 2012; Henrique et al., 2016; Vandorpe et al., 2012), there is **a current gap in literature regarding how specific OSP features might be associated with children's motor competence, physical and psychosocial health** (*the fourth objective*). Addressing this gap in CHAPTER 4 (**STUDY 5**), we examined the predictive value of three specific OSP features simultaneously (i.e., single sport vs. multiple sports participation, average amount of practice across childhood, type of sports practiced across childhood) on four different outcome measures of interest (i.e., AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports).

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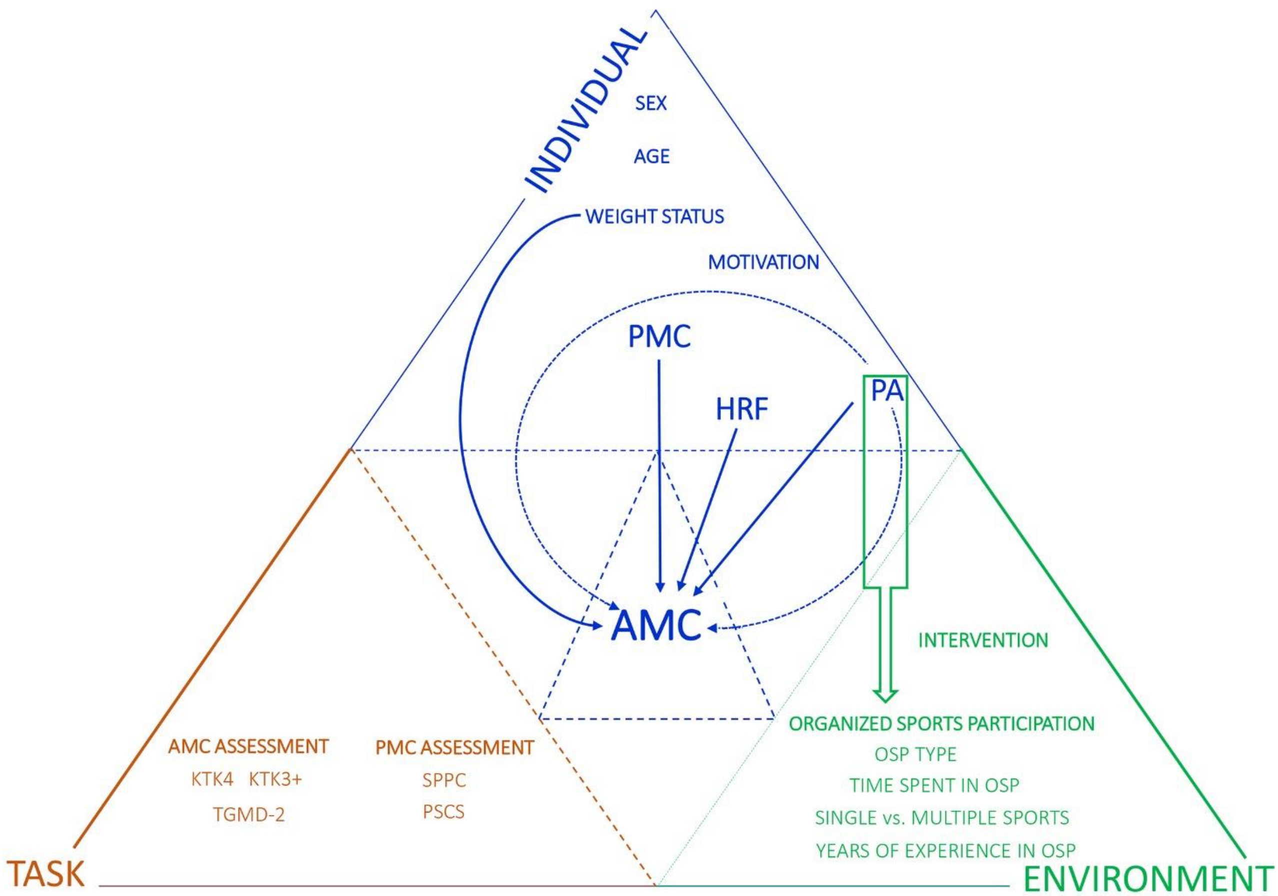
PART II: ORIGINAL RESEARCH

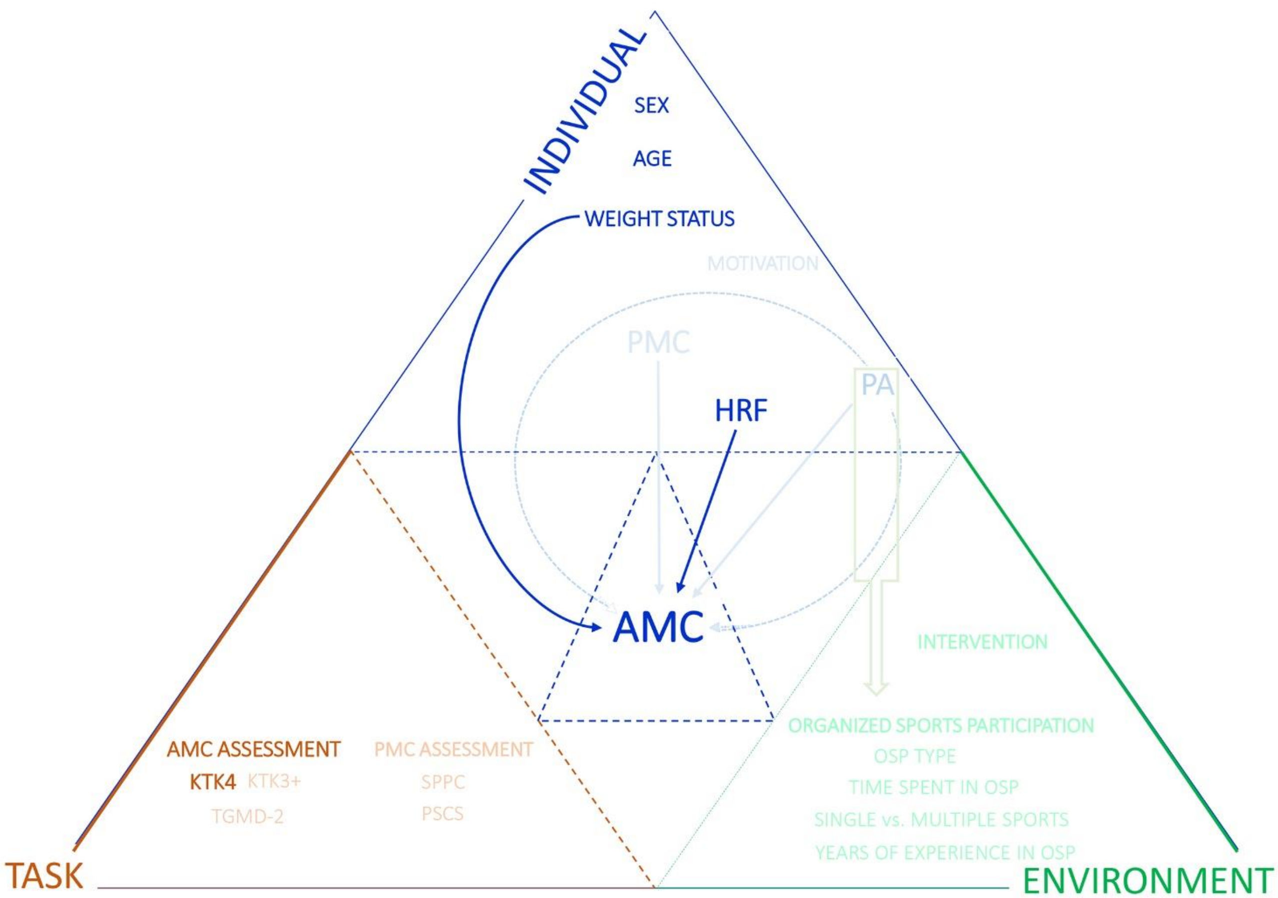


- CHAPTER 1 -

GAINING MORE INSIGHT INTO CHILDREN'S INDIVIDUAL CHANGE IN MOTOR COMPETENCE ACROSS CHILDHOOD

STUDY 1

DEVELOPMENTAL CHANGE IN MOTOR COMPETENCE: A LATENT GROWTH CURVE ANALYSIS



This study is based on **Coppens, E.***, Bardid, F.*, Deconinck, F. J.A., 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. *These authors share first authorship.
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ABSTRACT

Background: The development of childhood motor competence demonstrates a high degree of inter-individual variation. Some children's competence levels increase whilst others' competence levels remain unchanged or even decrease over time. However, few studies have examined this developmental change in actual motor competence (AMC) across childhood and little is known on the influencing factors.

Aim: Using latent growth curve modeling (LGCM), the present longitudinal study aimed to investigate children's change in AMC across a two-year timespan and to examine the potential influence of baseline weight status and physical fitness on their trajectory of change in AMC.

Method: 558 children (52.5% boys) aged between 6 and 9 years participated in this study. Motor assessments took place three times across a two-year timespan. Baseline measurements included weight status, AMC (i.e., KörperkoördinationsTest für Kinder; KTK) and physical fitness (i.e., sit and reach, standing long jump and the 20m shuttle run test). LGCM was conducted to examine change in AMC over time, based on the raw scores of the four KTK subtests.

Results: The analyses showed a positive linear change in AMC across two years ($\beta = 28.48$, $p < .001$) with significant variability in children's individual trajectories ($p < .001$). Girls made less progress than boys ($\beta = -2.12$, $p = .01$). Children who were older at baseline demonstrated less change in AMC ($\beta = -0.33$, $p < .001$). Weight status at baseline was negatively associated with change in AMC over time ($\beta = -1.418$, $p = .002$). None of the physical fitness components, measured at baseline, were significantly associated with change in AMC over time.

Conclusions and Implications: This two-year longitudinal follow-up study reveals that weight status significantly influences children's AMC trajectories whilst physical fitness demonstrated no significant influence on AMC trajectories. Future studies should further explore children's differential individual trajectories over time and potential factors influencing that change.

1 INTRODUCTION

Actual motor competence (AMC), which reflects the degree of proficient performance in various motor skills as well as the underlying mechanisms (e.g., motor control and coordination) that impact it (Utesch & Bardid, 2019), is considered a key component in developing a healthy and active lifestyle from early childhood onwards (Cattuzzo et al., 2016; Robinson et al., 2015; Stodden et al., 2008). Various terminologies have been used interchangeably in past literature to refer to this latent concept including 'motor proficiency', 'motor performance', 'movement (skill) competence', 'motor ability', 'motor function', 'motor coordination' and 'fundamental movement / motor skills' (Robinson et al., 2015). In alignment with previous studies (e.g., Cattuzzo et al., 2016; D'Hondt et al., 2013; Robinson et al., 2015), this paper uses the term AMC as a general construct encompassing all forms of goal-directed human movement involving gross body coordination and control.

The role of AMC for children's health is well described in the conceptual model of Stodden et al. (2008). This model denotes the relationship between AMC and physical activity across childhood as well as their interrelations with perceived motor competence, weight status and physical fitness. Physical fitness can be defined as the capacity to perform physical activity and includes components such as cardiorespiratory fitness, musculoskeletal fitness (i.e., muscular endurance and strength) and flexibility (Caspersen & Christenson, 1985; Ortega et al., 2008). As noted in a review article by Robinson and colleagues (2015), a wealth of predominantly cross-sectional studies show that multiple health-related outcomes, including physical activity (Holfelder & Schott, 2014; Logan et al., 2015) and physical fitness (Cattuzzo et al., 2016; Hands, 2008; Utesch et al., 2019) are indeed positively associated with AMC. Previous literature has also shown an inverse relationship between weight status and AMC (Cattuzzo et al., 2016; D'Hondt et al., 2011). However, given the role of AMC in the development of an active and healthy lifestyle, it is important to understand how AMC develops across time during childhood. Therefore, we need more longitudinal research that examines the development of AMC over time and its relationship with other health-related outcomes. For instance, de Souza et al. (2014) compared AMC, physical activity and physical fitness of children at 6 years of age relative to their physical fitness and physical activity levels at 10 years. The authors found that children who were both fit and active at 10 years of age had a more favorable activity and fitness profile at 6 years and they were also more competent at 6 years compared to their unfit and sedentary peers. Similarly, Henrique et al. (2018)

found a significant relationship between AMC, physical fitness and weight status over time in children aged 6 to 9 years. Children with consistently better AMC during the four years of follow-up had lower body weight, lower body mass index, lower subcutaneous fat, and higher physical fitness levels at age 6 compared to those with consistently low(er) levels of AMC (Henrique et al., 2018). However, Henrique and colleagues (2018) focused on specific changes in AMC (i.e., stable and unstable trajectories of children scoring below or above a specific percentile) and not on how factors measured at baseline might influence the development of AMC.

The development of AMC during childhood is also noted by a high degree of inter-individual variation (Rodrigues et al., 2016). Some children's competence levels increase whilst others' competence levels remain unchanged or even decrease over time. However, few studies have taken into account individual change in AMC development. To our knowledge, Rodrigues et al. (2016) were the first to highlight the importance of individual trajectories in AMC and physical fitness measures over time. However, the study of Rodrigues et al. (2016) used a test battery that mainly focused on components of physical fitness. Therefore, further research using specific and standardized assessment tools is needed to explore change in AMC over time.

Using latent growth curve modeling, the aim of the present longitudinal study was (1) to gain more insight into children's individual change in AMC across a two-year timespan and (2) to investigate the potential influence of weight status and physical fitness at baseline on changes in AMC trajectories over time. Based on previous studies (Robinson et al., 2015; Rodrigues et al., 2016; Stodden et al., 2008), it was hypothesized that there would be significant variability in children's trajectory of AMC at the individual level. It was also expected that children's individual trajectory of AMC would be influenced by age and sex as well as by their weight status and physical fitness level.

2 METHODS

2.1 Participants and procedures

The present study represents a secondary data-analysis from a large-scale longitudinal research project (Vandorpe et al., 2011). These data were collected in primary school children between September 2007 and January 2009. Children were recruited from 13 randomly selected primary schools from all five Flemish provinces and the Brussels-capital region of Belgium. Motor assessments took place annually for three consecutive years (i.e., 2007, 2008 and 2009). Of the original sample of 712 children assessed at each time point, only those children who completed the motor assessments annually and the anthropometric measurements and physical fitness tests at baseline were retained for the purpose of this study. This resulted in a total sample of 558 children (i.e., 293 boys and 265 girls) aged between 6 and 9 years at baseline. Written informed consent was provided for each child by a parent or legal guardian. The study protocol was approved by the Ethics Committee of Ghent University Hospital.

All participants wore light sports clothing and were barefoot during testing, except for the 20m shuttle run (for which they wore sports shoes). Assessments took place during the physical education classes in the gymnasium of the children's schools and were conducted three times on an annual basis (during the same season). Test sessions lasted approximately 85 minutes, with a group of trained examiners conducting the assessments using standardized instructions in accordance with the testing guidelines.

2.2 Measurements

Actual Motor competence. The KörperkoordinationsTest für Kinder (KTK) was used to evaluate AMC. It is a standardized normative product-oriented test battery for 5- to 15-year old children with typical and atypical motor development, which is widely used in Europe (Kiphard and Schilling, 1974, 2007, 2017). The test battery is considered a highly reliable instrument with excellent test-retest reliability for the total raw score (r = 0.97), inter-rater reliability and intra-rater reliability for the subtest raw scores (r values > 0.85 and r values = 0.80 - 0.96, respectively; Kiphard and Schilling, 1974, 2007). Content and construct validity have been documented (Kiphard and Schilling, 1974, 2007), and its convergent validity has been established through moderately strong correlations with other standardized assessment tools such as the Bruininks-Oseretsky Test of Motor Proficiency – 2nd Edition (BOT-2; Bruininks & Bruininks, 2005; Fransen et al., 2014), the Motoriktest für Vier- bis Sechsjährige Kinder (MOT 4-6; Bardid et al., 2016; Zimmer & Volkamer, 1987), and the Movement Assessment Battery for Children (M-ABC; Henderson and Sugden, 1992; Smits-Engelsman et al., 1998). The KTK is also considered a very useful motor test battery for longitudinal research because each test item is identical at any age (D'Hondt et al., 2013). The test includes four subtests: (1) balancing backwards (BB) over 3 beams of decreasing width, (2) moving sideways (MS) with the aid of two wooden boards in 20 seconds (two attempts), (3) jumping sideways (JS) as often as possible over a bar in 15 seconds (two attempts), and (4) hopping for height (HH) on one leg over foam squares with consecutive steps of 5 cm per added foam square. For the purpose of the present analysis, the raw scores of each subtest were summed to compute an overall motor competence score. In addition, a standardized motor competence score (or motor quotient, MQ) was also computed using the manual's normative tables based on the performance of the reference sample (Kiphard & Schilling, 2017). To this end, the raw subtest scores were first transformed into standardized scores adjusted for age (all subtests) and sex (BB, JS and HH). These standardized subtest scores were then summed and converted into the total KTK MQ.

Physical fitness. Different subtests of the European Test of Physical Fitness (EUROFIT) with adequate reliability were used to assess the health-related components of physical fitness (Council of Europe, 1988). The selection of these tests was based on practical considerations regarding age-appropriateness, user-friendliness and discriminative power among children aged 6 to 11 years. Cardiorespiratory fitness or endurance was assessed using the multistage fitness test, also known as the EUROFIT 20 meter shuttle run test (20m SR), with an accuracy of 0.5 min. This test involves continuous running between two lines (20 meters apart) on time in agreement with recorded beeps. The frequency of the sound signals is gradually increased during this test, requiring children to run faster with each increase frequency of signals (plus 0.5 km/h each minute from a starting speed of 8.5 km/h). The test was stopped if the subject could no longer keep the pace and failed to reach the line (within 2 meters) for two consecutive times and after a warning. The EUROFIT standing long jump test (SLJ) was used as an indicator of musculoskeletal fitness and explosive power (Pillsbury et al., 2013). In this test, participants have to jump as far as possible from standstill and land on both feet. The test is performed twice with the best result used for data analysis with an accuracy of 1.0cm. Trunk flexibility and hamstrings length were assessed with the EUROFIT sit and reach test (SAR) with an accuracy of 0.1 cm. For this test, participants had to sit on the ground with straight legs, reaching as far as possible with the fingertips to a metal board, with the better of two consecutive efforts used for data analysis.

Weight status. Participants' body height was measured by using a portable stadiometer with an accuracy of 0.1 cm (Harpenden, Holtain Ltd, Crymych, UK) and their body weight was determined using a digital scale with an accuracy of 0.1 kg (Tanita, BC-420 SMA, Weda BV, Naarden, Holland). These measures were then combined to compute children's body mass index (BMI, kg/m^2), which was used as an estimate of weight status.

2.3 Statistical Analyses

Descriptive statistics were calculated for the AMC scores (i.e., KTK total raw score) at each time point and for the different health-related components of physical fitness (i.e., 20m SR, SLJ, SAR) and weight status (i.e., BMI) at baseline using SPSS 25 for Windows.

Latent growth curve models (LGCMs; see Figure 1) were conducted to examine change in AMC over time, summed into an overall motor competence score based on the raw scores on the KTK test items (at each time point). Effects of confounding factors such as sex and age were considered in the analysis. Additionally, effects of participants' baseline weight status (i.e., BMI) and physical fitness components (i.e., 20m SR, SLJ, SAR) on change in AMC were examined. Maximum likelihood estimation was used for the LGCMs and significance level was set at $p < .05$.

A series of LGCMs were run to investigate change in AMC over time. First, an intercept-only model with the intercept mean and residual variance constrained across time points (Model 1) was run. The intercept variance was then estimated in Model 2. Next, the slope mean and variance were included in Model 3 to estimate change in AMC over time. Subsequently, sex and age were added to the model (Model 4). Sex was inserted as a dummy variable (i.e., 0 = boy; 1 = girl), whereas age (months) was inserted as a continuous variable and mean centered in the LGCMs. Next, baseline weight status was included as a continuous variable in Model 5 to examine the potential influence on change in AMC over time. Similarly, 20m SR, SBJ and SAR were entered as continuous variables in Model 6 to examine possible effects of baseline physical fitness on AMC change over time. Both weight status and the 3 abovementioned physical fitness variables were z-transformed adjusting for age and sex. Finally, a model with only significant effects of baseline weight status and physical fitness components was run (Model 7). All latent growth curve analyses (LGCA) were conducted in R version 3.5.2 using the *Lavaan* package (Rosseel, 2012).

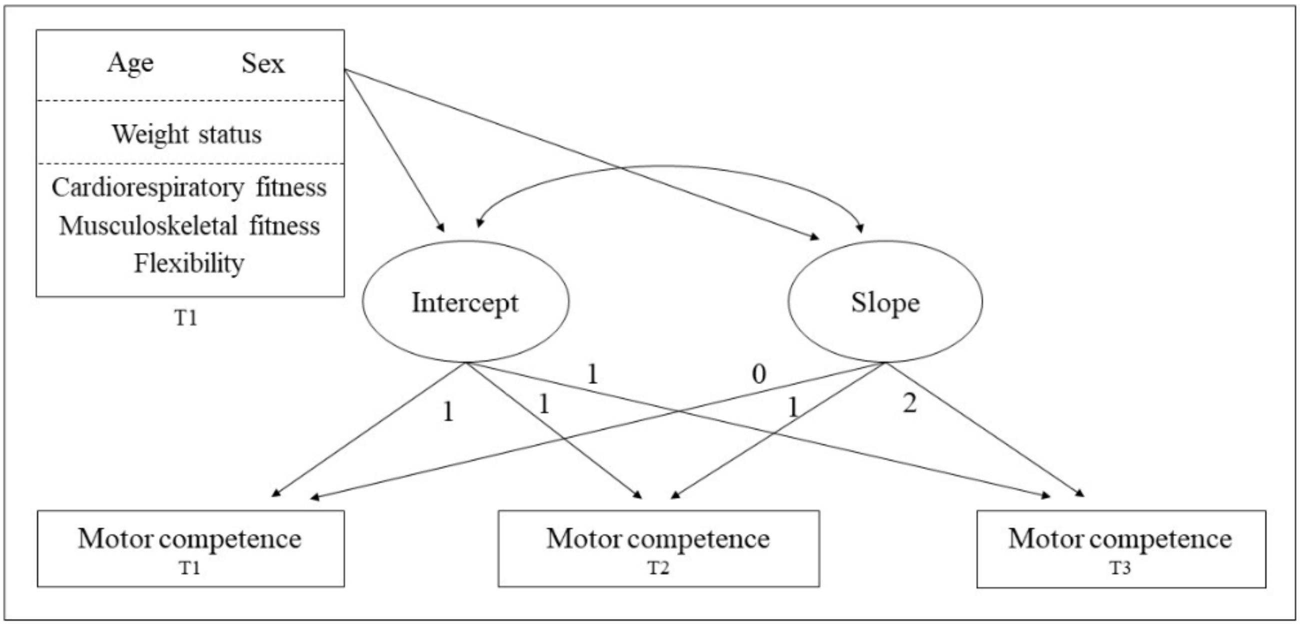

FIGURE 1 - Representation of the latent growth curve model of actual motor competence measured at three one-year interval time points (T1, T2 and T3) with age, sex, weight status and physical fitness as time-invariant covariates measured at baseline (T1). The latent intercept is constant for any child across time points as indicated by the fixed values of 1 for the factor loadings. The latent slope represents a child's actual motor competence trajectory with varying values (i.e., 0, 1 and 2) for the factor loadings. The value starts at 0 to allow the mean intercept to be interpreted as the mean actual motor competence score at baseline (T1). The value increase by 1 indicates an equal amount of time between measurements.

Figures were also produced to illustrate individual trajectories of change in AMC. To this end, children were divided into three groups based on their change in AMC over time (i.e., from time point 1 to 3): low rate of change group (< P25), average rate of change group (P25 - P75), and high rate of change group (> P75). Figure 2 shows individual changes in AMC over time based on the total raw score on the KTK, whereas Figure 3 displays individual changes in AMC development based on the total MQ of the KTK.

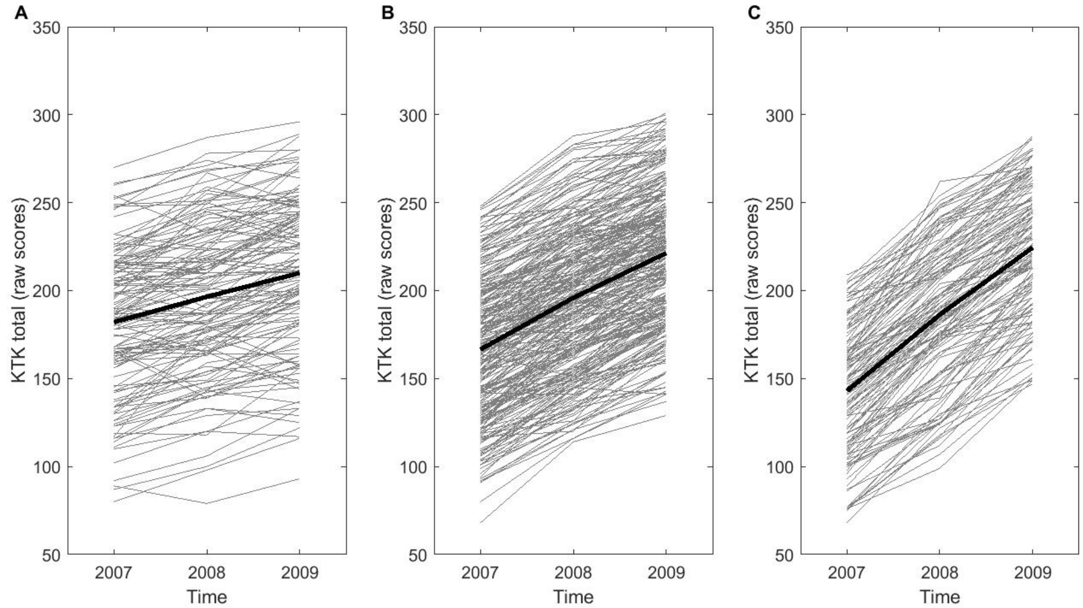

FIGURE 2 - Individual trajectories in actual motor competence over time based on the total sum of raw scores on the KTK: representation of **(A)** the lowest (< P25), **(B)** average (P25 - P75), and **(C)** highest (P > 75)rate of change (RoC) in the total sample, with the average trajectory being indicated by the thick black line in each of the RoC groups.

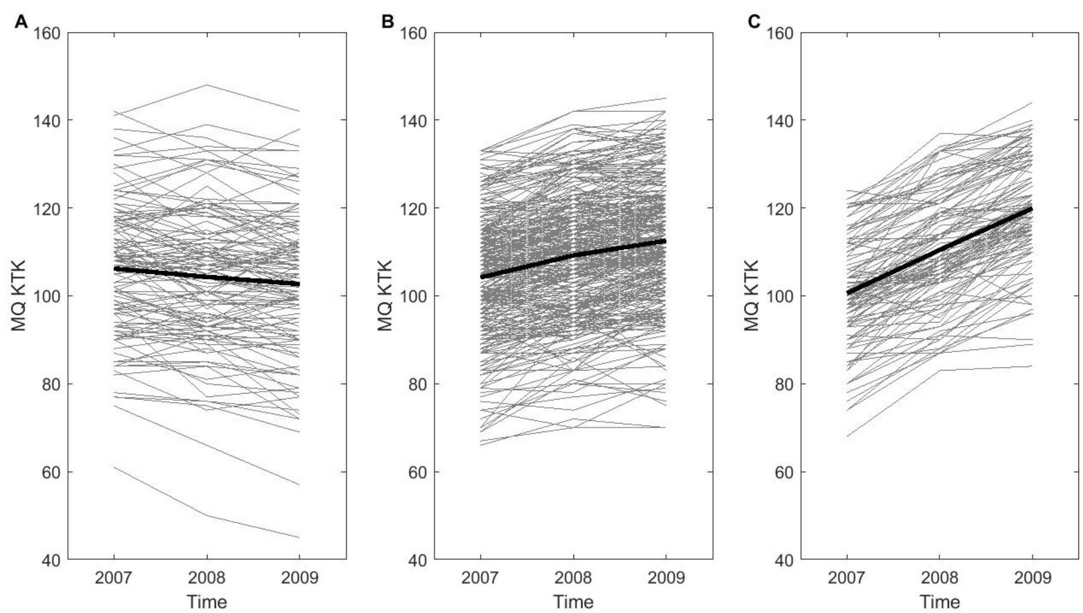

FIGURE 3 - Individual trajectories in actual motor competence over time based on the total motor quotient (MQ) scores on the KTK: representation of **(A)** the lowest (< P25), **(B)** average (P25 - P75), and **(C)** highest (P > 75) rate of change (RoC) in the total sample, with the average trajectory being indicated by the thick black line in each of the RoC groups.

3 RESULTS

Table 1 shows the means and standard deviations of weight status at baseline (i.e., BMI), fitness scores at baseline (i.e., 20m SR, SBJ, SAR) and levels of AMC (total raw scores on the KTK) at each time point for boys and girls separately as well as for the total sample. AMC generally increased over time, which is also visualized by the thick black lines in Figure 2 (change in total raw score) and Figure 3 (change in total MQ), representing the average trajectory in the low, average and high rate of change group. Both figures show the variability in individual change of AMC for the total sample visualized by the thin lines, representing the individual trajectory of AMC across time.

The results of the LGCA are reported in Table 2. The LGCMs with random intercepts and slopes demonstrated good model fit (RMSEA ≤ .073; SRMR ≤ .014; CFI ≥ .994). Based on the total raw scores on the KTK, the analyses showed a positive linear change in AMC over time (β = 28.48, p < .001) with significant variance in this change (p < .001). There was no significant relationship between AMC at baseline and change in AMC over time, based on the overall total raw scores on the KTK (p = 0.33).

TABLE 1 - Descriptive statistics of age, weight status at baseline, physical fitness scores at baseline and actual motor competence raw scores at each time point, in boys, girls and the total sample.

	Boys (N = 293)	Girls (N=265)	Total Sample (N=558)
Age (year)	8.2 ± 1.09	8.1 ± 1.15	8.2 ± 1.1
Weight status (kg/m2) at baseline	16.21 ± 2.01	16.32 ± 2.16	16.26 ± 2.08
Physical fitness at baseline			
Cardiorespiratory fitness: 20m SR (min)	4.85 ± 2.22	3.55 ± 1.73	4.23 ± 2.10
Musculoskeletal fitness: SBJ (cm)	124.11 ± 20.49	118.83 ± 20.62	121.61 ± 20.70
Flexibility: SAR (cm)	19.51 ± 5.18	22.57 ± 4.93	20.96 ± 5.28
Actual motor competence at each time point			
$KTK_{TOTAL\ T1\ (RAW\ SCORE)}$	166.10 ± 39.84	162.89 ± 43.01	164.57 ± 41.37
$KTK_{TOTAL\ T2\ (RAW\ SCORE)}$	196.24 ± 40.17	191.52 ± 41.00	194.00 ± 40.60
$KTK_{TOTAL\ T3\ (RAW\ SCORE)}$	224.85 ± 40.70	216.99 ± 42.23	221.12 ± 41.59

SR: shuttle run, SBJ: standing broad jump, SAR: sit and reach, KTK: Körperkoordinationstest für Kinder

Sex was not a predictor of differences in the KTK total raw score at baseline but was negatively associated with change in AMC across two years; girls made less progress in AMC than boys (β = -2.12, *p* = .01). Age was significantly related to the KTK total raw score at baseline, with older children demonstrating higher AMC at baseline (β = 1.90, $p < .001$). Additionally, age at baseline was negatively associated with change in AMC across time. Children who were older at baseline demonstrated less change in AMC across two years (β = -0.33, $p < .001$). When considering the intercept and slope variance, 40.4% and 34.8% was explained by sex and age.

Children's weight status at baseline was negatively associated with the KTK total raw score at baseline as well as with the change in AMC across two years. A higher BMI level at baseline was associated with decreased AMC (β = -3.67, $p = .004$). Similarly, a higher BMI at baseline was inversely related to AMC change over time (β = -1.418, $p = .002$). After accounting for sex and age, weight status explained 8.9% and 4.5% of the intercept and slope variance, respectively.

Of the physical fitness outcomes, baseline levels of 20m SR (β = 8.08, $p < .001$) and SBJ (β = 15.51, $p < .001$) were directly related to AMC levels at baseline. When considering change in AMC over time, none of the physical fitness components measured at baseline was shown to be significantly associated. After accounting for sex, age and BMI, both 20m SR and SBJ explained 36.84% of the intercept variance.

TABLE 2 - Results of the latent growth curve analyses.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept mean	192.53***	192.53 ***	165.16 ***	165.33***	165.19***	165.20 ***	165.20 ***
Sex				-0.36 *n.s.*	-0.33 *n.s.*	-0.25 *n.s.*	-0.25 *n.s.*
Age				1.89 ***	1.90 ***	1.90 ***	1.90 ***
Weight status					-9.97 ***	-3.66 **	-3.67 **
Cardiorespiratory fitness						8.40 ***	8.08 ***
Musculoskeletal fitness						15.38 ***	15.51 ***
Flexibility						1.98 *n.s.*	
Intercept variance		1191.05***	1583.02***	943.15***	859.66***	543.65***	546.97***
Residual variance	2116.59	925.55	131.13	131.13	130.84	130.63	130.63
Slope mean			27.37 ***	28.41 ***	28.47 ***	28.48 ***	28.48 ***
Sex				-2.19 **	-2.22 ***	-2.12*	-2.12 *
Age				-0.29 ***	-0.30 ***	-0.30 ***	-0.3 ***
Weight status					-1.38 ***	-1.76 ***	-1.42 **
Cardiorespiratory fitness						-0.49 *n.s.*	
Musculoskeletal fitness						-0.72 *n.s.*	
Flexibility						0.34 *n.s.*	
Slope variance			45.30 ***	29.52 ***	28.21 ***	26.76 ***	27.50 ***
Covariance			-86.23 ***	10.17 *n.s.*	-1.75 *n.s.*	10.96 *n.s.*	11.10 *n.s.*
$\chi 2$	2407.75	1905.34	11.88	15.80	16.11	22.87	23.01
df	7	6	3	5	6	9	10
RMSEA	0.784	0.753	0.073	0.062	0.055	0.053	0.049
SRMR	0.634	0.380	0.014	0.010	0.009	0.007	0.011
CFI	0.000	0.027	0.995	0.995	0.996	0.994	0.995

* *p* < .05; ** *p* < .01; *** *p* < .001; *n.s.*: not significant

4 DISCUSSION

The purpose of this longitudinal study was to gain more insight into developmental change in children's AMC over time and to investigate the potential influence of weight status and physical fitness on that change. Therefore, a LGCA was conducted to investigate the developmental change in AMC. This approach is appropriate as it models trajectories of change in AMC across time and considers differences in developmental trajectories across children and the potential influence of baseline weight status and physical fitness on this individual change.

Consistent with previous research (e.g., Ahnert et al., 2009; dos Santos et al., 2018; Vandorpe et al., 2011), an average positive change in AMC over two years was found. Yet, the results of the LGCA revealed that there was significant variance in how children's AMC develops over time, which is also consistent with dos Santos et al. (2018), and clearly illustrated in both Figure 2 and 3 of the present paper.

Visual inspection of Figure 2 shows a large variability in the rate of change across the current sample. In some children, the overall motor competence raw score demonstrates improvement in a linear fashion over the two years, whereas others show little change after one year followed by an improvement in year 2, and still others show an increase in year 1 that levels off in year 2. It is interesting to note that when these raw scores are converted to age- and sex-adjusted MQs as displayed in Figure 3, a number of children actually stagnated (1.1%) or demonstrated a delayed development (14.7%) of AMC compared to the reference sample (Figure 3; Kiphard and Schilling, 2017). MQ is considered a relatively stable construct over time for the average child (Vandorpe et al., 2011), but results of the LGCA analyses demonstrate there was statistically significant variability in trajectories of change in AMC among individual children. Whilst an improvement in raw scores on the KTK was present in virtually every child in the sample (99.6%; see Figure 2), this improvement may be considered insufficient to keep up with the expected motor development, which is evident from Figure 3, where only 39.0% makes progress, with respect to age- and sex-related norms.

Regarding the level of AMC at baseline, the LGCA showed that there was no significant relationship between AMC at baseline and the change in AMC over time. Indeed, inspection of Figure 2 and 3 shows that each rate of change group included children with a high(er) or low(er) level of AMC at baseline. Our results thus suggest that each child can improve his/her level of

AMC over a period of two years, regardless of his/her initial level of AMC. The finding of inter-individual variation in AMC development is in agreement with the study of Rodrigues et al. (2016), where children also demonstrated divergent developmental pathways in fitness across childhood. Interestingly, the study by Rodrigues and colleagues (2016) reported that many children in the low rate of change group did not change in raw performance or actually decreased in raw performance over time, whereas the present study demonstrated a general positive change in AMC over time irrespective of the level of AMC at baseline. In contrast, dos Santos et al. (2018) found that higher levels of AMC at 6 years of age demonstrated lower rate of change over time. It should be noted that both studies included samples of one age group or grade (i.e., 6 years / grade 1) followed over time, whilst the present study sample covered a larger age range at baseline (i.e., 6-9 years). Additionally, Rodrigues and colleagues (2016) mainly focused on components of fitness rather than AMC (i.e., SLJ, 50m dash, 10m SR, 60s sit-ups, flexed arm hang, SAR, 20m SR). The extent to which children can improve their AMC level and redirect their trajectories later on, remains a pertinent question and should be further explored.

The present findings showed that there was no significant difference in AMC between boys and girls at baseline. Most previous studies have reported sex differences in favor of boys in this age range although different results have been found across specific motor domains. In their systematic review, Barnett et al. (2016) found strong evidence for boys scoring better on motor coordination compared to girls whilst reporting inconclusive evidence for girls outperforming boys on stability measures. As the KTK covers both aspects of motor coordination and dynamic balance, this might explain the divergent finding in the present study. Interestingly, boys in our sample made more progress in AMC over time compared to girls. Prior research has generally not specifically investigated how sex influences AMC development. The study of dos Santos et al. (2018), however, found differences in the trajectory of change favoring girls whilst the study of Rodrigues et al. (2016) found no differences. In light of these contrasting findings, there clearly is a need for more research into how boys and girls develop their AMC levels over time and how this might be (differently) affected by factors such as physical activity participation and sports preferences.

In alignment with previous literature (e.g., Barnett et al., 2016), the present study results showed a positive relationship between age and the level of AMC at baseline. However, our data indicate that as age increases, change in AMC decreases. Although data on this topic in literature is limited, it is generally assumed that early childhood is marked by major changes in physical and motor development (Gallahue, Ozmun, & Goodway, 2012). However, as noted by Gallahue and Ozmunn (2005), middle childhood is characterized by “slow but steady increases in height and weight and progress toward greater organization of the sensory and motor systems” (p. 178). Although older children still make progress in their AMC, these findings do seem to support early interventions focused on developing AMC at a younger age. This, in turn, will help children successfully participate in sports, games and other types of physical activity as they grow older.

Another purpose of this study was to examine if weight status and physical fitness influenced children’s individual trajectory of change in AMC over time. Results revealed a significant inverse relationship between weight status and AMC at baseline, which is in agreement with previous research (Cattuzzo et al., 2016; D’Hondt et al., 2013; D’Hondt et al., 2014; Lima et al. 2018; Lopes et al. 2012; Martins et al., 2010; Rodrigues et al., 2016). Moreover, children’s baseline weight status was inversely associated with change in AMC. Specifically, a higher weight status at baseline was associated with less progress in AMC. This partly supports Stodden and colleagues' (2008) notion of a negative spiral of disengagement where children with a less optimal weight status are at greater risk to end up in becoming less motor competent over time, which may lead to reduced physical activity participation and lower physical fitness.

With respect to physical fitness, it was indeed shown that baseline levels of cardiorespiratory and musculoskeletal fitness were significantly related to AMC at baseline, which is consistent with findings from earlier studies (Cattuzzo et al., 2016; Lubans et al., 2010; Utesch et al., 2019). However, no significant relationship between trunk flexibility and AMC at baseline was found. Contrary to these findings, Lopes et al. (2017) found a positive association between flexibility and AMC in children. It should be noted that there is an age difference between the sample of the present study (6-9 years) and that of the study of Lopes et al. (2017; 9-12 years). More research is warranted to further understand the association between AMC and flexibility as there is currently limited evidence available on this relationship (Cattuzzo et al., 2016; Utesch et al., 2019). Although physical fitness is considered an important marker of current and future health in both children and adults, none of the components of physical fitness (i.e., cardiorespiratory fitness, musculoskeletal fitness and flexibility) were significantly associated to change in AMC over time. This is in contrast with the study by dos Santos et al. (2018) who found that children in the age range of 6 to 9 years with higher levels of physical fitness demonstrated higher scores on AMC across a four-year timespan. It should be noted that our study particularly focused on how physical fitness at baseline influenced change in AMC over time. In light of the limited longitudinal evidence on this topic, there is a need for more research investigating the role that different physical fitness components may have on AMC development across childhood.

The present study investigated children's trajectories of change in AMC across two years and explored the influence of baseline weight status and physical fitness on these trajectories. The longitudinal design and the inclusion of LGCA are definitely strengths of the current study. Using this statistical approach allows for the estimation of inter-individual variability in intra-individual trajectories of change over time, whereas more traditional methods for analyzing repeated measures data are more limiting. However, some limitations need to be addressed. First, the present study only investigated linear change in AMC as data were only collected across three time points. However, considering the variability in individual trajectories (see Figure 2) across a longer time frame should be investigated and may demonstrate nonlinear change in AMC across time (i.e., including ≥ 4 time points). This type of analysis will provide a more comprehensive understanding of childhood developmental pathways of AMC. Second, children's BMI was used as the sole indicator of weight status. As BMI is an indirect estimate of adiposity, further investigations should include additional anthropometric measures, such as waist circumference and skinfolds and or more advanced techniques (such as Bioelectrical Impedance Analysis (BIA) or Dual-energy X-ray Absorptiometry (DXA) to better estimate weight status and/or fat percentage. Third, the present study focused solely on gross motor coordination and did not examine other behavioral attributes such as physical activity and sport participation. For this reason, it is impossible to determine if the variability in intra-individual trajectories of change over time is related to the sports practice or physical activity participation. As AMC is associated with many health related outcomes, more research is recommended to explore how other components of AMC change over time and how this variation is linked with both physiologic and intrinsic factors (e.g., physical fitness, weight status, perceived competence and motivation) as well as behavioral factors (e.g., physical activity, sport participation). As noted by Robinson et al. (2015), children's development is "a complex and multifaceted process that synergistically evolves across time" (p. 1273). Barnett et al. (2016) determined that child-level variables such as age, sex, weight status, physical activity, fitness, and socioeconomic background are all important individual correlates of AMC. Therefore, future longitudinal studies are recommended to further explore the potential role of such (additional) correlates in order to gain more insight in the mechanisms underlying children's individual trajectories of AMC across time.

Conclusions and implications

In summary, this two-year longitudinal follow-up study demonstrates a general positive linear change in children's AMC over time, although there is significant variance in trajectories among individuals. Moreover, the level of AMC at baseline was not found to be associated with change in AMC over time. Our findings call for a shift toward a person-centered developmental approach for understanding change in AMC development. This study further showed that weight status is not only negatively associated with AMC at baseline, but also negatively influences change in AMC across childhood. It appears that particularly overweight children are at higher risk of making less positive change in AMC over time. Additionally, whilst both cardiorespiratory and musculoskeletal fitness were positively related to AMC at baseline, they did not significantly affect change in AMC over time. Our findings highlight the importance of exploring individual change in AMC across childhood in order to develop more effective movement programs and to better support children's motor development.

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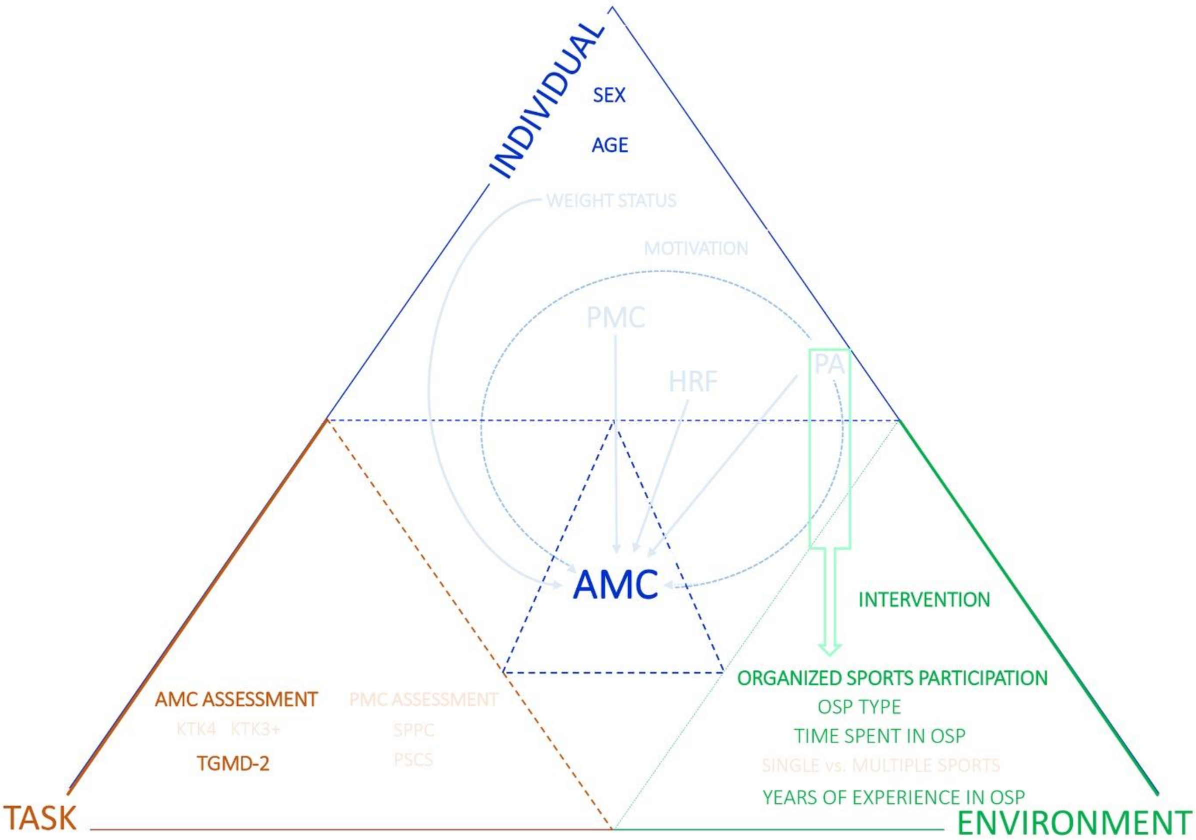
- CHAPTER 1 -

GAINING MORE INSIGHT INTO CHILDREN'S INDIVIDUAL CHANGE IN MOTOR COMPETENCE ACROSS CHILDHOOD

STUDY 2

LONG-TERM EFFECTIVENESS OF A FUNDAMENTAL MOTOR SKILL INTERVENTION IN BELGIAN CHILDREN: A 6-YEAR FOLLOW-UP



This study is based on **Coppens, E**., Rommers, N., Bardid, F., Deconinck, F. J., De Martelaer, K., D'Hondt, E., & Lenoir, M. (2021). Long-term effectiveness of a fundamental motor skill intervention in Belgian children: A 6-year follow-up. *Scandinavian Journal of Medicine & Science in Sports*, *31*, 23-34. https://doi.org/10.1111/sms.13898

ABSTRACT

The aim of this study was (1) to examine the long-term effectiveness of the ‘Multimove for Kids’ program, a 30-week fundamental motor skill intervention (approximately 1 hour per week) for typically developing children between 3 and 8 years, and (2) to determine the influence of participation in organized sports on actual motor competence (AMC) six years after the intervention.

Of the 992 children who took part in the ‘Multimove’ program, 399 (intervention group: N = 228, control group: N = 171) were tested again at 6-year follow-up. AMC was measured with the Test of Gross Motor Development, 2nd Edition. To examine the long-term impact of ‘Multimove’ on AMC and the effect of participation in organized sports a latent growth curve analysis was conducted.

After the 30-week intervention, the intervention group outperformed the control group (β = 5.57, $p < .001$). However, when the entire study period, including the 6-year follow-up, was considered, the intervention group made less progress in AMC than the control group (β = -0.41, $p < .05$). Looking at the engagement in organized sports, it was found that years of experience before the intervention had no significant influence on the evolution of AMC over time, whereas a positive effect was observed for children’s average sports participation (h/week) during the 6-year retention period (β = 0.14, $p < .001$). Finally, children practicing predominantly object control-oriented sports during retention, obtained slightly better AMC scores at follow-up (β = 0.01, $p < .01$).

The effect of the ‘Multimove’ intervention does not have a long-term effect on the development of AMC. However, participation in organized sports has a positive influence on AMC evolution over time.

1 INTRODUCTION

Motor competence (AMC) represents the degree of proficient performance in various motor skills as well as its underlying mechanisms (e.g., motor control and coordination; Utesch & Bardid, 2019). AMC is associated with a range of health-related outcomes and is considered important in developing an active lifestyle (Cattuzzo et al., 2016; Robinson et al., 2015; Stodden et al., 2008). Apart from displaying positive relationships with physical activity (Hulteen et al., 2018; Logan et al., 2015), AMC is also associated with physical fitness (Cattuzzo et al., 2016; Utesch et al., 2019), psychosocial well-being (Skinner & Piek, 2001), cognitive skills (van der Fels et al., 2015), and inversely related to weight status (Cattuzzo et al., 2016; D'Hondt et al., 2013) across childhood and adolescence. As a result, AMC is considered an important prerequisite toward sports participation (De Meester et al., 2014), since it is a key factor in learning new motor skills and building the necessary proficiency for novel motor tasks.

In order to improve health-related outcomes in children, numerous AMC intervention programs have been implemented (Bardid et al., 2017; Logan et al., 2012; Van Beurden et al., 2003). One of those interventions was the policy-based 'Multimove for Kids' program, implemented in 2012 in Flanders (Belgium), which is a fundamental motor/movement skill (FMS) intervention for typically developing children between 3 and 8 years. This 30-week program, consisting of weekly 1-hour sessions and focusing on 12 FMS themes, was found to significantly improve AMC, both locomotor and object control skills (Bardid et al., 2017).

The main aim of such programs is to counter the secular decline in AMC and to have all children enjoy the lifelong benefits of an adequate AMC level in the domains of physical activity, health, mental, and psychological well-being (Cairney et al., 2019; Hulteen et al., 2018). However, while most AMC intervention studies provide evidence of short-term positive effects on AMC, there is a dearth of studies looking into long-term effects (Morgan & Barnett, 2013). As an exception, Barnett and colleagues (Barnett et al., 2009) investigated the long-term impact of the "Move It, Groove It" intervention in primary school children by re-assessing children's FMS six years later, which yielded mixed results. The intervention group scored better on catching, jumping, and galloping, whereas no differences were found in throwing and kicking when compared to the control group. An important factor that may explain the discrepancy between findings is the child's engagement in sports or other activities during the retention period, since Logan et al.(Logan et al., 2015) provided strong evidence of positive associations between AMC and physical activity. Previous studies already demonstrated that children practicing (a larger number of) organized sports or children being involved in more hours of organized sport per week displayed a more pronounced improvement in AMC over developmental time (Fransen et al., 2014; Henrique et al., 2016; Vandorpe et al., 2012). In addition, Barnett et al. (2013) and Henrique et al. (2016) suggested that the effect of sports participation on long-term AMC development may depend on the type of sports practiced in an organized context. Likewise, the biological constructs age and sex could also influence the development of AMC. While previous research has already shown that girls have better scores on the balance tasks, no clear differences between both sexes were found on the locomotor tasks (Barnett et al., 2016; Rodrigues et al., 2019). In addition, boys outperformed girls on object control-oriented tasks (Bardid et al., 2017; Barnett et al., 2016). When it comes to age, a positive relationship with AMC has been demonstrated (Ahnert et al., 2009; Barnett et al., 2016; Rodrigues et al., 2019; Vandorpe et al., 2011). However, the effect of potentially important factors such as sex or age, has yet to be extensively studied to fully appreciate the long-term impact of AMC interventions.

To fill this gap, we studied the long-term effectiveness of a AMC intervention while taking into account the potential influence of sex, age and organized sports participation. Therefore, the primary aim of the present study was to investigate the long-term effect of the 30-week 'Multimove' intervention, measured after a retention period of six years. The second aim was to study to what extent sex, age, as well as aspects of participation in organized sports (i.e., the years of experience in organized sports at the start of the study, the average amount of hours on weekly basis during retention, the type of organized sports practiced during retention) are responsible for AMC improvement over six years.

2 METHODS

2.1 Participants and procedures

The present study is a follow-up of the large-scale 'Multimove' project (Bardid et al., 2017), in which 992 children, between 3 and 8 years, took part. Of this sample, 523 children received a 30-week intervention in 2012 (see procedures). The remaining 469 children did not receive any intervention and were classified as the control group. Follow-up data were then collected between August 2018 and February 2019, approximately six years after the end of the intervention. Of the original 992 participants, 399 participants were re-assessed. A total of 228 children were part of the intervention group (response rate 43.6%; 125 boys; mean age: 11.82 ± 1.41 years) and 171 belonged to the control group (response rate 36.5%; 91 boys; mean age: 10.79 ± 1.17 years). Written informed consent to participate in the follow-up study was provided for each child by their parent(s) or legal guardian. The study protocol was approved by the Ethics Committee of Ghent University Hospital.

In 2012, children in the intervention group received 30 weekly one hour exercise sessions focusing on FMS development. The 'Multimove' program provided a wide range of activities using six locomotor themes (i.e., running, climbing, swinging, gliding, rotating, jumping) and six object control themes (i.e., catching and throwing, pushing and pulling, lifting and carrying, hitting, kicking, dribbling) and has been described in detail elsewhere (Bardid et al., 2017). Briefly, the development and selection of the program content (i.e., developmentally appropriate activities for each skill theme) was based on motor development literature. During each session of approximately one hour, children of the intervention group practiced two or three FMS, using appropriately selected activities. For instance, hitting can be performed in different ways (e.g., underhand, overhand), alone or in a group, with different tools (e.g. hand, racket, stick) and objects (e.g., balloon, beach ball, tennis ball), stationary or moving, in various setups (e.g., even-inclined, high-low), and with different targets (e.g., small-large, close-distant). Six years later, all participants of the original intervention and control group received an invitation to be part of the follow-up measurement. During each measurement point (i.e., before the intervention (pre), after the 30-week intervention (post), six years later (follow-up)), participants wore light sports clothing and were barefooted. Test administration was conducted by experienced examiners conducting the assessments using standardized instructions in accordance with the test manual.

2.2 Measurements

Motor competence. The Test of Gross Motor Development, 2nd edition (TGMD-2) was used to evaluate AMC. It is a process-oriented, validated, reliable, and norm-referenced test battery to assess actual AMC in 3- to 10-year-old children (Ulrich, 2000). The TGMD-2 shows an excellent test-retest reliability ($r \geq 0.88$) and inter-rater reliability ($r > 0.98$) as well as good internal consistency (Cronbach α = 0.85 for locomotor subtests, 0.88 for object control subtests, 0.91 for the total score). Content, construct, and concurrent validity have also been documented (Ulrich, 2000). The TGMD-2 includes six locomotor skills (i.e., run, gallop, hop, leap, horizontal jump, and slide) and six object control skills (i.e., striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll). Children are given two trials per skill and for each trial the performance is compared against technical criteria (three to five per skill), each of which is rated as present (= 1) or absent (= 0). A total of 24 criteria is assessed for both locomotion and object control skills, resulting in a maximum score of 96 (24 criteria × 2 trials × 2 types of skills). The total raw sum score was used in the analysis.

Organized sports participation. General information about children's participation in organized sports (i.e., average hours on a weekly basis and current type of sport) was obtained using sections of the Flemish Physical Activity Questionnaire (Philippaerts et al., 2006), which is shown to be a reliable instrument (test-retest reliability coefficients ranging from 0.69 to 0.93) to assess different dimensions of usual physical activity. Children's parent(s) or legal guardian completed a demographic questionnaire, including questions on their child's present engagement in organized sports activities and his/her sports history during retention (i.e., years of experience in organized sports at the start of the study, average hours of participation in organized sports on weekly basis during retention, and types of organized sports practiced during retention). Regarding the average number of hours in organized sports participation on weekly basis during retention, three questions related to each year of life were answered (1. *"Did your child participate in organized sports when he/she was X years old?"*, 2. "*Which organized sports did your child do when he / she was 2 years old?"*, 3. *"As a X year old child, how many hours per week in total did your child practice these organized sports activities during a regular week?")*, starting at the age of 2 years up to the current age of the child at the follow-up measurement (with a maximum of 14 years of age). When the answer to the first question was negative or when all three questions were completed for a certain age, the three questions were repeated for the child being one year older.

The child's experience in organized sports at baseline was calculated by subtracting his/her starting age in organized sports participation (reported in the first question for each year of life of the child) from his/her calendar age at baseline. For example, a 6-year-old child who participated in organized sports starting at the age of four was considered to have two years of experience in organized sports at the start of the study. In addition, we verified the received information with the governing body overarching all Flemish sports federations, allowing us to check whether or not the children were actually enrolled in organized sports in the period of this research.

As suggested in the review of Hardesty and Bearden (2004), the opinion of experts should be used when using a new scale to determine face validity. Therefore, we used the opinion of 13 academic experts in the field of motor development (all with a master degree and / or PhD in movement science) to determine the type of sports in which the children of this study participated during retention. The experts were asked to classify these sports as follows: predominantly locomotor (score -1), mixed (score 0), predominantly object control (score +1). Reliability analysis was performed by using Fleiss' kappa (Fleiss et al., 2003), which measures inter-rater agreement between the experts. Fleiss' kappa showed moderate agreement between the experts (κ = .428 (95% CI, .428 to .429); p <.001). Based on the input of the experts, an averaged value between -1 and +1 was obtained for all reported sports (see Figure 1). For example, all experts agreed '*running*' to be a predominantly locomotor-oriented sports with a value of '-1', '*Multimove*' to be a mixed sports with a value of '0', and '*golf*' to be a predominantly object control-oriented sports with a value of '1'. Three experts considered '*basketball*' to be a predominantly object control-oriented sports, while 10 other experts considered it as a mixed sport. This resulted in an averaged valued of 0.23 on the continuous scale '-1 to +1'. Finally, an individual weighted mean value was calculated for each participant. This was based on the expert-based values of the different reported sports the child practiced each year during retention, using the following formula: *weighted mean value = (mean (values of sports practiced in year 1) +…+ mean (values of sports practiced in year 6)/6).*

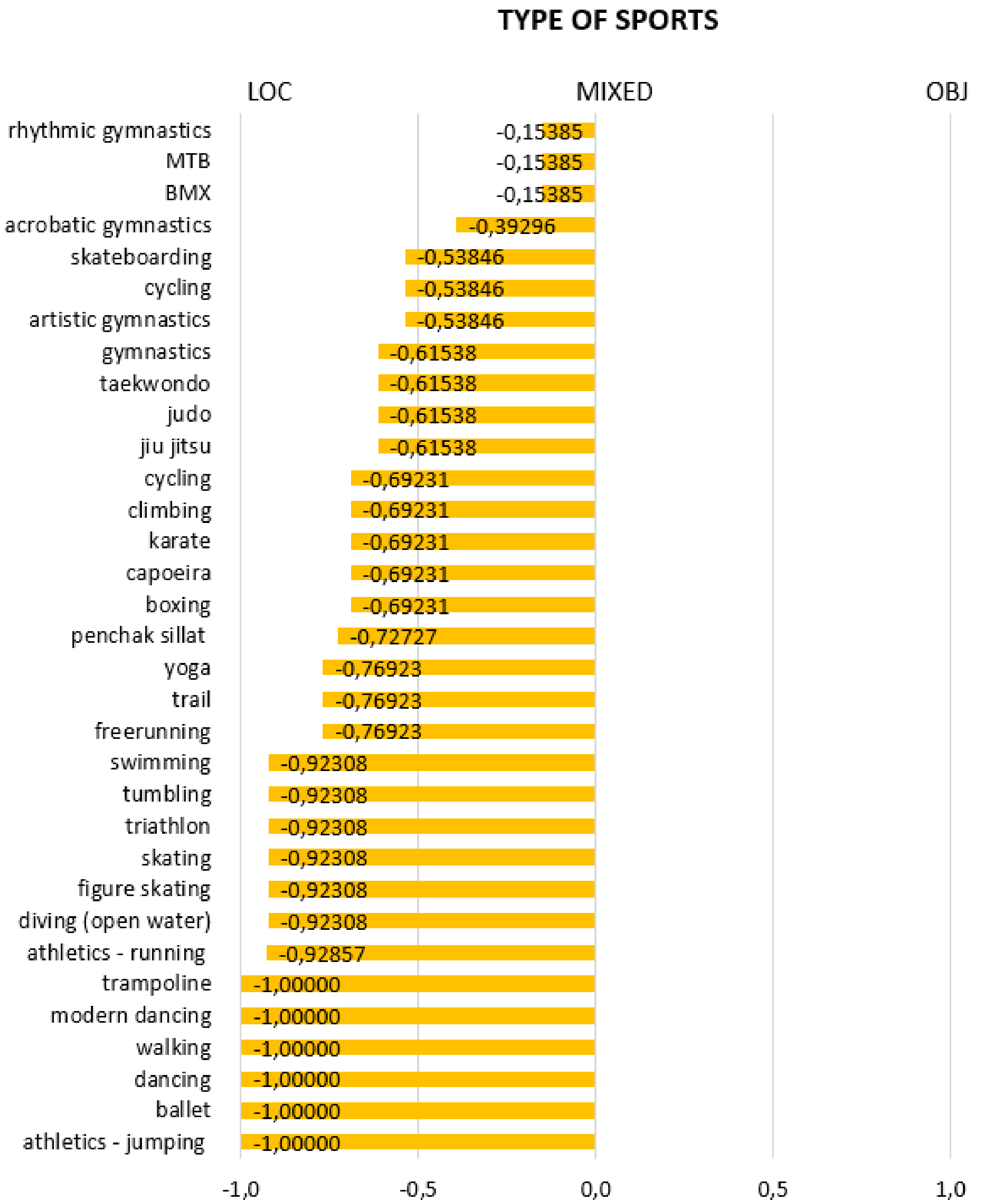


FIGURE 1A- Averaged value between -1 (i.e., predominantly locomotor-oriented) and 0 based on experts value to determine the type of sports

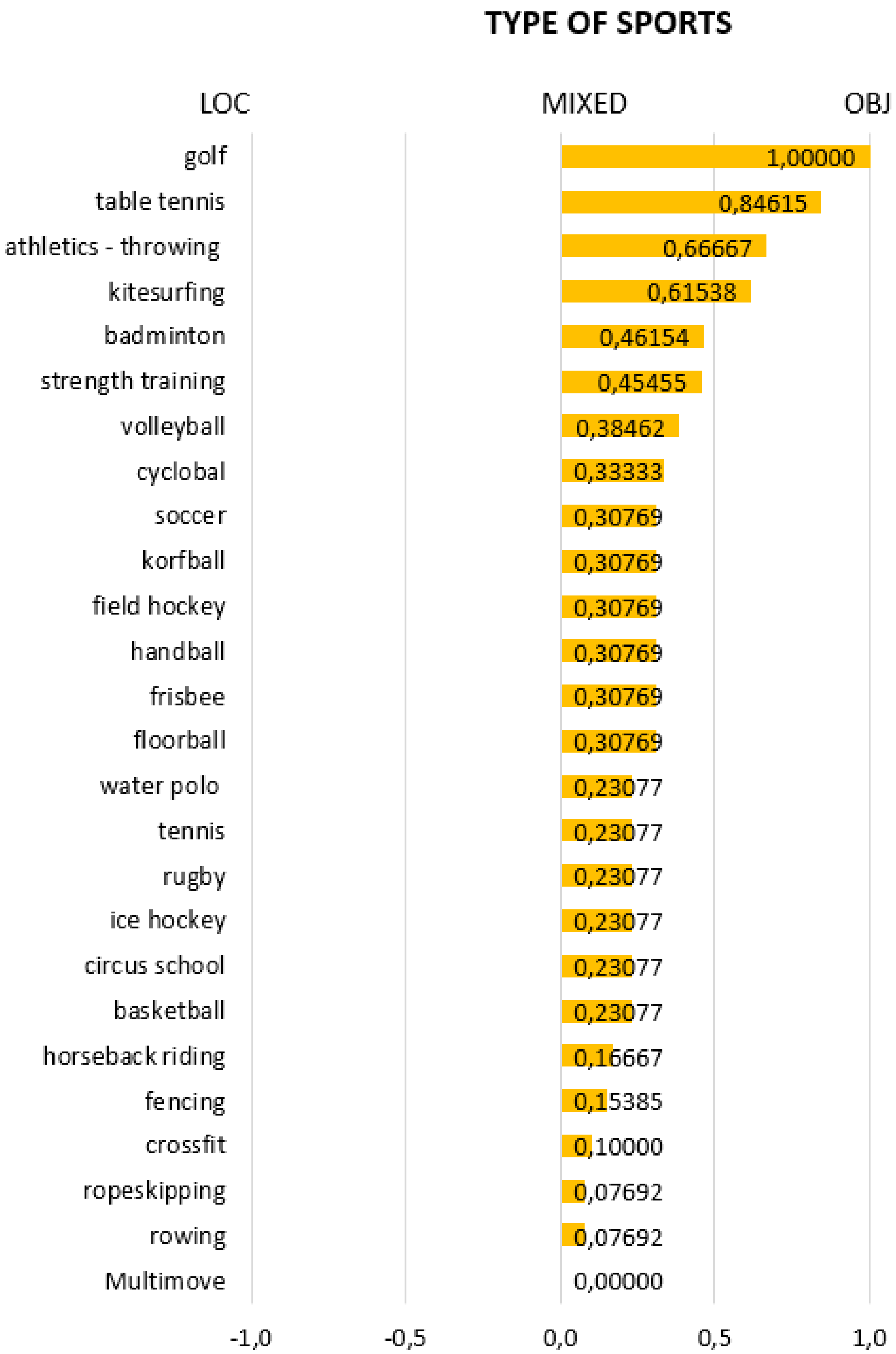


FIGURE 1B - Averaged value between 0 and +1 (i.e., predominantly object control-oriented) based on experts value to determine the type of sports

2.3 Statistical Analyses

A series of latent growth curve models (LGCMs; see Figure 2) were conducted for overall AMC, locomotor skills, and object control skills to examine the change in AMC over time. LGCM is a statistical technique used to analyze longitudinal data, to estimate growth over a period of time. Using this statistical approach allows for the estimation of inter-individual variability in intra-individual trajectories of change over time (Duncan & Duncan, 2009). Effects of potentially confounding factors sex, age, and intervention participation (intervention versus control) were considered in the analysis. Additionally, it was examined whether participation in organized sports (i.e., years of experience in organized sports measured at baseline, average hours of organized sports participation on weekly basis as well as type of sports practiced during retention) affected the slope. Finally, the effect on the slope of AMC evolution was also examined specifically for the intervention participation at post-measurement (T2) (see Figure 2). Maximum likelihood estimation was used for the LGCMs and significance level was set at $p < .05$.

A series of LGCMs were conducted. First, an intercept-only model with the intercept mean and residual variance constrained across time points was run (Model 1). In Model 2, the intercept variance was estimated. Next, the slope mean, and variance were included in Model 3 to estimate change in AMC over time. In Model 4, sex and age were added to the model as covariates. Sex was inserted as a dummy variable (i.e., 0 = boy, 1 = girl), whereas mean-centered age (years) was inserted as a continuous variable. In Model 5, we included group as a dummy variable (i.e., 0 = control group, 1 = intervention group) and the effect of the intervention on the AMC level at 30 weeks (i.e., post-intervention). In Model 6, participation in organized sports was included. We entered the experience in organized sports (years) as a continuous variable centered around the start of baseline assessment. Organized sports participation (mean hours/week) and type of sports (expert-based value) were included as continuous variables to examine their influence on change in AMC. Finally, a model with all significant effects was run (Model 7). All latent growth curve analyses (LGCA) were conducted in R version 3.5.2 using the *Lavaan* package (Rosseel, 2012).

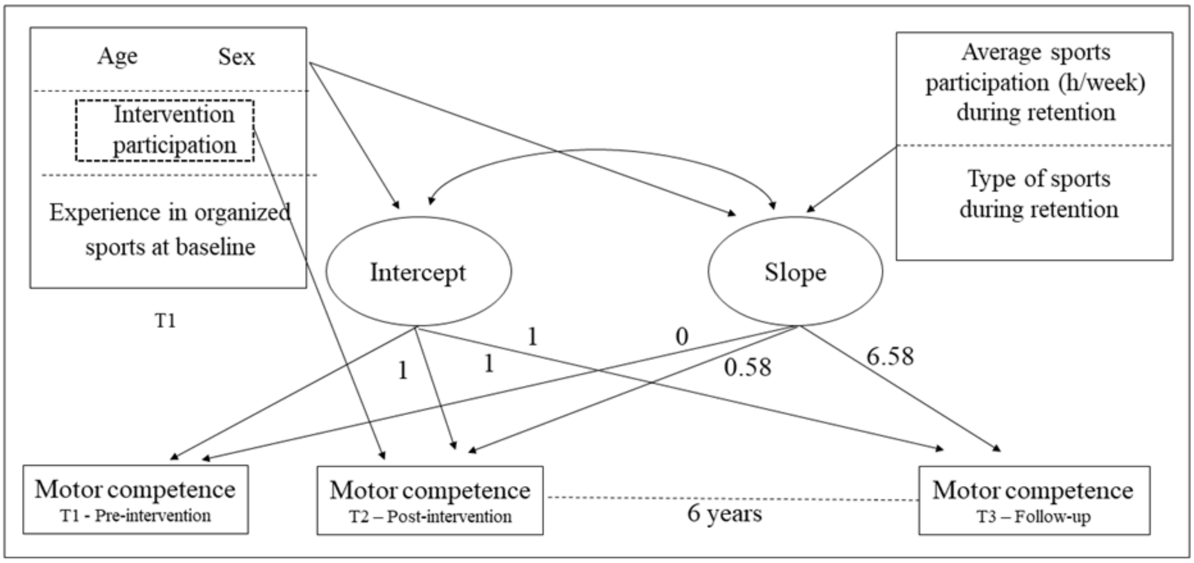


FIGURE 2 - Representation of the latent growth curve models of motor competence measured at three time points (T1, T2 and T3) with baseline (T1) age, sex, intervention participation as well as experience in organized sports as time-invariant covariate. Mean weekly amount of sports participation and type of sports (in between T2 and T3) were included as time-varying covariates, potentially affecting the slope. The latent intercept is constant for any child across time points as indicated by the fixed values of 1 for the factor loadings. The latent slope represents a child's motor competence trajectory with varying values (i.e., 0, 0.58 and 6.58) for the factor loadings representing the years in between the time points. The value starts at 0 to allow the mean intercept to be interpreted as the mean motor competence score at baseline (T1).

3 RESULTS

Table 1 presents the means and standard deviations of levels of AMC (total raw scores on the TGMD-2) at each time point for the original intervention and control group separately as well as for the total sample. The children aged from 3-8 years at baseline to 9-14 years at follow-up (mean age at follow-up: 11.3 years ± 1.33). Their AMC generally increased over time, which is also visualized in Figure 3A (the intervention group) and Figure 3B (the control group). Both figures show the variability in individual change of AMC visualized by the thin lines, representing the individual trajectories of AMC across six years. The results of the LGCA, based on the TGMD-2 total raw score, are reported in Table 2. The LGCMs with random intercepts and slopes demonstrated an average to good model fit (Hooper et al., 2008) (RMSEA ≤ .099; SRMR ≤ .036; CFI ≥ .961). The analyses showed a positive linear evolution in TGMD-2 score over time (β = 3.88, $p < .001$) with significant inter-individual variance ($p < .001$).

TABLE 1 - Descriptive statistics of age at follow-up, motor competence raw scores at each time point and participation in organized sports in both the intervention and control group, as well as in the total sample.

	Intervention group (*N* = 228; 125 boys)	Control group (*N*=171; 91 boys)	Total Sample (*N*=399; 216 boys)
Age (years) at T3	11.82 ± 1.41	10.79 ± 1.17	11.3 ± 1.33
Motor competence at each time point			
TGMD-2$_{\text{TOTAL RAW SCORE}}$ at T1	60.38 ± 15.3	52.06 ± 14.7	56.81 ± 15.6
TGMD-2$_{\text{TOTAL RAW SCORE}}$ at T2	67.92 ± 14.9	56.17 ± 14.5	62.88 ± 15.8
TGMD-2$_{\text{TOTAL RAW SCORE}}$ at T3	82.76 ± 7.2	83.22 ± 6.8	82.96 ± 7.0
Participation in organized sports			
Experience in organized sport at baseline (years)	1.77 ± 1.88	1.45 ± 2.57	1.62 ± 2.23
Mean organized sports participation (hours/week)	3.05 ± 1.53	2.51 ± 1.48	2.83 ± 1.53
Type of sports (-1 [locomotor] to +1 [object control])	.31 ± .42	.29 ± .43	.29 ± .42

TGMD-2: Test of Gross Motor Development - 2nd edition ; T1: Pre-intervention/Baseline, T2: Post-intervention, T3: Follow-up

Girls had a lower TGMD-2 score at baseline (β = -4.06, *p* < .001). However, the improvement over time was not different for boys and girls. Older children had a significantly higher TGMD-2 score at baseline (β = 8.41, *p* < .001) and demonstrated less change in TGMD-2 score over time (β = -1.11, *p* < .001).

At baseline, no significant difference existed between the intervention and control group. After the 30-week intervention, the intervention group outperformed the control group (β = 5.57, *p* < .001). However, the intervention group made less progress in AMC than the control group across the entire study period, including the 6-year follow-up (β = -0.41, *p* < .05).

With respect to participation in organized sports, the LGCA showed that the years of experience in organized sports at baseline was associated with a higher TGMD-2 score at baseline (β = 0.57, *p* < .001), but had no influence on the evolution of AMC. Organized sports participation (mean hours/week) during retention was positively related to change in TGMD-2 score over time (β = 0.14, *p* < .001). With respect to type of sports, children predominantly practicing object control-oriented sports during retention showed a better evolution in AMC (β = 0.01, *p* < .01). The fit indices indicated that Model 5 seems to be the best model, showing that the organized sports variables are of no large influence when fitting the best model for change in AMC over time.

Additional analyses for the raw locomotion scores and raw object control scores are presented in Table 3 and Table 4, respectively. The results of these additional analyses were generally in line with the abovementioned findings for the total test battery, described in Table 2.

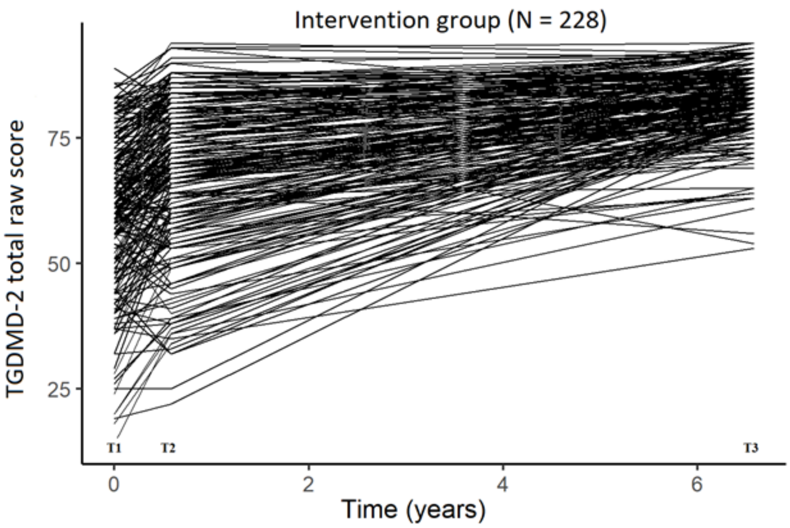


FIGURE 3A - Individual trajectories in actual motor competence over time, measured at three time points (T1 = pre-intervention , T2 = post-intervention and T3 = follow-up), based on the TGMD-2 total raw score for the *intervention group*.

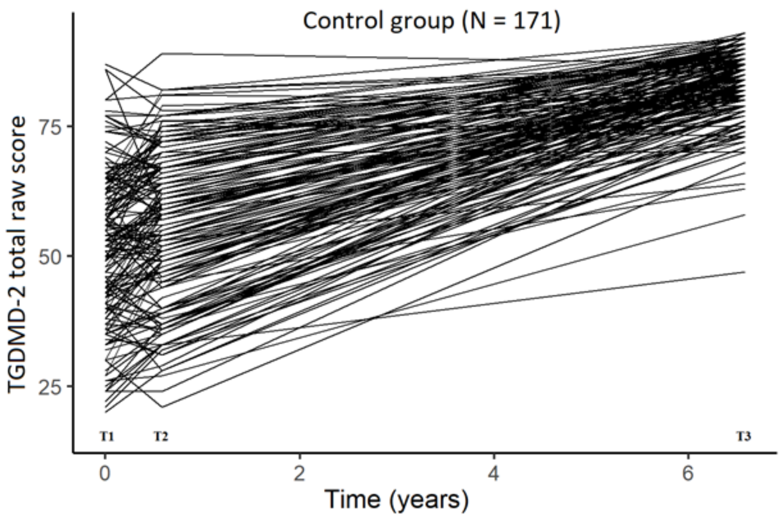


FIGURE 3B - Individual trajectories in actual motor competence over time, measured at three time points (T1 = pre-intervention , T2 = post-intervention and T3 = follow-up), based on the TGMD-2 total raw score for the *control group*.

TABLE 2 - Results of the latent growth curve analyses based on total raw score of the TGMD-2

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
Intercept mean	67.55	***	67.55	***	58.68	***	62.50	***	60.47	***	55.51	***	57.56	***
Sex							-3.95	***	-3.82	***	-4.31	***	-4.06	***
Age							9.19	***	8.82	***	8.13	***	8.41	***
Intervention participation									0.60	*n.s.*	-1.03	*n.s.*	-0.55	*n.s.*
Experience in organized sports (years)											0.93	***	0.57	***
Intercept variance			34.37	**	216.05	***	64.45	***	67.20	***	64.34	***	64.98	***
Residual variance	305.74		271.37		48.80		48.80		39.19		35.78		35.78	
Slope mean					3.72	***	4.02	***	4.48	***	4.29	***	3.88	***
Sex							-0.04	*n.s.*	-0.06	*n.s.*	0.02	*n.s.*	-0.04	*n.s.*
Age							-1.16	***	-1.06	***	-1.05	***	-1.11	***
Intervention participation									-0.76	***	-0.31	*n.s.*	-0.41	*
Mean organized sports participation (hours/week)											0.15	***	0.14	***
Type of sports (locomotor-mixed-object control)											0.01	**	0.01	**
Experience in organized sports (years)											-0.08	*n.s.*		
Time varying effects														
Intervention at post-measurement									5.56	***	5.57	***	5.57	***
Slope variance					2.96	***	0.52	*	0.76	***	1.08	***	1.09	***
Covariance					-26.05	***	-7.13	***	-7.42	***	-8.39	***	-8.48	***
$\chi 2$	1446.04		1431.20		76.72		82.00		15.11		43.63		46.97	
df	7		6		3		5		5		10		11	
RMSEA	0.718		0.772		0.248		0.196		0.071		0.1		0.099	
SRMR	1.922		1.907		0.071		0.048		0.013		0.033		0.036	
CFI	0.000		0.000		0.865		0.920		0.990		0.964		0.961	

* $p < .05$; ** $p < .01$; *** $p < .001$; *n.s.*: not significant

TGMD-2: Test of Gross Motor Development - 2nd edition

TABLE 3 - Results of the latent growth curve analyses based on locomotion raw score

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
Intercept mean	36.58	***	36.58	***	32.68	***	30.33	***	29.14	***	26.12	***	26.12	***
Sex							0.99	*n.s.*	1.08	*n.s.*	0.80	*n.s.*	0.80	*n.s.*
Age							4.31	***	4.10	***	3.68	***	3.68	***
Intervention participation									0.61	*n.s.*	-0.14	*n.s.*	-0.14	*n.s.*
Experience in organized sports (years)											0.52	***	0.52	***
Intercept variance			9.93	***	55.71	***	22.14	***	22.54	***	21.50	***	21.50	***
Residual variance	74.63		64.70		19.11		19.11		16.80		16.68		16.68	
Slope mean					1.63	***	2.02	***	2.29	***	2.36	***	2.36	***
Sex							-0.18	*	-0.20	*	-0.15	*n.s.*	-0.15	*n.s.*
Age							-0.59	***	-0.54	***	-0.51	***	-0.51	***
Intervention participation									-0.26	**	-0.19	*n.s.*	-0.19	*n.s.*
Mean organized sports participation (hours/week)											0.07	***	0.07	***
Type of sports (locomotor-mixed-object control)											0.00	*	0.00	*
Experience in organized sports (years)											-0.06	*	-0.06	*
Time varying effects														
Intervention at post-measurement									2.74	***	2.84	***	2.84	***
Slope variance					0.77	***	0.15	*n.s.*	0.19	*	0.24	**	0.24	**
Covariance					-7.33	***	-2.75	***	-2.76	***	-2.94	***	-2.94	***
$\chi 2$	1176.45		1156.35		47.49		47.55		19.17		45.14		45.14	
df	7		6		3		5		5		10		10	
RMSEA	0.642		0.688		0.191		0.145		0.084		0.102		0.102	
SRMR	1.965		1.956		0.062		0.042		0.030		0.04		0.04	
CFI	0.000		0.000		0.877		0.934		0.979		0.943		0.943	

* $p < .05$; ** $p < .01$; *** $p < .001$; n.s.: not significant

TABLE 4 - Results of the latent growth curve analyses based on object control raw score

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7	
Intercept mean	30.96	***	30.96	***	25.97	***	32.26	***	31.41	***	29.47	***	29.83	***
Sex							-5.01	***	-4.95	***	-5.21	***	-5.16	***
Age							4.87	***	4.72	***	4.44	***	4.49	***
Intervention participation									-0.03	*n.s.*	-0.86	*n.s.*	-0.78	*n.s.*
Experience in organized sports (years)											0.41	**	0.35	***
Intercept variance			13.11	***	64.21	***	18.14	***	19.10	***	18.36	***	18.38	***
Residual variance	102.82		89.72		22.80		22.80		20.27		19.16		19.16	
Slope mean					2.09	***	1.98	***	2.18	***	1.90	***	1.90	***
Sex							0.16	*n.s.*	0.15	*n.s.*	0.18	*n.s.*	0.17	*n.s.*
Age							-0.58	***	-0.54	***	-0.54	***	-0.55	***
Intervention participation									-0.14	*n.s.*	-0.13	*n.s.*	-0.15	*n.s.*
Mean organized sports participation (hours/week)											0.09	***	0.09	***
Type of sports (locomotor-mixed-object control)											0.00	*n.s.*		
Experience in organized sports (years)											-0.02	*n.s.*		
Time varying effects														
Intervention at post-measurement									2.87	***	2.84	***	2.79	***
Slope variance					0.67	***	0.07	*n.s.*	0.14	*n.s.*	0.25	**	0.25	**
Covariance					-6.83	***	-1.80	***	-1.92	***	-2.26	***	-2.25	***
$\chi 2$	1161.30		1142.95		54.27		61.33		22.58		34.12		30.58	
df	7		6		3		5		5		10		9	
RMSEA	0.640		0.687		0.206		0.167		0.094		0.084		0.084	
SRMR	1.226		1.203		0.088		0.060		0.029		0.03		0.032	
CFI	0.000		0.000		0.878		0.932		0.979		0.968		0.972	

* $p < .05$; ** $p < .01$; *** $p < .001$; *n.s.*: not significant

4 DISCUSSION

The purpose of this study was to investigate the long-term effect of the 'Multimove' program, six years after the intervention. In addition, the effect of sex, age, and the impact of participation in organized sports (i.e., years of experience in organized sports at baseline, organized sports participation (mean hours/week) during retention and type of sports (expert-based value) during retention) on AMC evolution was examined.

A significant positive average change in AMC over time was found, which is consistent with previous research (Ahnert et al., 2009; dos Santos et al., 2018; Vandorpe et al., 2011). In addition, significant variability in change in AMC among individuals was established, similarly to the findings of Coppens et al. (2019) and Rodrigues et al. (2016). This variability in the rate of change across the current sample is also visible in Figure 3A and 3B. The results show that the intervention group demonstrated higher levels of AMC at post-measurement compared to the control group, which is in line with the findings of Bardid et al. (2017). Nonetheless, while there was an overall positive change in both groups during the retention period, the control group seemed to have caught up with their peers from the intervention group, indicating no long-term 'Multimove' effect on AMC. Previous studies of Barnett et al. (2009) and Zask et al. (2012) have found mixed results with regard to the long-term effects of interventions on AMC. For instance, Zask et al. (2012) found differences in object control skills between the intervention and control group three years after the intervention. However, no differences were found when it comes to locomotor skills. One explanation for not finding a persistent effect of the Multimove program in this study may be the age difference between groups at baseline. Children in the control group were approximately one year younger than those in the intervention group at the time of follow-up, maybe providing them with a somewhat greater window of opportunity to level up their AMC. However, after controlling for age, no significant difference between the intervention and control group at baseline was found. Another explanation might be that the 30-week intervention was not long or intensive enough to accomplish sustained effects. Since time spent in FMS practice is of great importance in improving AMC (Morgan & Barnett, 2013), further investigations are needed to determine the optimal characteristics of interventions for long-term success, including program duration and frequency.

At baseline, boys outperformed girls on object control skills and overall AMC, which is consistent with the findings in the systematic review of Barnett et al. (2016). No differences were found between boys and girls at baseline for locomotor skills. However, sex did not influence the change in AMC over time, which is in agreement with the findings of Rodrigues et al. (2016). In fact, the role of sex on AMC development seems to be ambiguous as Coppens et al. (2019) and dos Santos et al. (2018) found contrasting results. Both of these studies used the product-oriented Körperkoördinationstest für Kinder, which focuses on a different aspect of AMC when compared to the process-oriented TGMD-2 used in the current study. The wide variation of AMC instruments often inhibits the comparison of results across studies (da Luz et al., 2017; Stodden et al., 2008). In light of these contrasting findings, there is a need for more research into how sex relates differently to various aspects of AMC (evolution) and how this might be moderated by factors such as organized sports participation.

Older children had a higher level of AMC at baseline. At the same time, our study results indicated that younger children show a more pronounced improvement of AMC, which is consistent with previous findings of Coppens et al. (2019). Since the TGMD-2 is a criterion-referenced battery with a theoretical maximum total raw score, it is possible that the instrument encounters a ceiling effect, which limits the chance to identify changes in AMC (Barnett et al., 2016), especially in older and more skilled children (Barnett et al., 2016; Morgan & Barnett, 2013). Indeed, the distribution of total raw scores on the TGMD-2 in our sample was slightly skewed to the left, with 79.2% of the participants scoring above P75 and 11.0% even above P90 at follow-up. It is important to note here that the age at follow up ranged between 9 and 14 years, which implies that the majority of the group was older than the upper limit of the TGMD-2 (i.e., 10 years and 11 months).

A second purpose of this study was to examine how participation in organized sports might influence the children's individual trajectories of change in AMC. Therefore, we investigated three outcomes in relation to organized sports participation in order to answer three related secondary research questions (i.e., years of experience in organized sports at baseline: *Do the years of experience a child has in organized sports at baseline influence the subsequent development of AMC, when looking at it six years later?*, average amount of hours on a weekly basis: *Do the children who spend more time participating in organized sports during retention have a better evolution in their AMC development over the years?*, type of organized sports: *Does the type of sports practiced during retention has any influence on the AMC development over time?*).

The years of experience in organized sports at baseline did not influence the evolution in overall AMC or object control. However, children with less years of experience in organized sports, showed a steeper evolution in locomotor skills. This might be due to a greater margin for improvement in children with less expertise, who would score lower at baseline. Children involved in more weekly hours of organized sports during retention, displayed a more pronounced AMC improvement. These findings are in line with other longitudinal studies (Fransen et al., 2014; Henrique et al., 2016; Vandorpe et al., 2012), showing a positive association between AMC and sports participation. This indicates that organized sports participation supports children in developing their motor skills, which is in agreement with the positive spiral of engagement as suggested by Stodden and colleagues (2008). As noted by Barnett et al. (2013) and Henrique et al. (2016), the effect of sports participation on long-term AMC development may depend on the type of sports. Indeed, our study showed that children practicing predominantly object control-oriented sports during retention, displayed a slightly better evolution in AMC. It may be that predominantly object control-oriented sports (e.g., football) provide more opportunities to develop both object control and locomotor skills compared to predominantly locomotor-oriented sports (e.g., running). However, while this is in line with previous studies that demonstrated an advantage of object control skill over locomotor skill development in childhood due to continued and more varied participation in sports and games (Barnett et al., 2011; Stodden et al., 2014), the effect in the present study was only marginal. Furthermore, when the progress in locomotion and object control was considered separately, the effect of the type of sports practiced during retention was negligible, given the very small coefficient value. It is clear that organized sports participation benefits AMC development but more research is needed to understand what type of organized sports participation influences AMC development and to what extent. This will help further inform policy and practice.

Strengths and limitations

Our longitudinal design with a retention period of six years and the use of LGCA are major strengths of the current study. In addition, to our knowledge, this is the first intervention study in the field of motor development research that studies the impact of three different outcomes in relation to organized sports participation. However, some limitations need to be addressed. First, since 40.2% of the original sample agreed to participate in the follow-up measurement, there is a chance of non-random failure in the data. In order to correct for any baseline differences, group was included in the model as a covariate for the intercept. Secondly, the TGMD-2 was used for the assessment of AMC across time although the majority of children already fell outside the age range of the test during follow-up measurement. However, few AMC instruments have been developed for use in both children and adolescents and many focus on child populations (Hulteen et al., 2020). As noted by Hulteen et al. (2020), there is a need for further investigation into the use of existing instruments in adolescent populations. Third, we have used proxy-report for the outcomes of organized sports participation, which are subjective and prone to recall bias, especially with retrospective information requested on sports participation history. However, this is a first attempt to capture organized sports participation in a more detailed and systematic manner using specific questions on type and frequency of participation across years. Nonetheless, more research is needed to further investigate this proxy-report and its psychometric properties.

Perspectives

As current research mainly provides insight in the short-term effect of AMC interventions, studies investigating the long-term impact are needed. Equally important is to gain more insight in the individual and environmental factors underlying children's AMC trajectories over time, especially in view of the secular decline in AMC levels among youth (Roth et al., 2010; Vandorpe et al., 2011). More longitudinal evidence is needed to determine the optimal characteristics of effective interventions in order to expose children to positive sports experiences, allowing them to develop AMC (Vandorpe et al., 2011), which is a key factor in improving the likelihood for long-term engagement in sports and other forms of physical activity (Hulteen et al., 2015). While previous studies already indicated that the duration of effective intervention programs varied (Bardid et al., 2017; Logan et al., 2012), further investigations are needed to determine the optimal characteristics of a MC program (e.g., type of approach, amount of instruction time, frequency, duration) to be successful in maintaining its intervention effects in the long run. This can help us in order to provide guidelines for a more efficient design to facilitate an effective long-term impact of interventions like the 'Multimove' project. In addition, this will help to support positive health trajectories across childhood and adolescence (Robinson et al., 2015), and to inform decision making in policy and practice.

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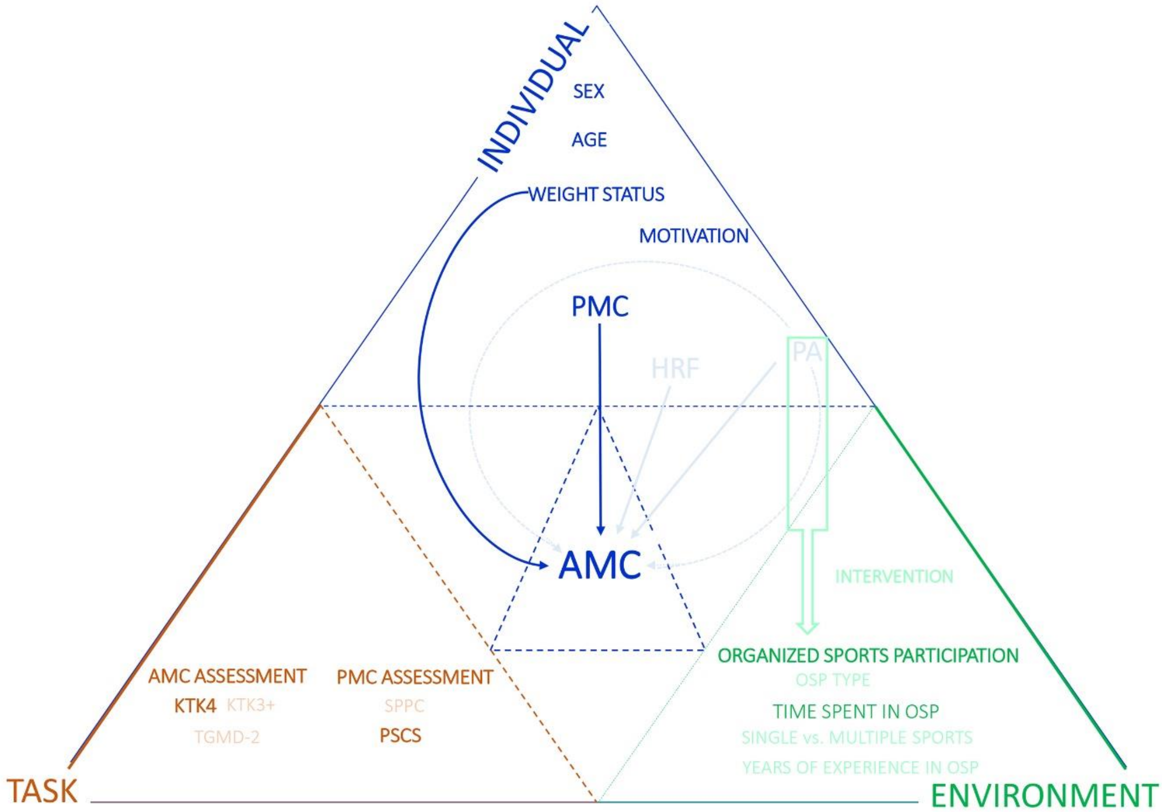
- CHAPTER 2 -

A DEEPER UNDERSTANDING OF PREVIOUSLY IDENTIFIED MOTOR COMPETENCE BASED PROFILES

STUDY 3

DIFFERENCES IN WEIGHT STATUS AND AUTONOMOUS MOTIVATION TOWARD SPORTS AMONG CHILDREN WITH VARIOUS PROFILES OF MOTOR COMPETENCE AND ORGANIZED SPORTS PARTICIPATION



This study is based on **Coppens, E.**, De Meester, A., Deconinck, F. J., De Martelaer, K., Haerens, L., Bardid, F., Lenoir, M., & D'Hondt, E. (2021). Differences in weight status and autonomous motivation towards sports among children with various profiles of motor competence and organized sports participation. *Children*, *8*(2), 156. https://doi.org/10.3390/children8020156

ABSTRACT

This study aimed (1) to identify profiles in children based on actual motor competence (AMC), perceived motor competence (PMC), and organized sports participation (OSP), and (2) to examine differences among these profiles in weight status as well as autonomous motivation toward sports. Children's (*N* = 206; 112 boys; M_{age} = 10.83 ± 0.92 years) AMC, PMC, OSP, weight status and autonomous motivation toward sports were measured using validated assessment tools. Cluster analyses identified three profiles with completely convergent levels of AMC, PMC and OSP and three profiles with partially convergent levels. Children in the convergent profiles with average to high levels of AMC, PMC and OSP had the most optimal profile as they combined a healthier weight status with elevated levels of autonomous motivation, while the opposite was true for children with low levels on all three cluster-variables. Partially convergent profiles showed that AMC and PMC appear crucial for weight status as profiles with relatively low levels of AMC and PMC had the highest weight status, independent of their OSP levels. Overall, the findings highlight the importance of promoting AMC, PMC and OSP simultaneously to help children in achieving a healthy weight status and being autonomously motivated toward OSP.

1 INTRODUCTION

Actual motor competence (AMC), which can be defined as the degree of proficient performance in various motor skills as well as its underlying mechanisms such as motor control and coordination (Utesch & Bardid, 2019), is associated with a range of health-related outcomes including a healthy weight status (Barnett et al., 2016; Cattuzzo et al., 2016; Lima et al., 2017). AMC is also considered important in developing an active lifestyle (Robinson et al., 2015; Stodden et al., 2008) since previous research has established a positive relationship between AMC and physical activity (PA) (Hulteen et al., 2018; Logan et al., 2015). According to the conceptual model of Stodden and colleagues (Stodden et al., 2008), a mediator in this reciprocal AMC-PA relationship is **perceived motor competence** (PMC), which refers to the self-perception of one's AMC (Harter, 1999). Both AMC and PMC are considered to be consistent predictors of PA levels more generally (Babic et al., 2014; Robinson et al., 2015), and (organized) sports participation more specifically (De Meester et al., 2014; Marques et al., 2016). Likewise, PMC is found to be an important intrapersonal protective factor against dropout from **organized sports participation** (OSP; Crane & Temple, 2015), while persistent OSP during childhood and adolescence is found to be a significant predictor of adult PA (Telama et al., 2006).

The positive relationship between AMC and PMC is extensively examined in the literature (De Meester, Barnett, et al., 2020). However, the systematic review and meta-analysis of De Meester, Barnett, et al. (2020), which included data from 69 studies, showed that the strength of the relationship between AMC and PMC in children and adolescents was only low to moderate. Also, most of the studies included in the meta-analysis only used a variable-centered approach. In this approach the association between AMC and PMC is judged based upon a correlation between the two constructs at group level (i.e., the study sample and/or specific subsamples). In doing so, a variable-centered approach does not provide insight into how different AMC and PMC levels may be combined at the individual level (Bardid, De Meester, et al., 2016). Accordingly, a person-centered approach is needed to examine whether children with similar AMC levels may differ in the degree to which they perceive themselves as motor competent. Indeed, previous studies that used a person-centered approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Weiss & Amorose, 2005) revealed different profiles of children, with some of them combining convergent levels of AMC and PMC (i.e., low(er) levels of AMC and low(er) levels of PMC or high(er) levels of AMC and high(er) levels of PMC), and others combining divergent levels of AMC and PMC (i.e., low(er) levels of AMC and high(er) levels of PMC, or vice versa). Yet, a limitation of prior person-centered studies is that the attributes assessed with the AMC test batteries and the PMC questionnaires are often not the same; hence, the measures of AMC and PMC are not aligned. This leaves the question whether the discrepancy in these measures may constitute one of the reasons for finding the divergent profiles.

While previous studies have shown that PA levels generally decrease in adolescence (Kalman et al., 2015; Knuth & Hallal, 2009), OSP appears to be more stable over time (Guagliano et al., 2013; Telama et al., 2006). Moreover, OSP in early childhood significantly increases the likelihood of continuation of OSP throughout (middle and late) childhood (Henrique et al., 2016), which may promote lifelong positive pathways of health-promoting behaviors. Given the fact that OSP during childhood and adolescence has a positive effect on PA levels (Marques et al., 2016; Mooses & Kull, 2020), this could be the way to counteract the typical decrease in PA in adolescence (Kalman et al., 2015; Knuth & Hallal, 2009; Mooses & Kull, 2020). However, previous studies have shown that not all children have access to organized sports (Eime et al., 2013; Timperio et al., 2013). It is thus plausible that there is a group of children who do not participate in organized sports, for instance because of lower economic resources (Andersen & Bakken, 2019). Yet, some of those children might have high levels of AMC or PMC despite a lack of OSP. In contrast, other children might be supported by their environment to participate in organized sports without necessarily having high levels of AMC or PMC. Including OSP as an additional cluster variable (next to AMC and PMC as fixed variables in earlier research) can thus provide a deeper understanding of previously identified AMC and PMC profiles. Hence, the first aim of the present study was to identify profiles in children based on AMC, PMC and OSP, while using aligned motor competence assessment tools. To this end, we examined how the three cluster variables interact, and whether convergent and divergent profiles may be identified (i.e., aim 1).

The strength of the relationship between AMC, PMC and OSP may also relate to multiple intrapersonal characteristics, one of them being **weight status**, since all three cluster variables are negatively correlated with a higher body mass index (BMI). Estevan and colleagues (2019) found that children with relatively high levels of physical capacity (i.e., AMC and physical fitness) and PMC were more likely to be normal-weight compared to those with relatively low levels of physical capacity and PMC. This is in line with the assumption of a positive spiral of engagement in the conceptual model of Stodden and colleagues (Stodden et al., 2008), as well as previous research (Barnett et al., 2016). When it comes to the relationship between OSP and weight status, the evidence is rather inconclusive. While several studies established that OSP did not affect children's weight status (Marques et al., 2016; Nelson et al., 2011; Vella et al., 2013), another study suggested that OSP reduced the risk of childhood obesity regardless of the type of activity performed (Dunton et al., 2012). A person-centered approach with AMC-PMC-OSP based profiles might unravel this ambiguity and provide new insights. Specifically, the latter approach allows to investigate whether a higher level of one (or two) of these three cluster variables is already helpful in achieving a healthier weight status, regardless of the level of the third variable. Another intrapersonal characteristic of interest is **autonomous motivation** - the most optimal form of motivation - which involves the regulation of behavior with the experiences of volition, psychological freedom and reflective self-endorsement (Vansteenkiste et al., 2010). Autonomous motivation for PA is associated with a variety of physical and mental health outcomes (i.e., effective performance, psychological well-being, healthy development) (Teixeira et al., 2012). Children who are autonomously motivated, participate in PA and sports because they enjoy doing so or because they understand and endorse the personal relevance of participation (e.g., the health benefits ; Teixeira et al., 2012). Moreover, AMC and PMC both are an underlying mechanism of autonomous motivation toward PA, including sports (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016). Children with relatively low levels of PMC were less autonomously motivated toward sports than their peers with higher levels of PMC, irrespective of their AMC level (Bardid, De Meester, et al., 2016). In addition, De Meester and colleagues found that adolescents with relatively high levels of AMC and PMC were more autonomously motivated toward physical education than those with relatively high levels of AMC but low levels of PMC and those with relatively low levels of both (De Meester, Maes, et al., 2016). However, children with relatively low levels of AMC and high levels of PMC showed similar levels of autonomous motivation as their peers with high levels of both constructs. These studies thus suggest that higher levels of PMC could compensate for lower levels of AMC in terms of autonomous motivation toward sports (Bardid, De Meester, et al., 2016) or physical education (De Meester, Maes, et al., 2016). In addition, the study of De Meester, Maes, et al. (2016) revealed that students with relatively low levels of AMC and PMC were less autonomously motivated and were also less involved in OSP than their peers with higher levels of AMC and/or PMC. Taking into account these findings, identifying profiles based on AMC-PMC-OSP might reveal a group of children showing low levels of AMC, but high levels of PMC and OSP, who are indeed autonomously motivated toward sports. It seems, then, that understanding whether and how various profiles based on AMC-PMC-OSP differently relate to autonomous motivation for sports can help us in further promoting engagement in PA and sports in order to stimulate a healthy development. Therefore, the second aim of the current study was to compare the AMC-PMC-OSP profiles in terms of weight status and autonomous motivation toward OSP (i.e., aim 2). Based on studies using the person-centered approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019), it was hypothesized that children with relatively high levels of AMC, PMC and OSP would have a healthier weight status (Estevan et al., 2019) and a higher autonomous motivation toward OSP (Bardid, De Meester, et al., 2016) when compared to children with relatively low levels of AMC, PMC and OSP. It was also hypothesized that children with relatively high levels of PMC and OSP but low levels of AMC, would be more autonomously motivated toward sports compared to children with the opposite profile (i.e., low levels of PMC and OSP, but high levels of AMC) (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016; Rottensteiner et al., 2015).

2 METHODS

2.1 Participants and procedures

A sample of 206 children (112 boys) with a mean age of 10.83 years (SD = 0.92, range 9.07 - 12.95 years) agreed to participate in the current cross-sectional study. Data collection took place during weekends and school breaks (between August 2018 and February 2019), and took approximately two hours per participant. Each session consisted of completing anthropometric measurements, an AMC test battery and a questionnaire assessing PMC as well as weekly participation time in organized sports (see below for details), and autonomous motivation toward organized sports. Test administration was conducted by experienced examiners conducting the assessments using standardized instructions in accordance with the AMC test manual (Kiphard & Schilling, 1974). Participants wore light sports clothing and were barefooted to ensure uniformity of test conditions. When completing the questionnaire, participants had the opportunity to ask for clarification whenever necessary. In addition, a visual demonstration was given to illustrate the PMC items to the children. Written informed consent to participate in the current study was provided for each child by their parent(s) or legal guardian. The study protocol was approved by the Ethics Committee of Ghent University Hospital.

2.2 Measurements

Actual Motor Competence. The KörperkoordinationsTest für Kinder (KTK; Kiphard & Schilling, 1974, 2007, 2017) was used to evaluate children's AMC level. It is a standardized, normative, product-oriented test battery to assess AMC in terms of gross motor coordination in 5- to 15-year-old children with typical or atypical motor development. The KTK is a highly reliable instrument with excellent test-retest reliability for the total raw score (r = 0.97), and very good inter- and intra-rater reliability for the subtest raw scores (r values > 0.85 and ranging between 0.80 and 0.96, respectively; Kiphard & Schilling, 1974, 2007). In addition, it also a valid instrument, showing moderately strong correlations with other standardized AMC assessment tools (Bardid, Huyben, et al., 2016; Fransen et al., 2014; Henrique et al., 2016; Smits-Engelsman et al., 1998). The KTK test battery includes four subtests (i.e., walking backwards, moving sideways, jumping sideways and hopping for height), and takes approximately 20 min per participant to complete. The raw scores of each subtest are converted into standardized scores adjusted for age (all subtests) and sex (walking backwards, jumping sideways, and hopping for height). These standardized scores are then summed to compute an overall motor quotient (MQ), using the KTK manual's normative tables based on the performance of the reference sample (Kiphard & Schilling, 2007).

Perceived Motor Competence. An adapted version of the Physical Self-Confidence Scale (PSCS; McGrane et al., 2016) was used to assess children's PMC. The original PSCS contains 15 items for which participants rate their perceived self-confidence in performing specific motor skills on a 10-point Likert scale, ranging from "being not confident at all" (= 1) to "being very confident" (= 10). These items are aligned with the locomotor and object control skills assessed in the Test of Gross Motor Development-2 (TGMD-2; Ulrich, 2000; Ulrich & Sanford, 1985) and the balance skills assessed in the Victorian Fundamental Movement Skills Test

(Walkley et al., 1996). The PSCS's test-retest reliability is considered excellent with an overall intra class correlation of 0.92 (McGrane et al., 2016). Content validity and concurrent validity are also good, with the scale achieving a correlation coefficient of 0.72 with the Physical Self-Perception Profile (Fox & Corbin, 1989; McGrane et al., 2016). Following experts' advice, and since the aim was to measure perceived competence rather than self-confidence, the question stem of the items was altered from "how confident are you at performing" to "how well can you perform" (Estevan & Barnett, 2018). For the purpose of the present study, four items were added to this PSCS questionnaire, in alignment with the four KTK subtests (i.e., "*How well can you perform walking backwards on a balance beam?", "How well can you perform moving sideways as fast as possible with the aid of two wooden boards?", "How well can you perform jumping sideways over a slat as fast as possible?", "How well can you perform hopping for height on one leg over an increasing number of foam squares?").* For the current study, the participant's PMC subscore (ranging from 1 to 10) was determined by calculating the average score of the four items that were aligned with the four KTK subtests. To estimate the reliability of these four additional items, a test-retest procedure was performed. To this end, 64 children between 9 and 11 years of age completed these questions twice in similar conditions, with a 19-day interval, showing a moderate degree of reliability with an ICC of 0.78 and a 95% confidence interval ranging from 0.66 to 0.86 (F (60,60) = 8.181, $p < 0.001$). Convergent validity was established through a significant positive relationship between the PMC subscore based on the original 15 PSCS items and the PMC score based on the four KTK items, using Pearson's correlation ($r = 0.63$, $p < 0.001$).

Organized Sports Participation. General information about children's participation in organized sports was obtained using sections of the Flemish Physical Activity Questionnaire (Philippaerts et al., 2006), which has shown to be a reliable instrument (test-retest reliability coefficients ranging from 0.69 to 0.93) to assess different dimensions of habitual PA.

Weight status. Participants' body height was measured using a portable stadiometer with an accuracy of 0.1 cm (Harpenden, Holtain Ltd, Crymych, UK) and their body weight was determined by means of a digital scale with an accuracy of 0.1 kg (Seca, Model 770, Hamburg, Germany). These measures were combined to compute children's BMI (kg/m²). Next, reference population-based BMI z-scores (zBMI) were computed based on the Flemish growth curves to obtain a relative measure of adiposity adjusted for sex and age (Roelants et al., 2009, which was used as an estimate of children's weight status.

Autonomous Motivation for Sports. Children's autonomous motivation toward sports was assessed using an adapted (i.e., age-appropriate) version of the Behavioral Regulation in Exercise Questionnaire (BREQ) containing 12 items, which was validated in previous research in a sample of children with a similar age range as our sample (Sebire et al., 2013). For the purpose of the present study, only the six items regarding autonomous motivation were measured. Each of these six items starts with the stem *"I participate in organized sports because…"*. The items related to identified regulation (e.g., *"I participate in organized sports because it is important for me to participate in organized sports"*, 3 items), and intrinsic regulation (e.g., "*I participate in organized sports because participating in organized sports is fun"*, 3 items). Participants responded to each of the items via a 5-point Likert scale, ranging from "not at all true for me" (= 1) to "very true for me" (= 5). Each participant's autonomous motivation subscore (also ranging from 1 to 5) was determined by calculating the average score of both the identified regulation (3 items) and intrinsic regulation (3 items) subscales of the adapted BREQ.

2.3 Statistical Analyses

All statistical analyses were performed using IBM SPSS statistics version 26 (IBM Corporation. Armonk. NY. USA) with *p*-values below 0.05 being considered as statistically significant.

As a preliminary step, the relationship between all study variables (i.e., both cluster and outcome variables) was examined by means of Spearman's rank correlation coefficients. Correlation coefficients were interpreted as: negligible: < 0.30, low: 0.30-0.50, moderate: 0.50-0.70, high: 0.70-0.90, or very high: 0.90-1.00 (Everitt et al., 2001).

Cluster analyses were conducted based on the participating children's AMC, PMC and OSP scores to examine whether different profiles could be identified based on these three cluster variables (i.e., aim 1). After standardizing the scores of AMC, PMC and OSP (i.e., conversion into sample-based z-scores), six univariate outliers were removed (i.e., with an absolute z-score of more than three). Using the Mahalanobis distance measure, one additional multivariate outlier had to be removed, resulting in a final sample of 199 children. Next, a two-step procedure of hierarchical and non-hierarchical clustering methods was applied on AMC, PMC and OSP z-scores (Gore, 2000), and Ward's hierarchical clustering method was conducted to combine clusters based on similarity of squared Euclidean distance (Everitt et al., 2001). This analysis resulted in a three, four-, five-, and six-cluster solution. If the explained variance within a cluster solution was less than 50% for AMC, PMC and/or OSP, the cluster solution was eliminated from the following step (Milligan & Cooper, 1985). As a result, the three- and four-cluster solutions were eliminated (based on an explained variance for OSP of 48.8%. and 30.2%, respectively). Cluster centers were then used as non-random initial cluster centers in an iterative, non-hierarchical *k*-means clustering procedure (Asendorpf et al., 2001). After that, a double-split cross-validation procedure was conducted to explore the stability of the cluster solutions by randomly splitting the dataset into halves and applying the two-step procedure of Ward and k-means in each subsample (Breckenridge, 2000). The children in the first half were again clustered based on their Euclidean distances to the cluster center of the other half. The new and original clusters were compared for agreement by means of Cohen's kappa. A Cohen's kappa of > 0.60, indicating good agreement of the averaged two resulting kappa's, was considered as acceptable (Asendorpf et al., 2001). The six-cluster solution had a higher kappa value (0.742) than the five-cluster solution (0.404). Therefore, only the six-cluster solution was used for further interpretation, which explained 71.4%, 61%, and 63.6% of the variance in AMC, PMC, and OSP, respectively.

A Chi-square test was subsequently conducted to explore whether the sex distribution in the clusters matched the sex distribution in the total sample, and independent-samples t-tests were conducted to examine whether boys and girls significantly differed from each other in terms of the **outcome variables** (i.e., **weight status** and **autonomous motivation toward sports**). Furthermore, a one-way ANOVA was conducted to analyze potential age-related differences in the cluster and outcome variables.

To investigate differences in **weight status** (i.e., zBMI) and **autonomous motivation toward sports** among the six clusters (i.e., aim 2), a one-way MANOVA was conducted. Bonferroni adjusted post hoc analyses were used to detect significant subgroup (i.e., Profile) differences.

3 RESULTS

Table 1 presents the means and standard deviations of both the cluster and outcome variables, as well as the correlation coefficients among these variables.

TABLE 1 - Means and standard deviations of the cluster (i.e., 1-3) and outcome (i.e., 4-5) variables (N = 199, 109 boys) and correlations among variables

		Mean	SD	Min	Max	1	2	3	4
	Cluster Variables								
1	AMC (MQ)	107.32	14.44	60	138				
2	PMC *(scale 1-10)*	7.32	1.44	1	10	0.502**			
3	OSP *(hours/week)*	2.52	1.24	0	6.25	0.308**	0.137		
	Outcome variables								
4	BMI z-score	-0.14	0.95	-2.29	2.52	-0.292**	-0.197*	0.057	
5	Autonomous motivation *(scale 1-5)*	4.31	0.73	1	5	0.302**	0.333**	0.405**	-0.079

AMC: actual motor competence; MQ: motor quotient; PMC: perceived motor competence; OSP: organized sports participation; BMI: body mass index; SD: standard deviation; Min: minimum; Max: maximum
** $p < 0.001$; * $p < 0.01$

<u>AIM 1 - Identifying profiles</u>

Cluster analyses revealed six different profiles, which are shown in Figure 1. These identified profiles were labelled based on relative (i.e., compared to the study sample) levels of AMC (high - average - low), PMC (high - average - low) and OSP (high - average - low), respectively. A cluster variable (i.e., AMC, PMC, OSP) was labelled as high when the z-score was above + 0.50, as average when the z-score was equal to or between - 0.50 and + 0.50, and as low when the z-score was below - 0.50. Six profiles were identified, of which three profiles had completely convergent levels of AMC, PMC, and OSP (i.e., 'low-low-low', 'average-average-average', 'high-high-high'), representing 52.2% (*n* = 104) of the total sample. Furthermore, three profiles with partially convergent levels of AMC, PMC and OSP were found (i.e., 'low-low-high', 'average-low-low', 'high-high-low'), representing 47.8% (*n* = 95) of the study sample.

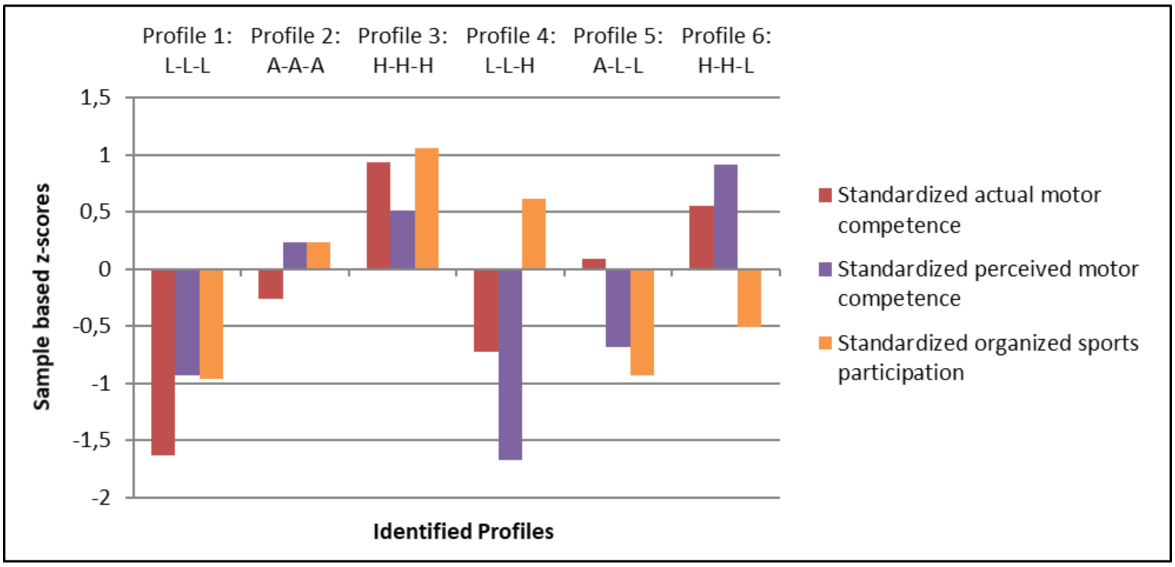


FIGURE 1 - Identification of six profiles based on sample-based z-scores for actual motor competence (AMC), perceived motor competence (PMC) and organized sports participation (OSP) (L: low, A: average, H: high).

Table 2 represents the means and standard deviations of the three cluster variables (i.e., AMC, PMC, and OSP) as well as both outcome variables (i.e., weight status [zBMI] and autonomous motivation) for each of the six identified profiles. Profile 1 (L-L-L; *n* = 20; 40.0% % boys) consisted of children who had relatively low levels of AMC, PMC and OSP when compared to children belonging to the other profiles. Profile 2 (A-A-A; *n* = 43; 69.7 % boys) was characterized by children who displayed relatively average levels of AMC, PMC and OSP when compared to children belonging to the other profiles. Children in Profile 3 (H-H-H; *n* = 41; 58.5 % boys) showed relatively high levels of AMC, PMC and OSP when compared to children belonging to the other profiles. A minority of children (i.e., Profile 4; L-L-H; *n* = 17; 58.8 % boys) was characterized by children who had relatively low levels of AMC and PMC but relatively high levels of OSP when compared to children belonging to the other profiles. Children in Profile 5 (A-L-L; *n* = 32; 56.2 % boys) displayed a relatively average level of AMC and relatively low levels of PMC and OSP when compared to children belonging to the other profiles. Finally, Profile 6 (H-H-L; *n* = 46; 41.3 % boys) consisted of children who showed relatively high levels of AMC and PMC but a low level of OSP when compared to children belonging to the other profiles. The three groups of children with relatively average or high levels of both AMC and PMC (i.e., Profile 2, Profile 3, and Profile 6) were the three biggest groups, together accounting for 65.3% of the total sample while the group of children with relatively low levels of AMC and PMC and high levels of OSP was the smallest group, accounting for only 8.5% of the total sample.

AIM 2 - Differences in weight status and autonomous motivation among profiles

Preliminary analyses were conducted to check for sex and age-related differences among clusters and outcome variables. A Chi-square test showed a similar sex distribution among each of the six identified profiles (χ^2 (5) = 9.408, p = 0.094, ϕ_{Cramer} = 0.217). Regarding age, a one-way ANOVA indicated a significant age-effect (F= 2.677, p =0.023, η^2 = 0.065). However, Bonferroni post hoc tests only revealed a significant, almost negligible, difference in age (p = 0.049) between the younger children in Profile 5 (i.e., 'average-low-low', mean age = 10.51 years) and the slightly older children in Profile 3 (i.e., 'high-high-high', mean age = 11.15 years). With respect to the outcome variables, independent-samples t-tests revealed no significant differences between boys and girls in weight status (t (197) = -0.138, p = 0.890, r = 0.098) and autonomous motivation toward sports (t (197) = -0.203, p = 0.840, r = 0.014) in the total sample. In addition, weight status (F = 2,298; p = 0.079; partial η^2 = 0.034) and autonomous motivation toward sports (F = 1.357; p = 0.257, partial η^2 = 0.020) did not differ between age groups (i.e., 9-9.99, 10-10.99, 11-11.99, 12-12.99 years). Therefore, both sex and age were not taken into consideration in the subsequent analyses.

The one-way MANOVA showed significant differences among the identified profiles for weight status (F = 6.744, p < 0.001) and autonomous motivation (F = 9.063, p < 0.001). With respect to **weight status** (i.e., zBMI), children in the 'high-high-high' profile (i.e., Profile 3), children in the 'average-low-low' profile (i.e., Profile 5) and children in the 'high-high-low' profile (i.e., Profile 6) demonstrated a significantly lower zBMI than children in the 'low-low-low' profile (i.e. Profile 1) and children in the low-low-high' profile (i.e., Profile 4). No other differences in weight status between the previously mentioned profiles were established, and no significant zBMI differences were found between children in the 'average-average-average' profile (i.e., Profile 2), and any of the other profiles.

TABLE 2 - Identified profiles: Means and standard deviations of the cluster variables (AMC, PMC, OSP) and outcome variables (BMI, autonomous motivation) for the six profiles (N=199).

	Profile 1 L-L-L n = 20 8 boys	Profile 2: A-A-A n = 43 30 boys	Profile 3 H-H-H n = 41 24 boys	Profile 4 L-L-H n = 17 10 boys	Profile 5 A-L-L n = 32 18 boys	Profile 6 H-H-L n = 46 19 boys
Cluster variables (z-scores)						
Actual motor competence	-1.63 ± 0.56 [a]	-0.26 ± 0.49 [c]	0.93 ± 0.42 [f]	-0.73 ± 0.61 [b]	0.09 ± 0.39 [d]	0.55 ± 0.46 [e]
Perceived motor competence	-0.93 ± 0.61 [b]	0.23 ± 0.42 [c]	0.51 ± 0.66 [c]	-1.67 ± 0.52 [a]	-0.68 ± 0.66 [b]	0.91 ± 0.41[d]
Organized sports participation	-0.96 ± 0.63 [a]	0.23 ± 0.44 [c]	1.06 ±0.58 [d]	0.61 ± 0.68 [c,d]	-0.93 ± 0.48 [a]	-0.51 ± 0.49 [b]
Cluster variables (raw scores)						
Actual motor competence	80.10 ± 0.91 [a]	102.26 ±7.92 [c]	121.59 ± 6.80 [f]	94.71 ± 9.81 [b]	107.94 ± 6.29 [d]	115.39 ± 7.45 [e]
Perceived motor competence	5.91 ± 0.91 [b]	7.64 ± 0.76 [c]	8.04 ± 0.98 [c]	4.81 ± 0.77 [a]	6.28 ± 0.97 [b]	8.64 ± 0.62 [d]
Organized sports participation	1.29 ± 0.86 [a]	2.90 ± 0.60 [c]	4.02 ± 0.79 [d]	3.41 ± 0.91 [c,d]	1.31 ± 0.65 [a]	1.90 ± 0.66 [b]
Outcome variables						
Body mass index (BMI) z-score	0.50 ± 1.25 [b,c]	0.02 ± 0.89 [a,b,c]	-0.39 ± 0.66 [a]	0.57 ± 1.17 [c]	-0.45 ± 0.79 [a]	-0.39 ± 0.82 [a]
Autonomous motivation for sports	3.72 ± 0.82 [a]	4.56 ± 0.44 [c,d,e]	4.70 ± 0.38 [e]	4.13 ± 0.70 [a,b]	3.99 ± 0.72 [a,b]	4.27 ± 0.87 [b,c]

L: low; A: average; H: high; [a,b,c,d,e,f] : A cluster mean is significantly different ($p < 0.05$) from another mean if they have different superscripts.
Differences between the six profiles were tested by Bonferroni adjusted post hoc analyses.

Autonomous motivation toward organized sports was significantly higher in the 'high-high-high' profile (i.e., Profile 3) when compared to the other profiles, with the exception of the children in the 'average-average-average' profile (i.e., Profile 2). Children in the 'low-low-low' profile (i.e., Profile 1), the 'low-low-high' profile (i.e., Profile 4) and the 'average-low-low' profile (i.e., Profile 5) scored significantly lower on autonomous motivation when compared to children in the 'average-average-average' profile (i.e., Profile 2) and children in the 'high-high-high' profile (i.e., Profile 3).

4 DISCUSSION

The present study used a person-centered approach to identify various profiles based on children's' AMC, PMC and OSP (i.e., aim 1). In addition, it was examined how children in the various AMC-PMC-OSP based profiles may differ from each other in terms of weight status (i.e., zBMI) and autonomous motivation toward sports (i.e., aim 2). We addressed these aims in a study sample with AMC levels that were slightly above average (i.e., MQ of 107 versus the reference value of 100) and PMC levels that were comparable to the PMC levels in an older sample (McGrane et al., 2016). When it comes to OSP, our study sample showed higher levels when compared to the reported OSP levels in a previous study in the same age category (De Meester, Wazir, et al., 2020). In terms of outcome variables (i.e., weight status and autonomous motivation), our study sample was comparable with other studies conducted in children within the same age range (Bardid, De Meester, et al., 2016; De Meester, Wazir, et al., 2020).

AIM 1 - Identifying profiles based on children's' AMC, PMC and OSP

The cluster analyses revealed three profiles with completely convergent levels of AMC, PMC, and OSP (i.e., 'low-low-low', 'average-average-average', 'high-high-high'), and three profiles with partially convergent levels thereof ('low-low-high', 'average-low-low', 'high-high-low'). When only considering AMC and PMC in the current sample, 5 out of 6 profiles (83.9% children of the total sample) had convergent levels of AMC and PMC, and only one profile (i.e., Profile 5) had divergent levels of AMC and PMC. In that respect, our findings differ from prior studies which revealed three

(De Meester, Stodden, et al., 2016) or four (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016) motor competence based profiles: one profile with relatively low levels of both AMC and PMC (i.e., 'low-low'), one profile with relatively high scores of both constructs (i.e., 'high-high'), one profile combining relatively low levels of AMC with relatively high levels of PMC (i.e., 'low-high'), and one profile combining relatively high levels of AMC with relatively low levels of PMC (i.e., 'high-low'). Interestingly, we did not clearly identify a 'low-high' or 'high-low' profile. However, Profile 2 ('average-average-average') and Profile 5 ('average-low-low') would have been considered as divergent profiles if we would have used the cut-off points of the previous studies (i.e., low [i.e., below average] or high [i.e., above average] based on AMC and PMC) (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016; De Meester, Stodden, et al., 2016). Another explanation for the majority of children having convergent AMC and PMC levels in the current study may be that we used an aligned (i.e., with the AMC test battery) product-oriented measure of PMC. The four KTK-related items in the PMC questionnaire were directly aligned with the test items of the AMC assessment tool (i.e., KTK), which may explain why we found a relatively stronger relationship between AMC and PMC in this study when compared to previous studies focusing on middle childhood (De Meester, Barnett, et al., 2020). Not only the alignment, but also the nature of the assessment tools, which were both product-oriented, may have resulted in a stronger relationship between AMC and PMC. It is possible that children have less difficulties with feeding product-oriented information back to themselves (e.g., *"How many steps did I walk backwards on the balance beam?"*) when compared to process-oriented information (e.g., *"Did I extend my arm while reaching for the ball as it arrives?"*) (True et al., 2017). Children may also have used the product-oriented feedback to provide additional relevant information about their self-perceived level of skill in comparison to process-oriented feedback (True et al., 2017), resulting in a stronger correlation between the aligned AMC and PMC in the current study when compared to earlier research also using a person-centered approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Pesce et al., 2018).

The addition of OSP as a third cluster variable yielded some additional and interesting insights that warrant further discussion. First, there appeared to be a small group of children (i.e., Profile 4) with relatively low levels of AMC and PMC but relatively high levels of OSP (i.e., 'low-low-high'). This may indicate that having low levels of AMC and PMC does not necessarily prevent children from taking part in organized sports, which is in contrast with previous literature (Babic et al., 2014; De Meester, Maes, et al., 2016; Robinson et al., 2015). On the other hand, the expected positive effect in the other direction, with more OSP being associated with higher levels of AMC (Niemistö et al., 2020) and PMC (Niemistö et al., 2019) also seems to be absent in Profile 4. One explanation may be that children in this 'low-low-high' profile are supported by their environment to participate in organized sports without necessarily having high levels of AMC or PMC. There was also a group of children, constituting of 23.1% of the sample (i.e., Profile 6), who had relatively high AMC and PMC levels but did not frequently participate in OSP (i.e., 'high-high-low'). A possible explanation for the (unexpected) low levels of OSP, which is in contrast to their high levels of AMC and PMC, may be that these children are physically active (e.g., active free play, active transport) and even participate in unorganized sports (i.e., running, swimming,…), but not necessarily in sports in an organized setting. Altogether, these findings demonstrate the added value of a person-centered approach and including OSP as an additional third cluster variable. Previous research has shown that several factors play a role in OSP (e.g., sex, socio-economic status, social support from parents and friends, and economic resources; Eime et al., 2013; Vandendriessche et al., 2012). Moreover, psychosocial barriers and facilitators in OSP might explain the differences in the divergent profiles. Therefore, further research exploring psychosocial factors such as socio-economic status and parental support as well as enjoyment, and the relationship of each of these factors with OSP (and by extension AMC and PMC), could be helpful to further unravel the identified profiles.

AIM 2 - Examining differences in weight status and autonomous motivation according to AMC-PMC-OSP profiles

First, taken together all findings, the children with average to high levels on all three variables (i.e., Profile 2 and 3) displayed the most optimal profile as they had both low levels of zBMI (representing a healthier weight status) as well as high levels of autonomous motivation toward sports, while the opposite was true for children with low levels of all three variables (i.e., Profile 1). These findings align with previous studies revealing that children with relatively low levels of AMC and PMC were more likely to have a higher BMI (representing a less healthy weight status) compared to those with relatively high levels of AMC and PMC (De Meester, Stodden, et al., 2016; Estevan et al., 2019), and with evidence that suggests that low levels of AMC and PMC is the least optimal combination in terms of autonomous motivation (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016).

Some interesting patterns further emerge when considering the divergent profiles. In terms of **weight status**, the two profiles with the lowest levels of AMC and PMC (i.e., Profile 1 and 4) revealed the highest zBMI, independent of whether they had low (i.e., Profile 1) or high (i.e., Profile 4) OSP levels. Our findings thus show that being involved in OSP does not necessarily compensate for low levels of AMC and PMC in terms of a healthy weight status. In fact, our study seems to indicate that more desirable levels of zBMI are associated with average (i.e., Profile 2) or high (i.e., Profile 3 and 6) levels of both AMC and PMC, further stressing the importance of promoting both AMC and PMC for a healthy weight status. In terms of **autonomous motivation**, findings clearly point toward the importance of promoting average to high levels of AMC, PMC, and OSP simultaneously. While previous research revealed that relatively high levels of PMC can compensate for relatively low levels of AMC in children (Bardid, De Meester, et al., 2016) as well as in adolescents (De Meester, Maes, et al., 2016; Estevan et al., 2020), this hypothesis could not be tested in the current study as we did not identify a group of children with relatively low AMC levels and relatively high PMC levels. However, a closer look at the profiles (Figure 1) reveals that at least some children in Profile 2 ('average-average-average') may have low(er) levels of AMC and high(er) levels of PMC, while having an average level of OSP. Finally, it was surprising to note that the group with average levels of AMC and low levels of PMC and OSP (i.e., Profile 5), which would be considered a less optimal profile, still had relatively low levels of zBMI. Yet, the latter group displayed lower levels of autonomous motivation. Thus, they were less likely to value and enjoy organized sports participation, hereby displaying a mixed pattern of outcomes, which is in line with the findings of Estevan et al. (Estevan et al., 2020).

Strengths and limitations, and recommendations for future research

A major strength of the present study is the use of a person-centered approach, which enabled a deeper understanding of how AMC, PMC and OSP are combined within 9- to 13-year-old children, and in turn relate to their weight status and autonomous motivation toward sports. As stated by Cairney et al. (2019), incorporating other domains than AMC and PMC in the person-centered approach allows to more profoundly examine the interrelationship among different health-related outcomes. Another strength is the use of aligned assessment instruments for the measurement of AMC and PMC. Using such measures that capture constructs in a similar way can help us to gain more insight into how children's perceptions of motor competence correspond to their AMC. In future studies, combinations of aligned and product- and process-oriented measures of PMC could be incorporated to examine how profiles and findings may differ depending on the type of measurement being used. Despite the strengths of this study, it must be taken into account that this study has a cross-sectional design. Therefore, the results do not provide any causal evidence regarding significant relationships that were found among study variables. Longitudinal and experimental studies should be conducted to gain more insight in the direction of these relationships. Furthermore, differences among the six identified profiles could have been less pronounced as group sizes were not equal, ranging from 17 to 46 participants per profile, but since the study sample was sufficiently large to perform cluster analyses (Breckenridge, 2000), results are to be considered legitimate. However, further research with a larger sample is recommended to support the identified cluster-profiles of the current study. Another limitation of this study is that only one specific type of PA (i.e., OSP) was included as a measurement of PA. Future research would benefit from also including measurements of other types of PA, such as participation in unorganized sports, active transport and school-based PA. In addition, using the KTK as AMC test battery, does not provide a comprehensive picture for MC since it mainly measures stability and locomotion (Iivonen et al., 2015). Finally, this study can set the stage for examining psychosocial and environment antecedents of children's profiles to examine which factors (e.g., socio-economic status, parental support) explain why children belong to a certain profile.

Conclusions

The present study identified three completely convergent and three partially convergent AMC-PMC-OSP based profiles in 9- to 13-year-old children. Results revealed that children with average to high levels on all three cluster variables displayed the most optimal health-related profile as they had (on average) a healthier weight status as well as higher levels of autonomous motivation, while the opposite was true for children with low levels of all three cluster variables. Our findings further showed that being involved in OSP does not necessarily compensate for low levels of AMC and PMC in terms of a healthy weight status. The results of the present study also highlight the importance of targeting and monitoring AMC and PMC in physical education and sports settings to help children in achieving a healthy weight status. These endeavors might result in a healthier weight status and higher levels of autonomous motivation toward sports, both essential aspects of a healthy and active lifestyle.

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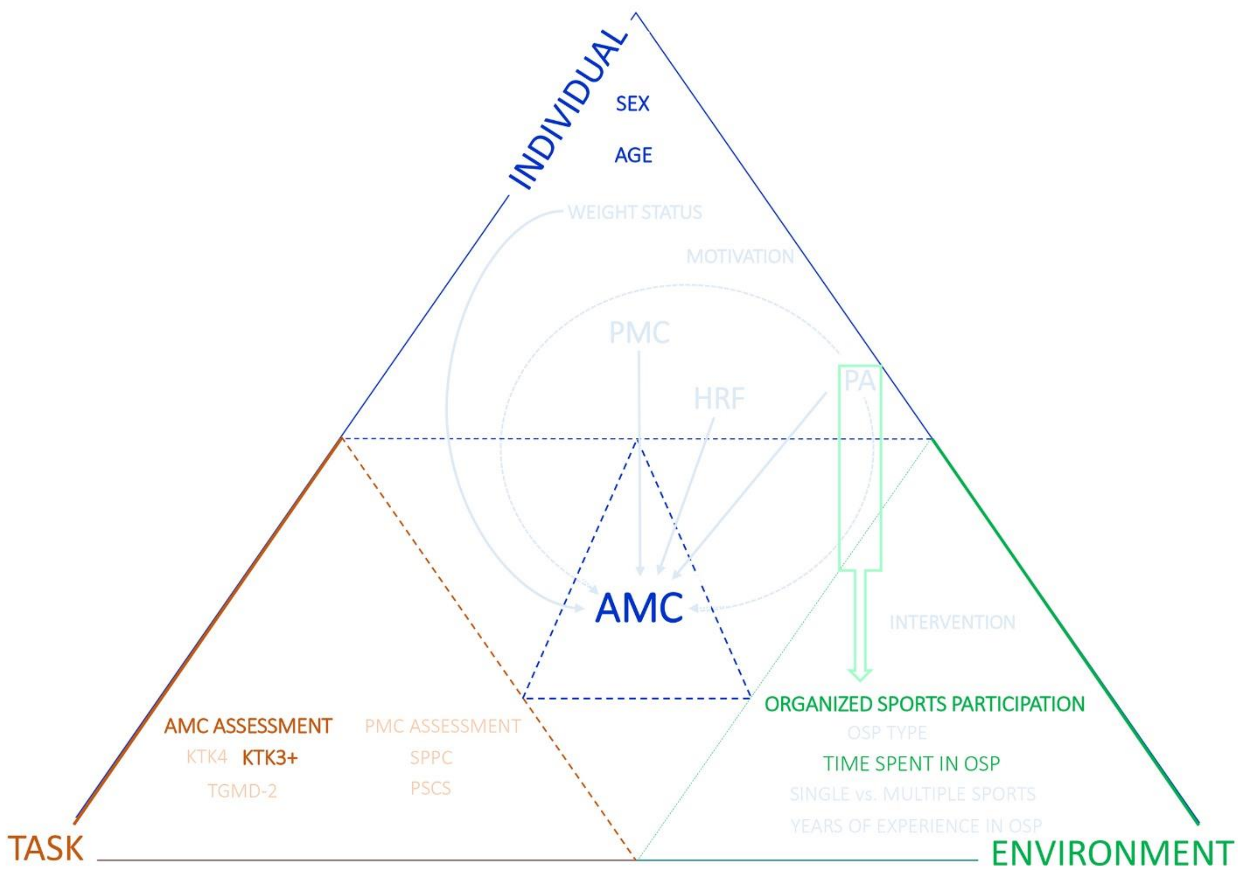
- CHAPTER 3 -

ADDRESSING SOME OF THE SHORTCOMINGS IN LITERATURE CONCERNING MOTOR COMPETENCE ASSESSMENTS

STUDY 4

VALIDATION OF A MOTOR COMPETENCE ASSESSMENT TOOL FOR CHILDREN AND ADOLESCENTS (KTK3+) WITH NORMATIVE VALUES FOR 6- TO 19-YEAR-OLDS



This study is based on **Coppens, E.***, Laureys, F;*, Mostaert, M.*, D'Hondt, E., Deconinck, F.J.A., & Lenoir, M. (2021). Validation of a motor competence assessment tool for children and adolescents (KTK3+) with normative values for 6- to 19-year-olds. *Frontiers in Physiology, 12*, 916. *These authors share first authorship. https://doi.org/10.3389/fphys.2021.652952

ABSTRACT

The use of the short form of the KörperkoordinationsTest für Kinder (KTK3) to evaluate children's and adolescents' actual motor competence (AMC) is increasing. When combined with an alternating one-handed catching and throwing ball task, assessing eye-hand coordination (EHC), it has been shown that the different aspects of motor skills are adequately covered in one compact KTK3+ test battery, studied in 6-to 10-year old children.

The present study aimed to validate the KTK3+ test battery and to provide contemporary AMC normative values for boys and girls from 6- to 19-year-old. A total of 2271 children and adolescents (1112 boys, 1159 girls) participated in this study and were evaluated on the four included test items: jumping sideways (JS), moving sideways (MS), balancing backwards (BB), supplemented by an EHC task. Children's participation in organized sport was registered using a demographic questionnaire. For the first objective, a factor analysis with multidimensional scaling demonstrated that the one-dimensional model provided the best fit, with all test items correlating to the same latent construct: 'AMC'. This was further supported with moderate to good correlations between all four test items (r = 0.453 – 0.799). Construct validity was investigated with a three-way MANOVA, demonstrating a significant multivariate interaction effect between sex and age group ($p = 0.001$) as well as a multivariate main effect of sex, age group and organized sport participation ($p < 0.001$). Boys outperformed girls on two out of the four tests (JS and EHC, $p < 0.005$), while girls were better than boys on the BB test ($p < 0.005$). Performance scores increased across age groups on all tests (p < 0.001). Only for the BB test score, a plateau effect was noted around the age of 12 years. Children and adolescents participating in sports generally outperformed their peers, who were not involved in organized sports, on the present KTK3+ test battery. For the second objective, raw score normative values are provided separately for both sexes between 6- and 19-year old children.

In combination with the one-factor structure confirmation, these sex, age, and sport participation effects demonstrate the validity of the test battery. The provided normative values are useful to evaluate AMC in children and adolescents from 6- to 19-year old. The use of only four test items

that are identical across all ages makes the KTK3+ test battery a practical instrument to assess and compare AMC development.

1 INTRODUCTION

Motor competence (AMC) can be defined as the degree of proficient performance in various motor skills as well as the underlying mechanisms such as motor control and coordination (Utesch & Bardid, 2019). The importance of AMC lies in its beneficial effect on children's and adolescents' general health and well-being (Cattuzzo et al., 2016; Robinson et al., 2015; Stodden et al., 2008), which is well documented in literature (Robinson et al., 2015). Across childhood and adolescence, AMC is known to be positively associated with many health-related outcomes, including physical activity (Logan et al., 2015), physical fitness (Cattuzzo et al., 2016; Utesch et al., 2019), well-being (Skinner & Piek, 2001) and cognitive health (Haapala, 2013). An inverse relationship between AMC and weight status has also been consistently reported (Cattuzzo et al., 2016; D'Hondt et al., 2013). AMC involves the mastery of fundamental motor skills, which are the foundation for more advanced and sport specific motor skills (Clark & Metcalfe, 2002; Malina et al., 2004). The construct of AMC is measured and assessed in a wide variety of settings and populations, ranging from clinical samples, typically developing children and adolescents, up to (young) elite athletes.

To date, multiple motor test batteries have been developed to enable the evaluation and monitoring of AMC in distinct periods throughout the lifespan. A widely used standardized normative and product-oriented test battery, is the KörperkoordinationsTest für Kinder ('KTK4') (Kiphard and Schilling, 1974). The KTK4 has been developed to assess gross motor coordination, which refers to one's ability to execute a wide range of motor activities involving whole body movement (Fransen et al., 2014). The original KTK4 assessment tool includes four non-sport specific test items, including jumping sideways (JS), moving sideways (MS), balancing backwards (BB), and hopping for height (HH). All of these tests integrate specific motor skills, such as balance and locomotion, but also rely on components of physical fitness and motor coordination. Kiphard and Schilling first validated the KTK4 in (1974), providing normative values based on the data of 1228 German children aged between 5 and 15 years with and without motor and/or health-related issues. Reliability was established for the total raw scores, with Cronbach Alpha scores ranging between 0.80 and 0.96 on the four individual test items, and a total Cronbach Alpha of 0.97 for the overall KTK4 score. Content and construct validity have been documented (Kiphard & Schilling, 1974, 2007), showing moderately strong correlations between the KTK4 scores and other standardized assessment tools such as the Bruininks-Oseretsky Test of Motor Proficiency – 2nd Edition (Bruininks & Bruininks, 2005; Fransen et al., 2014), the Motoriktest für Vier- bis Sechsjährige Kinder (Bardid et al., 2016; Zimmer & Volkamer, 1987), as well as the Movement Assessment Battery for Children (Henderson and Sugden, 1992; Smits-Engelsman et al., 1998). Furthermore, the KTK4 has been shown to be a good instrument to detect the delayed AMC development of children with special needs (i.e., children with brain disorder, behavior disturbances or speech impairments), as 91% of these children were identified correctly. Of note, the HH test is often omitted from the KTK4 test protocol in more recent studies due to time constraints and/or safety reasons, especially when applied in adolescents (Deprez, Fransen, Boone, et al., 2015; Lovell et al., 2018; Mostaert et al., 2016 ;Norjali Wazir et al., 2018; Pion et al., 2014; Pratorius & Milani, 2004). The resulting KTK short form ('KTK3') has also been demonstrated to represent a valid assessment tool of AMC per se, with a strong overall correlation between AMC scores of the three remaining tests (i.e., JS, MS, BB) (r = 0.98; Novak et al., 2017).

Because this latter test battery is easy and quick to administer and also has excellent psychometric qualities, the KTK3 is presently still used to detect motor impairment in children, to describe the current level and/or progress of AMC in typically developing children as well as to distinguish children with an adequate level from those with a more advanced level of AMC. The KTK3 is also considered to be a useful test battery for longitudinal research into motor development, because the AMC tasks involved are characterised by virtually no ceiling effect (Kiphard & Schilling, 1974) and each test item is identical from the age of 5 up until 15 years old (D'Hondt et al., 2013).

Both sex- and age-related normative values are needed to observe the gradual improvement in gross motor coordination across childhood and adolescence. In general, when participants perform a AMC test battery, it is often observed that girls have better scores on the balance tasks, whereas there are no clear differences on the locomotion tasks between both sexes (Barnett et al., 2016; Rodrigues et al., 2019). However, these results are mostly seen in the younger age groups, and there is no consensus in the older age groups. Current normative values of the KTK3 are limited to the original reference sample of individuals up to 15 years of age (Vandorpe, Vandendriessche, Lefevre, et al., 2011), but motor coordination test batteries are often used in older (sporting/athlete) populations (Deprez, Fransen, Boone et al., 2015; Deprez, Fransen, Lenoir, et al., 2015; Fransen et al., 2017; Norjali Wazir et al., 2018, 2019; O'Brien-Smith et al., 2019; Pion et al., 2014; Pion et al., 2015). More particularly, the KTK3 has also frequently been used for detection and identification of athletic talents (Deprez, Fransen, Boone, et al., 2015; Fransen et al., 2017; Mostaert et al., 2016; Norjali Wazir et al., 2018; Vandorpe, Vandendriessche, Vaeyens, et al., 2011; Vandorpe et al., 2012). Therefore, it is important for researchers and practitioners to consider the applicability of this test battery (or an adapted version thereof) in individuals older than 15 years of age, and provide them with normative values that have been validated for older age groups too.

Yet, another issue with the KTK4 test battery (and its KTK3 short form) is that only the MS test requires a (limited) degree of object control skill. Nonetheless, object control is considered as a fundamental aspect of AMC, in addition to locomotor and balance skills (Gallahue & Donnelly, 2003). These three main motor skill domains should be addressed conjointly to evaluate gross AMC in a comprehensive manner. Previous studies have shown the importance of object control skills to develop a physically active lifestyle and, more specifically, for sports performance (Butterfield et al., 2012). Therefore, it seems desirable to add an explicit object control task to the existing KTK3 test protocol. Research of Platvoet et al., (2018), examining 6- to 10-year-olds children showed that the KTK3, when supplemented with a catching and throwing task assessing eye-hand coordination (EHC), covers the three abovementioned main motor skill domains (i.e., locomotion, balance and object control). In addition, these studies revealed good test-retest reliability for all subtests: BB 0.80, MS 0.84, JS 0.95, EHC 0.87 (Faber et al., 2014; Platvoet et al., 2018). The EHC task, used by Platvoet et al. (2018), requires the individual to throw a tennis ball to the wall with one hand and catch the ball with the other hand. It is a simple and objective test to assess one's ball control and anticipatory capacity. The EHC task is easy to administer in various (large) settings, which may be sports related (e.g., ball and racket sports; Faber et al., 2014; Platvoet et al., 2018). Results of Platvoet et al. (2018) showed an increase in the raw score over the different age groups and a higher score for boys compared to girls. Although based upon data from a limited age range, these findings clearly indicated that, when combined with an EHC task, the KTK3 test battery is generally able to cover a broad spectrum of gross motor performance skills and could also discriminate between children with different AMC levels.

In the context of the preceding arguments and as suggested by Platvoet et al. (2018), there is a need to expand the current set of norms of the KTK3 and EHC for children and adolescents. This test battery will from now on be referred to as the **KTK3+**. Therefore, our aim is to validate the combined KTK3+ test battery and provide reference values for both children and adolescents up to emerging adulthood. First, a factor analysis will be performed with the hypothesis that all four test items included in the KTK3+ test battery relate to a single, latent variable: 'AMC'. Subsequently, the construct validity of the KTK3+ will be investigated by comparing sex, age groups and participants that are involved or not involved in organized sports participation. Finally, normative values for the KTK3+ test battery will be presented for boys and girls separately as well as per age, and this between the ages of 6 and 19 years. It is expected that girls will have higher scores on BB, but boys will outperform girls on the EHC task. For JS and MS, we expect no differences in the performance according to sex. Furthermore, we hypothesise that older children and adolescents will systematically outperform their younger counterparts year after year, and that the KTK3+ scores will be higher in those participants who are involved in organized sports.

2 METHODS

2.1 Participants and procedures

Participants in this large-sampled study were children and adolescents aged between 6 and 19 years, who were all based in Flanders (i.e., the Dutch-speaking part of Belgium). Participants were recruited through convenience sampling, since we aspired to test approximately 100 participants per age group, with the expectation of a relatively equal distribution of sex. This sampling method resulted in seven elementary schools, seven secondary schools (with a mix of students in general, technical and vocational education), two summer camp organisations and one university. This approach resulted in a total sample of 2271 participants (1112 boys and 1159 girls). Of this sample, 1248 participants (580 boys and 668 girls) were included in the first part of the study (i.e. the validation process), given that these participants completed a demographic questionnaire in addition to performing the four tests of the KTK3+ test battery. A written informed consent was obtained from each participant. Since the majority of the participants were minors, their parent(s) or their legal representative gave permission for participation in this study. All data were analyzed confidentially. This project has been conducted in accordance with the code of Ethics of the World Medical Association (Declaration of Helsinki, 1964 and Declaration of Tokyo, 1975, as revised in 1983) and was approved by the local ethics committee of the Ghent University Hospital.

Data collection for this cross-sectional study took place between September 2018 and September 2019. For the construct validation of the KTK3+ test battery, participants were grouped as being involved or not involved in organized sports. To this end, the participants' parent(s) or legal representative were asked to fill out a short demographic survey, also including a binary question (i.e., yes / no) of the involvement of organized sports activity of the child during the school year at the time of measurement. The university students (over 18 years old) filled-out this survey themselves.

The testing took place in group in the gymnasium of the participants' school / summer camp / university, during which they were asked to be dressed in light sports clothing and to perform the test battery barefooted. After taking the anthropometric measurements, participants were divided equally among the four AMC test items to start the administration of the KTK3+ test battery. When a test item was completed, the participant moved on to a next test item, without using a fixed order. Administration of the anthropometric measurements together with the KTK3+ test battery took approximately 45 minutes for one group (i.e., consisting of +/- 25 participants).

For each test day, at least one of the three first authors of this study was present to supervise a group of experienced examiners, who conducted the assessments using standardized instructions in accordance with the original testing manual guidelines (Faber et al., 2014; Kiphard & Schilling, 1974). Before actually conducting each test item of the KTK3+ test battery, participants were given a familiarisation trial for each motor task. Participants were also asked to perform each test item at their best. Test leaders were only allowed to give motivational feedback during actual task performance. However, if they noticed that the participants' test performance was not in line with the prescribed test instructions, they were asked to stop the test, gave correctional feedback and let the participant repeat the test at hand.

2.2 Materials

Anthropometry. The anthropometric measurements were conducted with standardized protocols and high-quality mobile equipment. Height was measured with a portable stadiometer with an accuracy of 0.1 cm (Harpenden, Holtain Ltd., Crymych, United Kingdom). Body weight was determined with a bio-electrical impedance scale with an accuracy of 0.1 kg (TANITA BC-420 SMA, Weda B/V., Naarden Holland). Based on these measurements, participants' body mass index (BMI, kg/m²) was calculated and using the most recent international cut-offs suggested by the International Obesity Task Force (IOTF; Cole & Lobstein, 2012), children and adolescents were classified as being under-weight, normal-weight, overweight or obese.

KTK3+ test battery

To evaluate children's and adolescents' AMC, the use of the KTK3 (Kiphard & Schilling, 1974; Novak et al., 2017) was supplemented with a catching and throwing task (Faber et al., 2014; Platvoet et al., 2018) assessing eye-hand coordination (EHC).

KTK3. General gross motor coordination was assessed using the KTK3 (Kiphard & Schilling, 1974, 2007; Novak et al., 2017). This is a highly validated, reliable and product-oriented (quantitative) test instrument that is frequently used on a global scale (Novak et al., 2017). The KTK3 consists of three test items. The first test is jumping sideways (JS), where participants had to jump with two feet over a wooden slat for 15 seconds. The final score results from the sum of the number of jumps on both trials being provided. For the second test, participants had to move sideways (MS) on a straight line handling two wooden platforms for 20 seconds. The total score results from summing the number of times participants putted down a wooden platform as well as the number of times participants stepped on the displaced wooden platform during both trials being provided. The third and final test of the KTK3 is balancing backwards (BB) with three trials per balance beam, that is decreasing in width as the test progressed (6.0cm - 4.5cm - 3.0cm). The total amount of steps were counted, with a maximum number of 72 steps (or 8 steps on each trial per balance beam) in total.

Eye-Hand Coordination. The EHC test is a valid and reliable product-oriented test (Platvoet et al., 2018) that determines the level of controlling a tennis ball while conducting repetitive movements (i.e., left hand throw, right hand catch followed by right hand throw and left hand catch, etc.) as frequently as possible in a time-constrained task of 30 seconds (Faber et al., 2014). The participants were free to use overhand and/or underhand techniques or a combination of both for throwing and catching. To this end, participants had to stand 1m from a wall, and throw the tennis ball at eye-level in a square ($1m^2$) taped on the wall with the bottom side of the square 1 m above the ground. Participants conducted this test twice, with the number of successful ball catches across both trials resulting in the test score.

2.3 Statistical Analysis

All data were analysed using SPSS version 26. To test the hypotheses concerning the structure and construct validity of the KTK3+ test battery, the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN; Prinsen et al., 2018) was applied. To examine the data for the possible impact of multicollinearity, the Variation Inflation Factor (VIF) was checked. The VIF was calculated three times, each time with the EHC task in relation with one of the KTK3 test items. If the VIF-score has a value ranging between 1 and 10, there is no impact of multicollinearity, which implies that the EHC test can be used in combination with the KTK3, resulting in the so-called KTK3+ test battery. Second, multidimensional scaling (MDS; Borg et al., 2013) was used to conduct a factor analysis in order to verify that all four tests included in the KTK3+ test battery relate to a single, latent variable: 'AMC'. MDS gives a more detailed insight in the relationship between the four test items (JS, MS, BB, EHC) by means of a graphical representation. On the accompanying visualisation, the x-axis represents the geometrical distance between the test items, which is to be interpreted as the (dis)similarities between them. Small distances indicate a high correlation or small dissimilarity, whereas large distances indicate a low correlation or large dissimilarity between test items. In this study, a PROXSCAL, non-metrical, MDS with Euclidean distance was applied (Giguère, 2006). The Euclidean distance between the standardized items is a measure of dissimilarity, and its interpretation is in correspondence with the Pearson's correlation analysis.

Furthermore, a three-way MANOVA, with sex, age group, and organized sport participation as between-subjects factors, was used to examine differences in KTK3+ test scores. To answer this question in view of the construct validity, only participants with no missing values for organized sport participation and each of the four KTK3+ test items were included in the analyses. For the feasibility of the latter statistical model, age-related differences were tested based on seven distinct age groups (i.e., 6-7.99, 8-9.99, 10-11.99; 12-13.99, 14-15.99; 16-17.99 and 18-19.99 years). In addition, the effect of organized sport participation was inspected, based on two different levels (i.e., participating in organized sports vs. not being involved at all in this kind of activity). Significant interaction and main effects were further examined with Bonferroni post hoc tests. Values of $p \leq 0.05$ were considered statistically significant for all analyses.

For the second research question, normative values were provided. These values were based on the descriptive statistics of all participants (i.e., also including participants with missing data on the KTK3+ test items), providing raw score normative values per sex and age in years (mean ± SD). In addition to the raw scores collected in our present reference sample, we also wanted to provide standardised values with conversion tables. Therefore, motor quotient (MQ) scores were computed for both boys and girls separately, for each single test item as well as for the total KTK3+ MQ-score. Therefore, individual means and standard deviations were calculated for each sex, age and test item in order to be able to apply the following formula:

$$z - score_{test} = \frac{(raw\ score_{test} - mean_{test})}{standard\ deviation_{test}}$$

MQ scores could then be derived from the z-scores, again for each single test item and for the total KTK3+ test score, with the following formula, after the example of Pion (2015):

$$MQ_{test} = 100 + (z - score_{test} \times 15)$$

For the total KTK3+ MQ-score, a classification on 5 levels of AMC based on the normal distribution can be made (Vandorpe, Vandendriessche, Lefevre, et al., 2011). Values below 70 are seen as an indicative of 'severe gross AMC disorder', values between 71 and 85 are considered to represent 'moderate gross AMC disorder', values between 86-115 are seen as 'normal gross AMC proficiency', and MQ-scores between 116 and 130 as 'good gross AMC proficiency', whilst values above 131 point to 'high gross AMC proficiency'.

3 RESULTS

First, a detailed overview of the number of participants per sex and age group can be found in Table 1. According to the most recent IOTF cut-off points for BMI (Cole & Lobstein, 2012), 12.9% of the participants in this study could be categorized as being under-weight, 77.2% as normal-weight, 8% as overweight and 1.9% as obese. This is in agreement with the Flemish prevalence numbers of BMI (Vancoppenolle et al., 2020), which speaks for the representativeness of this sample. The demographic survey revealed that 840 participants (419 boys, 421 girls) were involved in organized sports on a weekly basis during the school year at the moment of testing (i.e., from 1 up to 21 hours per week), whereas the remaining 403 participants (161 boys, 242 girls) were not involved in any organized sport activities at the moment of testing, apart from the regular physical education classes at school. A detailed overview of this additional sports related information collected in the subsample can be found per sex and age group in appendix (Table A).

TABLE 1 - Mean and standard deviation (SD) for the anthropometric variables of the participants within the various age-groups.

Age (years)		**Girls**	SD	**Boys**	SD	**Total**	SD
6	N	51		73		124	
	Height (cm)	117.66	5.7	118.45	4.59	118.13	5.07
	Weight (kg)	21.03	2.95	21.85	5.42	21.51	4.57
	BMI (kg/m²)	15.13	1.13	15.51	3.54	15.35	2.81
7	N	51		73		124	
	Height (cm)	126.41	5.85	126.74	5.69	126.6	5.73
	Weight (kg)	24.73	3.96	24.43	3.42	24.55	3.64

	BMI (kg/m²)	15.41	1.74	15.15	1.27	15.26	1.48
8	N	45		61		106	
	Height (cm)	131.41	5.65	134	8.61	132.91	7.58
	Weight (kg)	26.5	4.36	28.38	7.43	27.58	6.35
	BMI (kg/m²)	15.28	1.76	15.61	1.75	15.47	1.76
9	N	63		85		148	
	Height (cm)	138.77	7.16	138.25	6.16	138.47	6.58
	Weight (kg)	33.36	8.86	31.12	5.55	32.08	7.21
	BMI (kg/m²)	17.14	3.25	16.22	2.21	16.61	2.73
10	N	102		113		215	
	Height (cm)	144.06	7.69	143.83	6.93	143.94	7.28
	Weight (kg)	36.84	8.53	36.12	8.14	36.46	8.32
	BMI (kg/m²)	17.62	3.03	17.33	2.94	17.47	2.98
11	N	101		107		208	
	Height (cm)	150.81	7.12	148.75	7.83	149.75	7.55
	Weight (kg)	40.14	7.19	38.54	8.36	39.32	7.84
	BMI (kg/m²)	17.59	2.61	17.37	3.26	17.48	2.95
12	N	152		68		220	
	Height (cm)	155.64	7.84	155.13	8.62	155.48	8.07
	Weight (kg)	44.55	8.88	43.67	9.51	44.28	9.07
	BMI (kg/m²)	18.35	3.58	18.01	2.83	18.25	3.36
13	N	51		49		100	
	Height (cm)	163.47	6.02	162.45	9.02	162.97	7.62
	Weight (kg)	51.27	9.3	49.94	12.23	50.62	10.8
	BMI (kg/m²)	19.13	2.97	18.72	3.24	18.93	3.09
14	N	104		111		215	
	Height (cm)	164.01	6.83	168.89	8.49	166.53	8.09
	Weight (kg)	54.43	8.6	55.32	10.97	54.88	9.88
	BMI (kg/m²)	20.2	2.76	19.26	2.71	19.71	2.77
15	N	82		112		194	
	Height (cm)	163.75	6.67	173.82	6.67	169.57	8.31
	Weight (kg)	56.14	10.1	60.45	10.47	58.63	10.51
	BMI (kg/m²)	20.89	3.17	19.95	2.91	20.34	3.05
16	N	45		73		118	
	Height (cm)	165.83	7.41	178.52	7.1	173.68	9.48

	Weight (kg)	57.37	5.99	64.41	8.69	61.73	8.47
	BMI (kg/m²)	20.98	2.79	20.16	1.93	20.47	2.32
17	N	84		64		148	
	Height (cm)	165.99	6.58	179.38	7.03	171.78	9.49
	Weight (kg)	59.86	9	66.92	9.27	62.92	9.74
	BMI (kg/m²)	21.75	3.14	20.82	2.79	21.35	3.02
18	N	172		96		268	
	Height (cm)	167.93	5.75	179.78	6.62	172.17	8.32
	Weight (kg)	60.99	7.5	70.86	10.21	64.53	9.78
	BMI (kg/m²)	21.63	2.45	21.88	2.6	21.72	2.5
19	N	51		22		73	
	Height (cm)	167.42	6.1	183.4	6.44	172.23	9.61
	Weight (kg)	62.1	8.93	75.38	7.46	66.1	10.45
	BMI (kg/m²)	22.12	2.66	22.5	2.87	22.23	2.71

For the first research question, the factor structure of KTK3+ test battery was examined. The VIF for all KTK-3 test items in relation to the EHC task varied between 1 and 10, indicating that all four tests could remain combined (VIF_{JS} = 2.812; VIF_{MS} = 2.511; VIF_{BB}= 1.604). Afterwards, a one- to two-dimensional structure of the four items within the KTK3+ test battery was examined with the non-metric MDS analysis. Different fit indices were used to assess model fit. The scree test as well as the stress and fit measures revealed that a one-dimensional factor structure was most suitable. Both the raw stress score and Tucker's coefficient supported this, with good outcome scores (0.001 and 1.00, respectively; Lorenzo-Seva & Ten Berge, 2006). These measures show that 99.9% of the distances are explained by the one-dimensional configuration, indicating an excellent structure of the KTK3+ test battery (see Figure 1). The correlations between the four KTK3+ test items (i.e., JS, MS, BB, EHC) ranged from moderate to very good (r = 0.453 – 0.799; Schober et al., 2018), reflecting the one-dimensional structure of the KTK3+ test battery (Table 2).

The construct validity of the KTK3+ test battery was examined using a three-way MANOVA to compare differences in test scores (i.e., JS, MS, BB, EHC) according to sex, age group and organized sport participation. There was neither a significant three-way multivariate interaction effect, nor an interaction effect for sex*organized sport participation, and age group*organized sport participation at the multivariate level. A significant multivariate interaction effect was found, however, between sex and age group ($F_{(24;4225.88)} = 2.058$ and $p = 0.001$), as well as a significant main effects for sex ($F_{(4,1211)} = 39.472$; $p < 0.001$), age group ($F_{(24,4225.88)} = 110.92$; $p < 0.001$) and organized sport participation ($F_{(4,1211)} = 14.991$; $p < 0.001$).

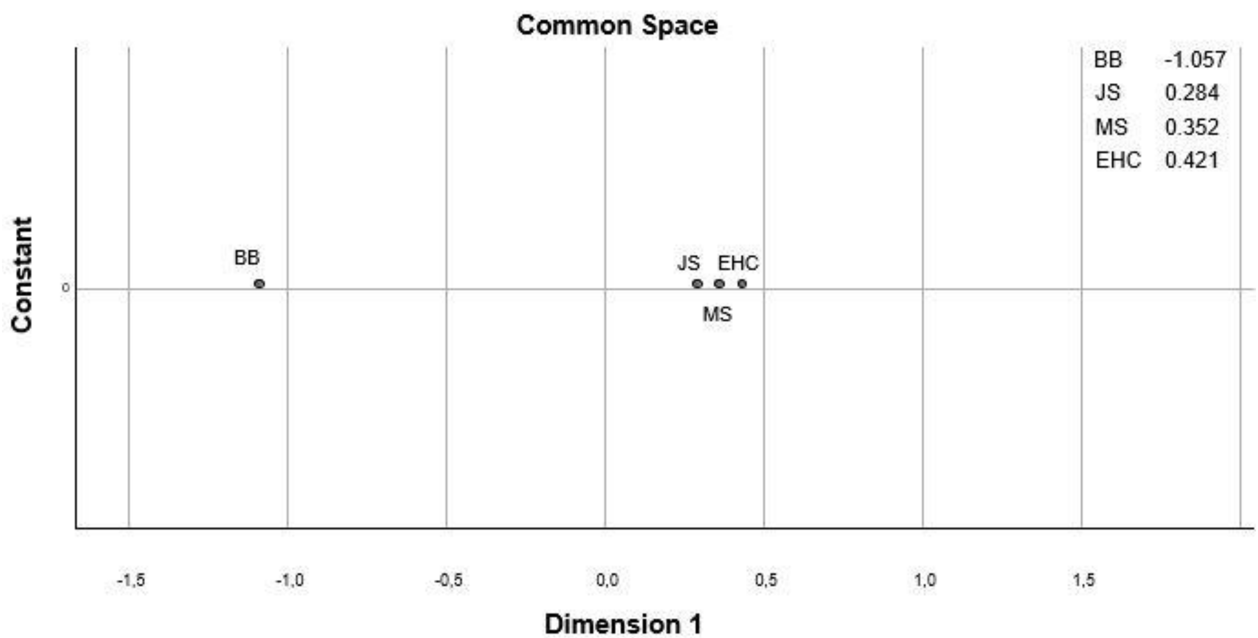


FIGURE 1 - One-dimensional configuration for the four items of the KTK3+ test battery. Dimension 1 represents the geometrical distance between the test items (JS = Jumping Sideways; MS = Moving Sideways; BB = Balancing Backwards; EHC = Eye-Hand coordination) translated as the (dis)similarities between the items, with small distances indicating a high correlation or small dissimilarity and large distances indicating a low correlation or large dissimilarity.

TABLE 2 - Correlations between the four items of the KTK3+ test battery in total and per age group

	MS	BB	EHC
6-7.99 years old			
JS	0.347**	0.538**	0.489**
MS		0.342**	0.268**
BB			0.184**
8-9.99 years old			
JS	0.301**	0.521**	0.615**
MS		0.354**	0.297**
BB			0.242**
10-11.99 years old			
JS	0.375**	0.413**	0.554**
MS		0.466**	0.233**
BB			0.163*
12-13.99 years old			
JS	0.564**	0.450**	0.348**
MS		0.438**	0.182**
BB			0.144*
14-15.99 years old			
JS	0.543**	0.433**	0.463**
MS		0.392**	0.293**
BB			0.216**
16-17.99 years old			
JS	0.569**	0.388**	0.504**
MS		0.291**	0.367**
BB			0.254**
18-19.99 years old			
JS	0.516**	0.372**	0.251**
MS		0.341**	0.178**
BB			0.067
Total			
JS	0.752**	0.584**	0.799**
MS		0.533**	0.695**
BB			0.453**

Univariate sex*age group interaction effects tended to be significant for the JS test and reached significance for the EHC task (p = 0.066 and p = 0.002; respectively). A closer inspection of this interaction showed that boys demonstrated better scores on the JS test and EHC task in each age group compared to girls. However, for the JS test, the difference between boys and girls was greater in older (≥ 16.00 years old) than in younger (< 16.00 years old) age groups. For the EHC test, in contrast, the sex difference became smaller with increasing age. Univariate main effects revealed that girls scored better on the BB test (p = 0.003) when compared to boys. For the MS test, a tendency toward a main effect of sex was observed (p = 0.079), in favour of the boys. Regardless of sex and organized sport participation, a significant increase in test scores was found for each age group on the four test items of the KTK3+ test battery (all p-values < 0.001). Post hoc Bonferroni tests showed differences between all age groups for the JS test, MS test and EHC task. For the BB test, only a significant difference in scores emerged in the younger age groups (i.e., until 10- to 11.99-year-olds), compared to the older age groups (Table 3). Regardless of sex and age group, it was found that children and adolescents who are involved in organized sports performed significantly better on all the KTK3+ test items when compared to peers who are not involved in any organized sports (all p-values < 0.005). Figure 2 displays the differences for the raw scores on all four test items for the total group and according to sex, age groups and organized sport participation.

For the second objective, normative values were established from the collected KTK3+ data in boys and girls aged between 6 and 19 years. Based upon the raw scores of the four test items (i.e., JS, MS, BB, EHC), percentile values at P5, P25, P50, P75 and P90 according to sex and age (per year) were calculated and presented (Table 4). Raw test scores were also converted into standardised values, based on the abovementioned z- and MQ-score formulas. The conversion tables from raw test scores into standardised values can be found in the supplementary material for each sex, age (per year), and KTK3+ test item separately as well as a conversion table to determine the total MQ-score based on the actual gross motor skill performances (see appendix: Table B, C, D, E).

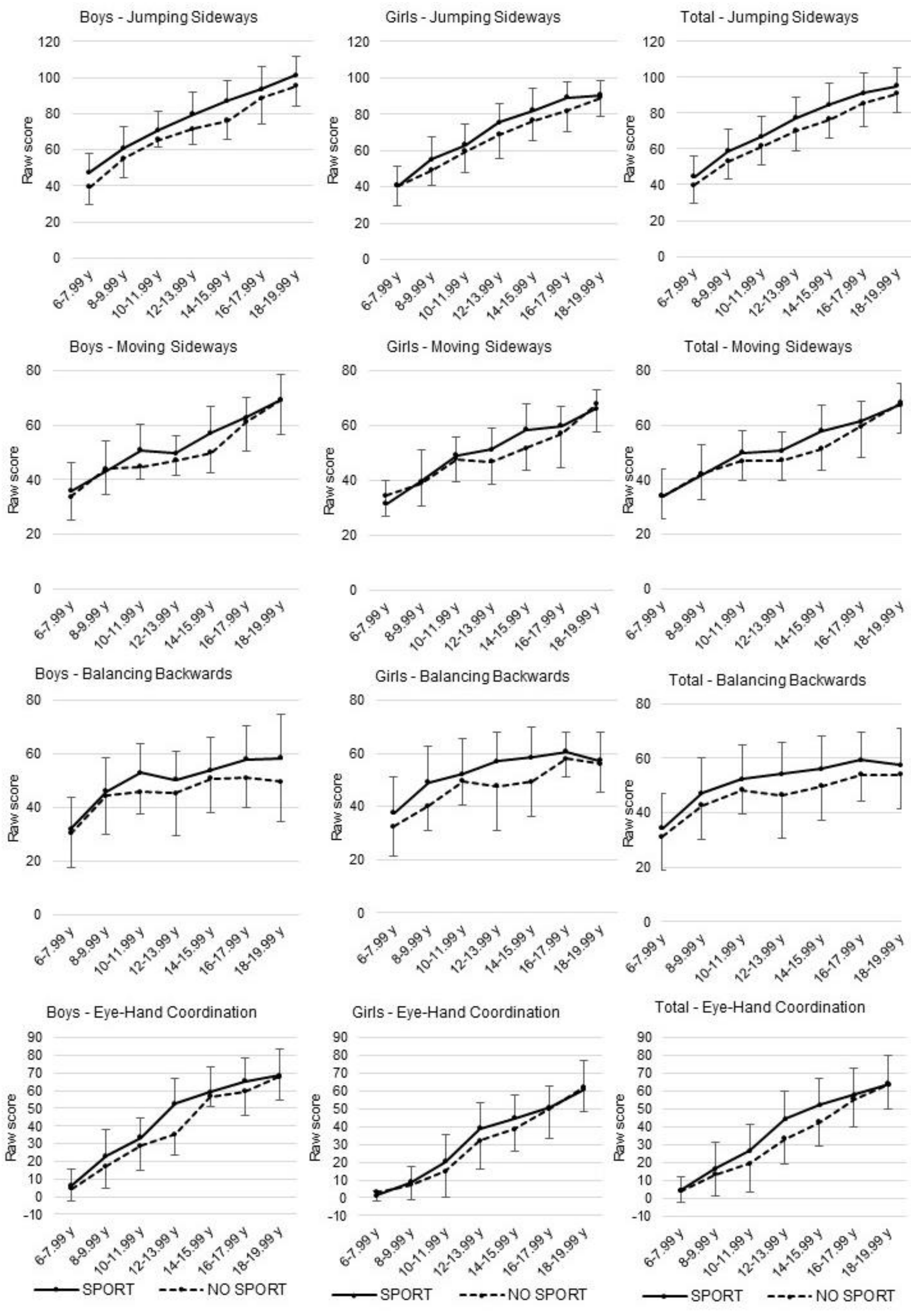


FIGURE 2 - Differences in raw scores on each KTK3+ test item for the total sample and between sex, age groups and organized sport participation.

TABLE 3 - Means and standard deviations (SD) from the raw scores on each KTK3+ test battery for the age categories, with the F, (df), P and partial η^2 values of the MANOVA

Age (years)	6-7.99 mean ± SD	8-9.99 mean ± SD	10-11.99 mean ± SD	12-13.99 mean ± SD	14-15.99 mean ± SD	16-17.99 mean ± SD	18-19.99 mean ± SD	**Sex**	**Age Group**	**Sport**	**Age Group x Sex**	**Age Group x Sport**	**Sex x Sport**	**Age Group x Sport x Sex**
Multivariate								$F = 39.472$ (4; 1211) $p < 0.001$ $\eta^2 = 0.115$	$F = 110.920$ (24; 4225.88) $p < 0.001$ $\eta^2 = 0.347$	$F = 14.991$ (4; 1211) $p < 0.001$ $\eta^2 = 0.047$	$F = 2.085$ (24; 4225.88) $p = 0.001$ $\eta^2 = 0.010$	$F = 1.312$ (24; 4225.88) $p = 0.141$ $\eta^2 = 0.006$	$F = 1.477$ (4; 1211) $p = 0.207$ $\eta^2 = 0.005$	$F = 1.367$ (24; 4225.88) $p = 0.109$ $\eta^2 = 0.007$
JS	43 ± 11 a	58 ± 12 b	66 ± 12 c	75 ± 12 d	83 ± 12 e	90 ± 12 f	93 ± 11 f. g	$F = 468.981$ (1) $p < 0.001$ $\eta^2 = 0.699$	$F = 468.981$ (6) $p < 0.001$ $\eta^2 = 0.699$	$F = 49.358$ (1) $p < 0.001$ $\eta^2 = 0.039$	$F = 1.987$ (6) $p = 0.066$ $\eta^2 = 0.010$	$F = 1.003$ (6) $p = 0.422$ $\eta^2 = 0.005$	$F = 3.466$ (1) $p = 0.063$ $\eta^2 = 0.003$	$F = 0.899$ (6) $p = 0.502$ $\eta^2 = 0.004$
MS	34 ± 9 a	42 ± 11 b	49 ± 8 c	50 ± 7 c. d	57 ± 10 e	61 ± 9 f	67 ± 10 g	$F = 3.087$ (1) $p = 0.079$ $\eta^2 = 0.003$	$F = 275.623$ (6) $p < 0.001$ $\eta^2 = 0.577$	$F = 8.489$ (1) $p = 0.004$ $\eta^2 = 0.007$	$F = 1.356$ (6) $p = 0.229$ $\eta^2 = 0.007$	$F = 2.298$ (6) $p = 0.033$ $\eta^2 = 0.011$	$F = 0.483$ (1) $p = 0.487$ $\eta^2 = 0.000$	$F = 0.630$ (6) $p = 0.706$ $\eta^2 = 0.003$
BB	33 ± 13 a	46 ± 13 b. c	52 ± 12 b. c. d. e. g	52 ± 13 c. d. e. g	55 ± 12 c. d. e. f . g	58 ± 10 e. f. g	56 ± 13 c. d. e. f. g	$F = 8.894$ (1) $p = 0.003$ $\eta^2 = 0.007$	$F = 70.394$ (6) $p < 0.001$ $\eta^2 = 0.258$	$F = 31.84$ (1) $p < 0.001$ $\eta^2 = 0.026$	$F = 0.548$ (6) $p = 0.772$ $\eta^2 = 0.003$	$F = 0.312$ (6) $p = 0.931$ $\eta^2 = 0.002$	$F = 0.033$ (1) $p = 0.857$ $\eta^2 = 0.000$	$F = 2.042$ (6) $p = 0.057$ $\eta^2 = 0.010$
EHC	4 ± 7 a	16 ± 13 b	25 ± 15 c	42 ± 16 d	51 ± 15 e	57 ± 15 f	64 ± 15 g	$F = 105.741$ (1) $p < 0.001$ $\eta^2 = 0.080$	$F = 501.39$ (6) $p < 0.001$ $\eta^2 = 0.712$	$F = 16.584$ (1) $p < 0.001$ $\eta^2 = 0.013$	$F = 3.432$ (6) $p = 0.002$ $\eta^2 = 0.017$	$F = 2.876$ (6) $p = 0.009$ $\eta^2 = 0.014$	$F = 2.442$ (1) $p = 0.118$ $\eta^2 = 0.002$	$F = 0.619$ (6) $p = 0.715$ $\eta^2 = 0.003$

JS = Jumping Sideways ; MS = Moving Sideways ; BB = Balancing Backwards; EHC = Eye-Hand Coordination

[a, b, c, d, e, f, g] : A mean is significantly different from another mean if they have other superscript letters

TABLE 4 - Overview of the raw scores that correspond with the 5th, 25th, 50th, 75th and 95th percentile on each of the four test items of the KTK3+ test battery (JS = jumping sideways; MS = moving sideways; BB = balancing backwards; EHC = eye-hand coordination) according to sex and age (per year)

Age (years)	**6**					**7**					**8**					**9**					**10**				
	P5	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**
JS																									
Boys	26	35	40	45	64	33	43	50	57	66	40	50	56	63	74	39	59	66	72	84	48	61	68	75	84
Girls	20	28	37	44	58	27	36	45	52	61	28	45	56	62	71	38	51	59	66	82	41	57	64	72	89
Total	23	32	39	45	59	31	40	48	55	63	33	47	56	63	72	38	54	62	70	83	46	59	67	74	84
MS																									
Boys	22	31	36	40	47	15	26	38	44	52	19	39	43	49	54	22	42	47	51	58	37	44	48	54	59
Girls	23	29	33	36	43	15	21	36	40	48	21	38	43	47	54	20	36	44	50	56	33	44	50	54	63
Total	24	30	34	39	45	15	24	36	42	51	20	39	43	48	54	21	40	46	50	57	36	44	49	54	60
BB																									
Boys	9	19	27	37	47	17	30	36	44	54	20	34	45	52	60	25	34	46	57	66	26	39	47	56	67
Girls	8	23	33	41	52	20	28	38	48	64	19	39	48	58	66	21	39	47	60	72	20	44	52	59	67
Total	8	20	30	38	50	18	29	37	46	55	20	36	46	53	64	24	38	47	59	68	24	41	49	58	66
EHC																									
Boys	0	0	1	4	20	0	2	5	13	33	0	6	16	30	43	2	11	28	37	50	6	28	34	45	56
Girls	0	0	0	1	4	0	0	1	4	16	0	1	4	8	29	1	4	11	23	33	2	5	14	26	43
Total	0	0	0	2	14	0	0	3	8	28	0	3	9	23	41	1	6	20	32	45	2	9	25	37	50

TABLE 4. (continued)

Age (years)	**11**					**12**					**13**					**14**					**15**				
	P5	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**
JS																									
Boys	53	67	73	83	94	59	70	78	86	103	61	74	80	91	101	63	75	84	90	101	62	77	85	94	106
Girls	50	61	70	76	86	57	66	74	82	96	50	67	74	86	99	57	70	77	84	97	58	71	79	88	101
Total	51	64	71	79	91	58	68	76	83	96	56	70	79	88	100	59	72	80	88	99	61	74	83	91	104
MS																									
Boys	29	45	50	56	65	39	47	52	59	68	40	49	55	58	64	33	49	55	63	72	38	51	56	64	74
Girls	36	46	51	56	63	38	47	51	57	65	31	48	54	60	69	40	49	55	62	71	38	52	58	65	75
Total	35	45	50	56	64	39	47	51	58	65	38	48	54	60	69	39	49	55	62	71	38	52	57	64	74
BB																									
Boys	26	44	54	61	70	26	42	52	60	69	28	41	53	62	70	31	42	55	62	71	24	40	51	60	69
Girls	30	49	55	63	72	32	48	56	65	72	29	43	55	65	72	30	44	55	63	72	36	49	58	65	72
Total	27	46	55	62	71	30	46	55	63	72	29	42	54	63	72	31	44	55	62	72	29	45	53	61	71
EHC																									
Boys	15	29	39	45	52	20	41	45	55	73	20	43	51	57	78	29	44	55	62	73	33	47	56	65	80
Girls	0	10	21	36	52	7	19	30	41	52	17	29	39	53	62	17	31	41	50	65	19	34	42	52	62
Total	3	19	34	44	52	10	22	36	45	59	17	31	49	54	76	20	37	48	58	69	25	39	51	61	76

TABLE 4. (continued)

Age (years)			**16**					**17**					**18**					**19**		
	P5	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**	**P5**	**P25**	**P50**	**P75**	**P95**
JS																				
Boys	64	80	89	100	113	67	86	94	102	115	82	91	99	107	116	69	81	94	105	122
Girls	67	78	85	92	104	65	78	85	90	99	75	84	90	95	106	71	83	88	95	107
Total	67	78	87	97	109	66	81	89	95	109	77	86	92	99	112	70	83	89	99	110
MS																				
Boys	44	54	62	68	79	51	57	62	72	80	52	64	71	76	87	51	59	66	73	90
Girls	45	52	58	64	78	44	54	60	65	75	54	62	67	71	81	55	63	67	72	87
Total	44	53	60	67	77	46	55	61	68	77	52	63	68	73	83	54	61	67	73	87
BB																				
Boys	29	49	57	66	72	30	43	51	60	72	28	45	54	66	72	15	37	50	62	72
Girls	43	53	60	65	72	38	49	58	66	72	30	50	57	67	72	41	47	53	62	72
Total	34	51	59	65	72	36	46	56	63	72	29	49	57	66	72	33	46	53	62	72
EHC																				
Boys	41	52	63	72	88	33	51	62	69	89	43	58	68	78	93	42	59	67	75	91
Girls	25	38	50	57	65	24	38	47	54	64	35	51	59	69	88	43	54	62	76	92
Total	30	45	56	67	87	27	44	52	62	83	38	53	62	73	89	42	56	63	76	91

JS, Jumping Sideways ; MS, Moving Sideways ; BB, Balancing Backwards ; EHC, Eye-Hand Coordination

4 DISCUSSION

The present study evaluated the validity of the combined KTK3+ test battery for evaluating AMC in children and adolescents up to emerging adulthood. First, this study showed an excellent structure validity. Second, our results revealed that the KTK3+ test battery was able to differentiate between gross motor coordination performances according to sex, age groups and organized sport participation. Next to the validation process of this particular assessment tool, normative values were provided for children and adolescents (i.e., for boys and girls separately, aged 6 to 19 years).

The structure validity of the KTK3+ test battery was checked using MDS. By adding the EHC-task (Platvoet et al., 2018) to the KTK3 (Novak et al., 2017), the three motor skill categories (i.e., locomotor skills, object control skills and stability skills) are all addressed in one comprehensive, quick and easy to administer test battery. Although the four test items each assess a slightly different skill category of gross AMC, they indeed all relate to the same, single construct. This outcome was previously found by Platvoet et al. (2018), who used both the KTK3 and EHC-task in 6- to 10-year-old primary school children. The present validation study showed that the combined KTK3+ test battery can also be used to evaluate gross AMC in a wider age range. Furthermore, normative values were provided for sex, age (per year) and each test item separately. However, the normative values provided in the present study are based on raw performance scores. Therefore, conversion tables with standardized values (i.e., MQ scores for each test item as well as the test battery in total) were added as appendices. In this way, the KTK3+ test battery can be used by practitioners and researchers to make a global evaluation of the level of AMC of the target group. Nonetheless, the MQ-scores are not discussed further in this article, because this is beyond the scope of the predetermined research questions.

In agreement with previous research, sex differences emerged on all tests during childhood and (early) adolescence (Barnett et al., 2016; Iivonen & Sääkslahti, 2014; Rodrigues et al., 2019). Our study revealed that boys systematically outperformed girls on three out of the four KTK3+ test items, while girls outperformed boys on the BB test. These findings are consistent with the assumption that sex appears to relate differently to various aspects of gross AMC and can be explained by biological influences on motor development (Barnett et al., 2016). Boys had significantly higher scores than girls on JS, and this difference was even more pronounced among the older age groups. This finding could also be explained by an underlying physical and physiological factor, as Platvoet et al. (2018) already suggested that strength and/or endurance are underlying requirements for a good performance on the JS. When it comes to MS, the mean scores for the boys were also found to be higher than in girls, but this only tended to be a significant effect. This borderline significant finding is in accordance with previous literature, where mixed results are seen when it comes to sex differences in locomotion (Barnett et al., 2010). Due to these sex differences, normative values of the KTK3+ test battery were provided separately for boys and girls at all ages in the present paper, since the differences between sex remained over time or with increasing age, even after puberty.

The significant improvement in AMC with age in the current study, where participants in older age groups scored significantly better than their counterparts in the younger age group(s), is in accordance with the studies of Ahnert et al. (2010) and Vandorpe, Vandendriessche, Lefevre, et al. (2011). Our results are also in line with the findings in the study of Rodrigues et al. (2019) and the systematic review of Barnett et al. (2016), showing a positive relation between age and AMC during and after adolescence. However, in our study the increase in motor performance with age was less pronounced after puberty. Therefore, separate age-related normative values seem warranted for children and adolescents as presented in our supplementary material. It should be noted that a floor effect was observed in the EHC task among the 6- to 7-year-olds. Since a complex spatial-temporal relationship between our visual system and manual motor system is needed to complete the EHC task, it might be that the EHC test is rather challenging for this specific young(er) age groups, which was also observed by Rizzo et al. (2017) and Platvoet et al. (2018). Another possible reason could be the smaller anthropometric measurements of younger children (i.e., hand size and arm length), also complicating ball catching and throwing. The current study only found a plateau effect on the BB task, starting from the age of 12 years, which could indicate that dynamic balance approaches the mature performance level around that age (Largo et al., 2001). However, for both the EHC and BB test variance was still seen between the percentile scales, which is also observable in Table 4.

Since the goal of this paper was to provide normative values validated for older age groups in both sporting and non-sporting populations, the KTK3+ test battery proved to be a highly practical and valuable tool. With this test battery, differences in performance between both groups were examined. Participants who were not involved in any organized sport activities scored systematically lower on all motor tasks included in the KTK3+ test battery when compared to peers who were involved in organized sports on a weekly basis. This difference was seen both in the younger and older age groups, however, the effect size found in this study was relatively low. Previous research has already shown that physical activity, including organized sport participation, has a positive impact on the development of AMC in childhood (Robinson et al., 2015). Additionally, taking into account studies in sports settings that already made use of the KTK3 (Söğüt, 2017; Vandorpe et al., 2012), the combined KTK3+ test battery could even be utilized in talent identification and development environments to detect the high AMC proficient movers, as suggested in the systematic review of O'Brien-Smith et al. (2019).

However, some limitations need to be addressed. First, researchers should be aware that the normative values presented in this study are solely based on a reference sample of Flemish children. Therefore, caution is needed when using these standardized values (MQ-scores) when assessing children elsewhere, given the effect of context and culture on motor development. Future studies should extend upon this, and add normative data from other countries to better understand motor competence on a global scale (i.e., its factorial structure and measurement invariance across groups). Second, this study has a cross-sectional design. Longitudinal and experimental studies should be conducted to gain more insight in the development of motor competence throughout the lifespan. Third, the participation in organized sports was only surveyed in a binary way. Therefore, future research would benefit from also including measurements of type of sport participation, training history, training intensity as well as other forms of PA, such as participation in unorganized sports, active transport, and school-based PA. In addition, exploring psychosocial factors such as socio-economic status and parental support as well as enjoyment could be helpful. Lastly, a floor effect in the EHC task and a plateau effect in the BB task were observed. This is relevant information for researchers using these test protocols within children and adolescent populations.

The present study revealed that the KTK3+ test battery is a valuable and valid tool for assessing AMC as a single construct in children and adolescents from 6- to 19-year-olds. The test battery is able to provide normative values that are sex and age specific and to discriminate gross motor performances between consecutive sex, age groups and organized sport participation. It creates opportunities for practitioners to better meet children's and adolescents individual developmental AMC needs and to evaluate the effectiveness of their own practices. The fact that the KTK3+ test battery can be used in children and adolescents from 6- to 19-year-old makes it a tool of high practical value, especially for the longitudinal follow-up of AMC. The large age range, easy test protocol and quick set up are major strengths of the KTK3+ test battery. In addition, the KTK3+ test battery measures the whole range of gross motor domains, including aspects of balance skills, locomotion and object control skills.

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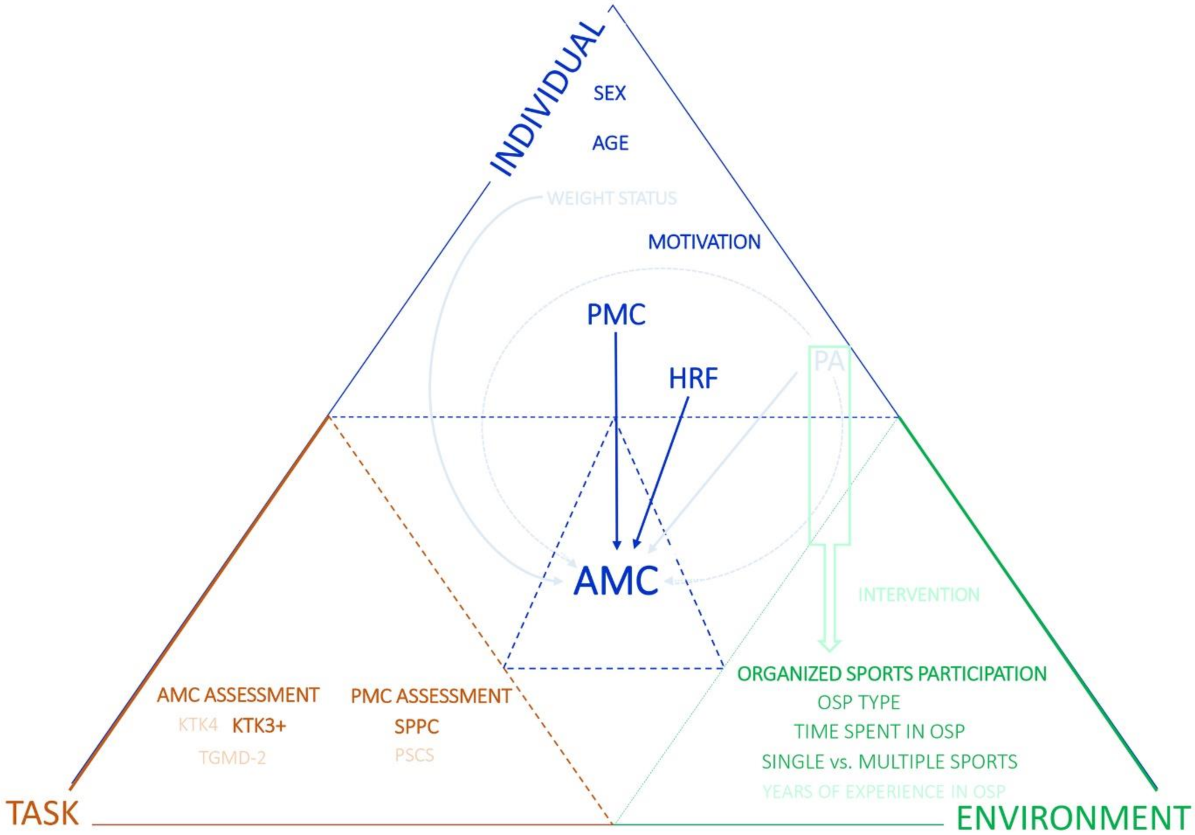
- CHAPTER 4 -

ASSOCIATIONS OF ORGANIZED SPORTS PARTICIPATION FEATURES WITH MOTOR COMPETENCE, PHYSICAL AND PSYCHOSOCIAL OUTCOMES

<u>STUDY 5</u>

FEATURES OF ORGANIZED SPORTS PARTICIPATION: ASSOCIATIONS WITH MOTOR COMPETENCE, CARDIORESPIRATORY FITNESS AND AUTONOMOUS MOTIVATION TOWARD SPORTS



This study is based on **Coppens, E**., Bardid, F., De Meester, A., Deconinck, F. J., De Martelaer, K., Haerens, L., Lenoir, M. & D'Hondt, E. (2021). Features of organized sports participation and children's health: Associations with motor competence, cardiorespiratory fitness and autonomous motivation toward sports. Submitted to *Journal of Sports Sciences*.

ABSTRACT

This study investigated (1) differences in actual motor competence (AMC) and cardiorespiratory fitness between children involved in organized sports and children who are not involved in organized sports. Secondly, it was examined whether features of organized sports participation (OSP) are associated with children's AMC, cardiorespiratory fitness, perceived motor competence (PMC) and autonomous motivation toward sports. OSP features included participation in single or multiple sports at the moment of testing, amount of practice (h/week) and type of sports (locomotor- vs. object control-oriented), considering children's OSP history from the age of 2 years onwards. A total of 346 children (172 boys; M_{age} = 9.77 ± 1.04 years) were assessed using validated measurement tools. A two-way MANCOVA adjusted for age revealed that the OSP group (*n* = 265; 76.6%) significantly outperformed the non-OSP group (*n* = 81; 23.4%) on AMC and cardiorespiratory fitness ($p < 0.001$). No sex differences in AMC were found ($p = 0.129$), whereas boys demonstrated better cardiorespiratory fitness than girls ($p < 0.001$). Within the OSP group, four separate hierarchical multiple regression analyses controlled for age and sex demonstrated that participating in more object control-oriented sports was associated with higher AMC levels ($p < 0.001$). Participation in multiple sports was associated with higher cardiorespiratory fitness ($p = 0.041$) and PMC levels ($p = 0.009$) compared to single sport participation. None of the examined OSP features were significantly related to autonomous motivation toward sports. The present findings indicate that OSP is an important strategy to support children's general development. Moreover, participation in multiple sports, spending more time in OSP and engagement in more object control-oriented sports were associated with better physical and psychosocial outcomes.

1 INTRODUCTION

Organized sports participation (OSP) constitutes an important way to facilitate children's motor skill development (Coppens, Rommers, et al., 2021; Fransen et al., 2012, 2014; Henrique et al., 2016; Vandorpe et al., 2012), and it usually takes place in a club setting (Eime et al., 2013). A sports club provides a stimulating environment to develop actual motor competence (AMC), which refers to the degree of proficiency in performing various motor skills as well as the underlying components such as motor control and coordination (Utesch & Bardid, 2019). In addition to supporting children's motor skill repertoire, sports clubs also provide an ideal setting to develop psychosocial skills (Goodway & Robinson, 2015). One of these outcomes is perceived motor competence (PMC), referring to the self-perception of one's AMC (Harter, 2012). Both AMC and PMC are associated with autonomous motivation toward physical activity, which includes OSP (Bardid et al., 2016; De Meester et al., 2016). Autonomous motivation is considered the most 'optimal form' of motivation, involving the regulation of behavior with the experiences of volition, psychological freedom and reflective self-endorsement (Deci & Ryan, 2000; Vansteenkiste et al., 2010). In this respect, research has shown that organized sports participation (OSP) during early childhood significantly increases the likelihood of continuing OSP in later childhood and adolescence (Henrique et al., 2016).

Children engage in organized sports in different ways. Across childhood, children can be enrolled in one sport or they can participate in multiple sports. In addition, the type of sports being practiced as well as the average weekly amount of time spent in OSP may vary. Interestingly, previous studies that have examined the relationship between OSP and other outcomes of interest, such as AMC, physical fitness, PMC, and motivation, rarely take the abovementioned features into account.

One OSP feature relevant to both physical and psychosocial health-related outcomes is children's participation in a **single sport vs. multiple sports**. Previous research revealed that combining multiple sports decreases dropout rates (Côté et al., 2009), and is positively associated with long-term sports involvement (Côté & Vierimaa, 2014). Yet, the systematic review of Kliethermes and colleagues (2020), involving seven different studies, showed that it remains unclear whether participants who are simultaneously involved in multiple sports demonstrate higher AMC and cardiorespiratory fitness levels when compared to participants who are involved in only one sport. If the included studies reported a difference, it was consistently in favor of the participants involved in multiple sports. For example, participating in multiple sports before the age of 12 years has been found to advance strength and coordination development in boys when compared to those participating in only one sport (Fransen et al., 2012). Another one-year-long longitudinal study in 11- to 12-year-old boys revealed that multiple sports participants displayed higher fitness and AMC levels than those practicing a single sport (Salin et al., 2021). However, the abovementioned studies did not include participants' long-term training history (i.e., over a period of several years), possibly incorrectly assuming little change in children's OSP over the years. Also, none of these studies examined differences in PMC or autonomous motivation toward sports between single and multiple sports participants in childhood. This is important since PMC is shown to be a protective factor against dropout from OSP among children and adolescents (Crane & Temple, 2015).

Another feature of OSP in relation to sports participants' AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports is the **amount of practice** (i.e., the average weekly amount of time spent in OSP), which has been investigated in the longitudinal study of Fransen et al. (2012). Although this study found a positive association between children's (weekly) amount of OSP at the time of measurement and their AMC and cardiorespiratory fitness levels, the study did not examine long-term OSP in preceding childhood years. Therefore, taking children's training history into account could provide a more profound insight into this matter. While the association between OSP and AMC has been investigated in several studies (Coppens, Rommers, et al., 2021; Fransen et al., 2012; Henrique et al., 2016; Vandorpe et al., 2012), few studies took into account the **type of OSP** (Barnett et al., 2013; Coppens, Rommers, et al., 2021), being associated with the dominant type or category of fundamental motor skills being practiced. An Australian study among 3-to 6-year-old children found that swimming was associated with higher levels of locomotor skills than dancing and gymnastics (Barnett et al., 2013). Another study in Belgian 3-to 14-year-olds revealed that children practicing object control-oriented sports displayed a slightly better increase in their AMC over a 6-year developmental timespan when compared to children who were involved in more locomotor-oriented sports (Coppens, Rommers, et al., 2021). Based on the results of these two studies, no general conclusions can be drawn yet regarding the influence of type of sports. However, the importance to specify and further examine the type of sports being practiced across childhood is clear as this OSP feature might affect the association with AMC and its development. In addition, none of the cited studies examined the influence of type of sports on children's level of PMC or autonomous motivation toward sports.

Taking part in organized sports is important for developing both motor and psychosocial skills (Goodway & Robinson, 2015). However, further research is required to determine the significance of OSP and its features that contribute most optimally to this. Hence, the present study investigated differences in AMC and cardiorespiratory fitness between children participating in organized sports and those not participating in organized sports. Based on previous studies, it was hypothesized that the OSP group would outperform the non-OSP group on both outcomes (De Meester et al., 2020; Drenowatz & Greier, 2019; Fransen et al., 2014; Vandorpe et al., 2012). The second and most central aim of this study was to examine if OSP features were associated with several physical (i.e., AMC and cardiorespiratory fitness) and psychosocial (i.e., PMC and autonomous motivation toward organized sport) outcomes. To this end, we explored the influence of three specific features (i.e., single sport vs. multiple sports participation, average weekly amount of practice across childhood, type of sports practiced across childhood) on four different outcome measures of interest (i.e., AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports). Regarding AMC and cardiorespiratory fitness, we hypothesized higher scores in children participating in multiple sports compared to their single sport counterparts (Fransen et al., 2012; Salin et al., 2021). Weekly amount of sports participation was expected to be positively associated with AMC and cardiorespiratory fitness (Fransen et al., 2012, 2014). Additionally, children engaging in more object control-oriented sports were expected to score higher on these outcomes compared to those in more locomotor-oriented sports (Coppens, Rommers, et al., 2021). Regarding children's PMC and autonomous motivation, it was also hypothesized that participation in multiple sports would increase the likelihood for children to find and engage in a sport that they are/feel competent in (PMC) and that they truly enjoy (autonomous motivation) when compared to single sport participants. It was also hypothesized that a larger weekly amount of practice in OSP across childhood would be associated with higher PMC levels and more autonomous motivation to engage in organized sports (De Meester, 2017). Given the lack of existing evidence on type of sports and its link with cardiorespiratory fitness, PMC and autonomous motivation, no specific hypotheses were formulated for these outcomes.

2 METHODS

2.1 Participants and procedures

For the present study, 13 Flemish sports federations were invited to collaborate, of which six sports federations agreed to participate. Each of these collaborating sports federations designated specific organized sports clubs (*N* = 12 in total) and asked consent to participate in the current study with their 8- to 12-year-old members. Children not being enrolled in any OSP were recruited from seven geographically spread elementary schools in East and West Flanders (Belgium). This combined approach resulted in a convenience sample of 346 children (172 boys) with a mean age of 9.77 years (SD = 1.04, range 7.54 to 12.00 years), all of whom agreed to participate in the current study.

Within this total sample, 265 children (76.6%, 133 boys) participated in organized sports (i.e., the OSP group), including 127 of them (36.7% of the total sample, 70 boys) participating in one sport and 138 of them (39.9% of the total sample, 63 boys) participating in multiple sports. The remaining 81 participants (23.4% of the total sample, 39 boys) were not enrolled in any form of OSP (i.e., non-OSP group). All participants were based in Flanders (Belgium). Since all participants were minors, their parent(s) or legal guardian provided written informed consent. The study protocol was approved by the Ethics Committee of Ghent University Hospital.

Data collection took place between August 2019 and March 2020, and was conducted in the children's respective sports clubs or schools. Participants wore light sports clothing and were barefooted to ensure uniformity of test conditions. Each participant completed an AMC test battery and a cardiovascular fitness test, which together took approximately 30 minutes for each participant. In the sports club, a questionnaire assessing children's PMC and autonomous motivation toward sports was also filled out, which took approximately 15 minutes for each participant to complete. An additional questionnaire was sent by e-mail to the parent(s) or legal guardian of the OSP group (*n* = 265), including questions on the child's present engagement in organized sports activities and their OSP history (see below for more detail). Eventually, 100 parental questionnaires were completed, resulting in a 37.7% response rate within the OSP group.[1]

2.2 Measurements

Actual Motor Competence. To evaluate children's AMC, we used the short form of the KörperkoordinationsTest für Kinder (KTK3; Novak et al., 2017), supplemented with a ball catching and throwing task to assess eye-hand coordination (EHC; Platvoet et al., 2018), resulting in the KTK3+ (Coppens, Laureys, et al., 2021). A recently published study indicated that the correlations between these four subtests ranged from moderate to very good (r = 0.453 – 0.799), reflecting the one-dimensional structure of the KTK3+ test battery (Coppens, Laureys, et al., 2021). Participants were given a practice trial before performing each of the actual test items and they were asked to perform each subtest at their best. The KTK3+ consists of (1) balancing backwards with three trials on each of three different balance beams (6.0cm - 4.5cm - 3.0cm), (2) moving sideways on a straight line, handling two wooden platforms for 20 seconds, (3) jumping sideways as fast as possible with two feet over a wooden slat for 15 seconds, and (4) controlling a tennis ball while conducting repetitive movements (i.e., throwing with one hand and catching with the other hand, followed by the reverse sequence) as frequently as possible in 30 seconds. The raw scores of all four KTK3+ subtests were converted into standardized scores adjusted for age and sex. These standardized scores were then summed to compute an overall motor quotient (MQ), using the KTK3+ manual's normative tables based on the performance of a large Flemish reference sample (Coppens, Laureys, et al., 2021).

Cardiorespiratory fitness. Cardiorespiratory fitness was assessed using the multistage aerobic capacity test, also known as the PACER or EUROFIT 20 meter shuttle run test (20m SR; Léger et al., 1984). The 20m SR test is widely used and has a moderate-to-high mean criterion-related validity for estimating cardiorespiratory fitness (r values = 0.66 - 0.84; Mayorga-Vega et al., 2015). In addition, this physical test has shown good to excellent test-retest reliability in 9-to 18-year old boys (ICC = 0.79) and girls (ICC = 0.90) with different sports backgrounds

[1] *It should be noted that data collection was impacted by the COVID-19 pandemic. In view of the study focus and due to logistic constraints (e.g., school and sports club closures), the original research plan was amended to focus on OSP and to limit data collection in the non-OSP group to AMC and cardiorespiratory fitness.*

(Henriques-Neto et al., 2020). In the 20m SR test, children run continuously back and forth between two lines that are 20 m apart, with recorded beeps determining the pace. The frequency of the sound signals gradually increases during this test, requiring children to run faster with each increase frequency of signals (i.e., an increase of 0.5 km/h each minute from a starting speed of 8.5 km/h). The test is stopped if the subject can no longer keep the pace and failed to reach the line (within 2 meters) for two consecutive times after a verbal warning. The completed time, registered with an accuracy of 0.5 min, was used in the analyses as an indicator of the participants' cardiorespiratory fitness.

Perceived Motor Competence. The sport/athletic competence subscale of the Dutch version of the Self-Perception Profile for Children (SPPC; Harter, 2012) was used to assess participants' perceptions of their ability to play sports within the OSP group. The SPCC is validated in 8- to 13-year-old children and the internal consistency reliability of the sport/athletic competence subscale is found to be high ($0.76 \leq r \leq 0.91$; Harter, 2012). The response categories for each of the six items of the sport/athletic competence subscale consist of a four-choice structured alternative format. The child was first asked to decide with which kind of child he or she identified the most: the one(s) described in the first part of the sentence or the one(s) described in the second part of the sentence (e.g., *"Some children do very well at all kinds of sports BUT other children don't feel that they are very good when it comes to sports."*). Subsequently, the child decided whether the chosen description was "*really true*" or "*sort of true*" for them personally. Accordingly, each item was scored from 1 (i.e., lowest level of PMC) to 4 (i.e., highest level of PMC). Finally, participants' PMC subscore (ranging from 1 to 4) was determined by calculating the average score across the six items (Harter, 2012).

Autonomous motivation toward sports. In the OSP sample, children's motivation toward sports was assessed using an age-adapted version of the Behavioral Regulation in Exercise Questionnaire (BREQ; Sebire et al., 2013), which has been validated in previous research among 7- to 11-year-old children. The adapted BREQ consists of 12 questions regarding autonomous and controlled motivation. Only the six items regarding autonomous motivation (Cronbach's α = 0.67) were analyzed for the purpose of the current study. Each of these six items started with the stem *"I participate in organized sports because…"* and measured one of the two sub-regulations of autonomous motivation. That is, identified regulation (e.g., *"I participate in organized sports because it is important for me to participate in organized sports."*) and intrinsic motivation (e.g., *"I participate in organized sports because participating in organized sports is fun."*). Each item was scored on a 5-point Likert scale, ranging from "*not true for me*" (= 1) to "*very true for me*" (= 5). Participants' autonomous motivation score (ranging from 1 to 5) was determined by calculating each individual's average score of both the identified regulation (3 items) and intrinsic regulation (3 items) subscale of the adapted BREQ (Sebire et al., 2013).

Organized sports participation. The parent(s) or legal guardian of the children in the OSP group were asked to complete a questionnaire, including questions on their child's present engagement in organized sports activities as well as his/her sports history (i.e., average weekly hours of participation in organized sports, types of organized sports practiced across childhood). Regarding the average weekly amount of OSP, three questions were answered for each year of life, starting at the age of two years up to the current age of the child (with a maximum of 12 years of age for this study): (1) *"Did your child participate in organized sports when he/she was X years old?"*; (2) "*Which organized sports did your child practice when he/she was X years old?"*; (3) *"As an X-year-old child, how many hours per week in total did your child practice these organized sports activities during a regular week?"*. The average weekly hours of OSP across childhood was then calculated using the following formula:

$$Mean\ value = \frac{(average\ hours\ per\ week\ in\ OSP\ at\ age\ 2 + \cdots + average\ hours\ in\ OSP\ per\ week\ at\ current\ age)}{(current\ age - 1)}$$

The aforementioned questions were also used to determine if a child was enrolled in only one sport or involved in more than one sport at the moment of testing, resulting in two possible allocation categories: single sports vs. multiple sports participation.

To determine the children's type of sports (i.e., locomotor-oriented vs. object control-oriented) being practiced across childhood, we calculated a sports type index using the same approach as Coppens, Rommers, et. al., (2021). This sports type index is an expert determined value ranging between -1 and +1, indicating whether a sport is predominantly locomotor-oriented (i.e., a score closer to -1) or predominantly object control-oriented (i.e., a score closer to +1; see p.89). Reliability (κ = 0.428, 95% CI [0.428 - 0.429]; $p < 0.001$) and face validity of this method was previously determined (Coppens, Rommers, et al., 2021). For the current study, the sports type index was first calculated separately for each year of life, starting at the age of two years up to the current age of the child (again with a maximum of 12 years of age for this study). For a particular year X during which the child engaged in 'n' sports, the equation is as follows:

$$Sports\ type\ index\ (year\ X) = \frac{(value\ of\ sports\ 1\ +\ value\ of\ sports\ 2\ +\ \dots +\ value\ of\ sports\ n)}{n}$$

Next, after calculating this weighted average per year of life, a weighted average across each individual child's lifespan was calculated, starting at the age of 2 years up to the current age of the child (with a maximum of 12 years), resulting in an overall sports type index:

$$Overall\ sports\ type\ index = \frac{Sports\ type\ index\ (age\ 2) + Sports\ type\ index\ (age\ 3) + \cdots + Sports\ type\ index\ (current\ age)}{current\ age - 1}$$

2.3 Statistical Analyses

All statistical analyses were performed using IBM SPSS 27 statistics (IBM Corporation. Armonk. NY. USA). The significance level was set at 0.05. First, a two-way MANCOVA - with age included as a covariate - was used to examine (non-)OSP group and sex differences in AMC and cardiorespiratory fitness. Estimated marginal means were compared using the Bonferroni pairwise comparison method. Partial eta square effect sizes were also reported. Secondly, within the OSP group, four separate hierarchical multiple regression analyses were conducted to examine the predictive value of OSP features (i.e., single sport vs. multiple sports, average weekly amount of OSP across childhood, type of sports across childhood) on AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports. In each of these regression models, age and sex (dummy coded as 0 = boy and 1 = girl) were added as covariates as a first step (i.e., Model 1). Next, single sport vs. multiple sport participation was entered as the ad hoc measurement of OSP (i.e., Model 2). Taking into account the children's training history across childhood, the average weekly amount of OSP was then added (i.e., Model 3), followed by the type of sports (i.e., locomotor- vs. object control-oriented; Model 4). Assumptions were tested and Cohen's f^2 effect sizes (Selya et al., 2012) were also reported.

3 RESULTS

3.1 Descriptive statistics

Table 1 represents the means and standard deviations of participants' age, their scores on the outcome measures of interest (i.e., AMC, cardiorespiratory fitness, PMC, autonomous motivation toward sports), and the different features of their OSP (i.e., single sport vs. multiple sports, weekly amount of OSP and type of sports practiced across childhood).

TABLE 1 - Means and standard deviations of age, the predefined outcomes and the OSP features of interest.

	OSP group	Non-OSP group
Age (years)	9.82 ± 0.98	9.57 ± 1.19
Ratio boys-girls (n)	172-174	39-42
Outcomes		
Actual motor competence *(MQKTK3+)*	105.67 ± 10.38	96.92 ± 10.77
Cardiorespiratory fitness *(20m SR, in min)*	5.02 ± 1.76	3.77 ± 1.56
Perceived motor competence *(scale 1-4)*	2.94 ± 0.44	
Autonomous motivation toward sports *(scale 1-5)*	4.52 ± 0.49	
OSP features	(*n* = 100)	
Single sport vs multiple sports *(scale 0-1, respectively)*	0.51 ± 0.50	
Weekly amount of practice *(h/week)*	2.49 ± 0.99	
Type of sports practiced (locomotor-oriented vs. object control-oriented) *(scale -1 to +1, respectively)*	-0.28 ± 0.44	

MQKTK3+: Motor quotient of the KörperkoordinationsTest für Kinder with eye-hand coordination task; 20m SR: 20 meter Shuttle Run; OSP: Organized sports participation.

3.2 Differences in AMC and cardiorespiratory fitness according to OSP group and sex

After controlling for age ($p < 0.001$) at the multivariate level, no significant group by sex interaction was found ($p = 0.982$). However, a significant main effect of both group ($p < 0.001$) and sex ($p < 0.001$) was observed (Table 2). At the univariate level, significant group differences (i.e., OSP vs. non-OSP group) were found for MQKTK3+ ($p < 0.001$) and the 20m SR ($p < 0.001$). Bonferroni pairwise comparisons of the estimated marginal means revealed that the OSP group significantly outperformed the non-OSP group on both outcomes ($p < 0.001$). With respect to the main effect of sex, no differences were found for MQKTK3+ ($p = 0.106$), whereas boys significantly outperformed girls on the 20m SR test ($p < 0.001$).

TABLE 2 - Estimated marginal means and standard errors (SE) for actual motor competence and cardiorespiratory fitness according to (non-)OSP group and sex, combined with the F (df), p and partial η² values of the two-way MANCOVA, adjusted for age.

	OSP group (n = 265)	Non-OSP group (n = 81)	Boys (n = 172)	Girls (n = 174)	Age (covariate)	Group	Sex	Group x Sex
Multivariate								
					F = 13.041 (2, 341) $p < 0.001$ $\eta^2 = 0.071$	F = 27.920 (2, 341) $p < 0.001$ $\eta^2 = 0.141$	F = 31.324 (2, 341) $p < 0.001$ $\eta^2 = 0.155$	F = 0.018 (2, 340) $p = 0.982$ $\eta^2 < 0.001$
Univariate								
MQKTK3+	105.67 ± .64	96.81 ± 1.17	100.16 ± .95	102.31 ± .93	F = 0.644 (1, 342) $p = 0.423$ $\eta^2 = 0.002$	F = 44.386 (1, 342) $p < 0.001$ $\eta^2 = 0.115$	F = 3.991 (1, 342) $p = 0.097$ $\eta^2 = 0.012$	F = 0.017 (1, 341) $p = 0.895$ $\eta^2 < 0.001$
20m SR (min)	5.00 ± .10	3.86 ± .18	4.98 ± .15	3.88 ± .14	F = 19.153 (1, 342) $p < 0.001$ $\eta^2 = 0.053$	F = 32.124 (1, 342) $p < 0.001$ $\eta^2 = 0.086$	F = 40.355 (1, 342) $p < 0.001$ $\eta^2 = 0.106$	F = 0.032 (1, 341) $p = 0.859$ $\eta^2 < 0.001$

MQKTK3+: Motor quotient of the KörperkoordinationsTest für Kinder with eye-hand coordination task; 20m SR: 20 meter Shuttle Run; OSP: Organized Sports Participation.

3.3 OSP features affecting AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports

Assumptions were tested for all regression models (i.e., one for each outcome measure of interest). There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. Independence of residuals was found, as assessed by a Durbin-Watson statistic of 2.126 for MQKTK, 1.846 for 20m shuttle run, 2.238 for PMC, and 1896 for autonomous motivation towards OSP. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. No evidence of multicollinearity was found, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, no leverage values greater than 0.2, and values for Cook's distance above 1. The assumption of normality was met, as assessed by a Q-Q Plot.

The hierarchical multiple regression analyses revealed that adding the covariates age and sex at stage one (i.e., Model 1) did not significantly improve the regression model (p = 0.821), only accounting for 0.4% of the variation in MQKTK3+. The addition of single sports vs. multiple sports (i.e., Model 2) did not lead to a statistically significant increase in R^2 either (i.e., 0.5%, p = 0.508, Cohen's f^2 = 0.005). However, the addition of the OSP feature average weekly amount of OSP across childhood (i.e., Model 3) led to a statistically significant increase in R^2 of 7.0% (p = 0.008, Cohen's f^2 = 0.081). Moreover, the addition of type of sports (i.e., locomotor-oriented vs. object control-oriented; Model 4) also led to a statistically significant increase in R^2 of 7.5% (p = 0.005, Cohen's f^2 = 0.177). When all independent variables were included in this fourth and final stage of the regression model, two OSP features significantly predicted MQKTK3+. The type of sports being practiced across childhood was the most important predictor (p = 0.005) and uniquely explained 7.6% of the variation in MQKTK3+ (i.e., based on the squared semi-partial correlation), with participation in more object control-oriented sports being associated with higher MQKTK3+ levels. The weekly amount of practice was also a significant predictor (p = 0.047) and uniquely explained 3.6% of the variation in MQKTK3+, with spending more time in OSP being associated with higher MQ KTK3+ levels. In total, the full model was statistically significant (p = 0.007), and accounted for 15.4% of the variance in MQKTK3+.

With respect to **20m SR**, adding the covariates age and sex at stage one (i.e., Model 1) significantly improved the regression model ($p < 0.001$) and accounted for 23.1% of the variation. The addition of single sports vs. multiple sports (i.e., Model 2) also led to a statistically significant increase in R^2 and accounted for 3.3% of the variation in 20m SR ($p = 0.042$, Cohen's $f^2 = 0.043$). However, the addition of the feature average weekly amount of OSP across childhood (i.e., Model 3) did not lead to a further statistically significant increase in R^2 (i.e., 0.2%, $p = 0.632$, Cohen's $f^2 = 0.046$). The addition of type of sports (i.e., locomotor-oriented vs. object control-oriented; Model 4) did lead to an increase in R^2 of 2.5%, but did not contribute significantly ($p = 0.070$, Cohen's $f^2 = 0.086$). When all independent variables were included in the fourth and final stage of the regression model, the only significant OSP predictor of the 20m SR was found to be single sports vs. multiple sports ($p < 0.041$), which uniquely explained 3.1% of the variance in this particular outcome (i.e., based on the squared semi-partial correlation), with multiple sports participation being associated with higher levels of cardiorespiratory fitness compared to single sports participation. The full model was also statistically significant ($p < 0.001$), and accounted for 29.1% of the variance in 20m SR (see Table 3A).

Regarding **PMC**, adding the covariates at stage one (i.e., Model 1) significantly improved the regression model ($p = 0.017$) and accounted for 8.1% of the variation in this outcome. The addition of OSP group (i.e., single sports vs. multiple sports; Model 2) did also lead to a statistically significant increase in R^2 and accounted for 7.0% of the variation in PMC ($p = 0.006$, Cohen's $f^2 = 0.082$). However, the addition of the feature average weekly amount of OSP across childhood (i.e., Model 3) did not lead to a statistically significant increase in R^2 (i.e., 0.4%; $p = 0.520$, Cohen's $f^2 = 0.086$), nor did the addition of type of sports (i.e., locomotor-oriented vs. object control-oriented; Model 4; R^2 change < .001, $p = 0.888$, Cohen's $f^2 = 0.088$). When all independent variables were included in this fourth and final stage of the regression model, the most important and only significant OSP predictor of PMC was found to be participating in a single sport vs. multiple sports ($p = 0.011$), which uniquely explained 6.2% of the variation in PMC (i.e., based on the squared semi-partial correlation), with multiple sports participation being associated with a higher level of PMC compared to single sport participation. The full model was also statistically significant ($p = 0.007$), and accounted for 15.5% of the variance in PMC.

The full model of the covariates and the three OSP features in order to explain variance in **autonomous motivation toward sports** was not found to be statistically significant (p = 0.247), indicating no good model fit for the data (see Table 3B).

TABLE 3A - Results of the hierarchical multiple regression for actual motor competence (AMC) and cardiorespiratory fitness.

AMC	Model 1			Model 2			Model 3			Model 4		
	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Constant	101.243***	10.21		101.026***	10.248		91.784***	10.505		94.034***	10.1	
Age	.534	1.030	.053	.492	1.035	.049	.745	1.007	.074	.734	.970	.073
Sex	- .583	1.928	- .031	- .620	1.93	-.033	.833	1.951	.044	4.256	2.22	.225
Single/Multi				1.272	1.915	.068	.330	1.888	.018	.510	1.82	.027
Weekly hours							2.652**	.984	.281	1.966*	.977	.208
Type Sports										7.311**	2.52	.347
R^2	.004			.009			.079			.154		
F	.198			.278			2.037			3.432**		
ΔR^2	.004			.005			.070			.075		
ΔF	.198			.441			7.260**			8.380**		
Fitness	Model 1			Model 2			Model 3			Model 4		
	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Constant	.773	1.762		.659	1.734		.370	1.842		.627	1.82	
Age	.502**	.178	.253	.480**	.175	.242	.488**	.177	.246	.486**	.174	.245
Sex	-1.428***	.333	-.384	-1.447***	.327	-.389	-1.402***	.342	-.377	-1.012**	.399	-.272
Single/Multi				.668*	.324	.181	.638	.331	.173	.659*	.327	.179
Weekly hours							.083	.173	.045	.005	.176	.003
Type Sports										.833	.454	.201
R^2	.231			.263			.265			.291		
F	14.549***			11.440***			8.569***			7.700***		
ΔR^2	.231			.033			.002			.025		
ΔF	14.549***			4.248*			.231			3.369		

Note: N = 100; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

TABLE 3B - Results of the hierarchical multiple regression for perceived motor competence (PMC) and autonomous motivation toward sports.

PMC	Model 1			Model 2			Model 3			Model 4		
	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Constant	2.492***	.437		2.455***	.422		2.360***	.448		2.355***	.452	
Age	.062	.044	.138	.055	.043	.122	.057	.043	.127	.057	.043	.127
Sex	-.199*	.082	-.236	-.205*	.080	-.243	-.190*	.083	-.226	-.198*	.099	-.235
Single/Multi				.222**	.079	.265	.212*	.081	.253	.211*	.081	.253
Weekly hours							.027	.042	.064	.029	.043	.068
Type Sports										-.016	.112	-.017
R^2	.081			.151			.154			.155		
F	4.278*			5.681**			4.339**			3.440**		
ΔR^2	.0081			.070			.004			< .000		
ΔF	4.278*			7.879**			.418			.020		
Motivation	Model 1			Model 2			Model 3			Model 4		
	B	SE B	β	B	SE B	β	B	SE B	β	B	SE B	β
Constant	5.282***	.559		5.275***	.562		5.317***	.597		5.404***	.590	
Age	-.068	.056	-.122	-.070	.057	-.124	-.071	.057	-.126	-.071	.056	-.127
Sex	-.134	.106	-.128	-.135	.106	-.129	-.142	.111	-.135	-.009	.129	-.008
Single/Multi				.042	.105	.040	.046	.107	.044	.053	.106	.051
Weekly hours							-.012	.056	-.023	-.039	.057	-.074
Type Sports										.285	.147	.244
R^2	.028			.030			.030			.067		
F	.251			.406			.568			.247		
ΔR^2	.028			.002			< .001			.0237		
ΔF	1.402			.159			.047			3.752		

Note: N = 100; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

4 DISCUSSION

A first aim of this study was to confirm findings of prior research regarding the benefits of participating in organized sports in terms of 8- to 12-year-old children's AMC and cardiorespiratory fitness levels. The second and more central aim of the current study was to examine to what extent different OSP features (i.e., single sport vs. multiple sports participation, average weekly amount of OSP across childhood and type of sports being practiced) are associated with physical and psychosocial outcomes (i.e., AMC, cardiorespiratory fitness, PMC and autonomous motivation toward sports), accounting for children's age and sex. Two of these three OSP features also took children's training history into account from the age of 2 years up to the current age of the child (i.e., type of OSP and average weekly amount of practice in OSP across childhood), while single sport vs. multiple sports participation was an ad hoc measurement.

The OSP group significantly outperformed the non-OSP group regarding AMC and cardiorespiratory fitness, which is consistent with results from previous research (Drenowatz & Greier, 2019; Fransen et al., 2012; Vandorpe et al., 2012). OSP is thus demonstrated to be positively associated with children's AMC and cardiorespiratory fitness, which is in agreement with the positive spiral of engagement in physical activity, as described by Stodden and colleagues (2008).
In the current study, no sex differences emerged with respect to children's AMC levels, which is not surprising since standardized scores adjusted for age and sex were used. For this, normative values were used from a recent large-scale KTK3+ validation study in 6- to 19-year-olds (Coppens, Laureys, et al., 2021). The latter study revealed that, when using raw scores, boys significantly outperformed girls on three KTK3+ test items (i.e., MS, JS, EHC), while girls outperformed boys on BB. It is also possible that sex differences become less pronounced when children participate in organized sports (Queiroz et al., 2014), which might explain why we did not find differences in MQKTK3+ between boys and girls in the current study.

Regarding cardiorespiratory fitness, boys outperformed girls on the 20m SR, which is consistent with the international normative 20m SR values based on data of over a million children representing 50 countries (Tomkinson et al., 2017). The normative data show that boys consistently outperformed girls at every age between 9 and 17 years. The sex-related differences were even more pronounced among the older age groups with boys experiencing larger age-related changes than girls, which is typically attributed to growth and maturation (Malina et al., 2004). While in the current study MQs were used for AMC, no standardized scores adjusted for age and sex could be used for cardiorespiratory fitness. This was also evident form the hierarchical multiple regression, revealing that age and sex accounted for 23.1% of the variance in the full model of this particular outcome (i.e., 29.1%). Accordingly, being a boy and being older were found to be factors associated with higher levels of cardiorespiratory fitness, which is in line with the findings of Fransen et al. (2014).

The present study also found that some OSP features showed greater physical and psychosocial benefits compared to others. One of these features was participation in **single sports vs. multiple sports**. Children who were involved in multiple sports at the moment of data collection reached higher cardiorespiratory fitness levels, but such an advantage was not found in view of their AMC levels. It is not surprising that the results of our study regarding this particular OSP feature were not straightforward since a recently published review also revealed inconclusive findings (Kliethermes et al., 2020). In this review, differences also tended to be in favor of participants involved in multiple sports, yet both for physical fitness and AMC, while we only found differences for fitness. Additionally, two recent studies not included in the latter review also investigated differences in physical fitness and AMC between single sport and multiple sports participation (Popović et al., 2020; Salin et al., 2021). In line with the review findings, the first study found evidence for multiple sports participation to be advantageous for both health-related fitness and AMC, yet only in boys and not in girls (Salin et al., 2021). However, the AMC assessment tool was a catching and throwing task, perhaps one of the reasons why Salin et al. (2021) could only confirm the positive effect in boys, since boys seems to be more involved in object control-oriented tasks compared to girls (Barnett et al., 2016; Bolger et al., 2021).The second study used similar assessment tools as those applied in the current study but found opposite results, with multisport participation being associated with higher AMC but not with higher cardiorespiratory fitness in a sample of 8-year-old children (Popović et al., 2020). However, when compared to our study, the term 'multisport' was operationalized in a different manner in the above study (i.e., indoor exercise program in a fully equipped gym - combined with one swimming session - each week being focused on one of the three fundamental motor skill categories: locomotion, object control, and stability skills). Also their single sport participants were all soccer players, which is also different than our single sport participants representing different disciplines within the OSP group (i.e., soccer, hockey, gymnastics and swimming). Together, these findings highlight that the effect of OSP on physical outcomes (i.e., AMC and cardiorespiratory fitness) may also depend on the measures of AMC being used and the nature of the multi- and single sports being examined (Barnett et al., 2013; Henrique et al., 2016). The other study found evidence for multiple sports participation to be advantageous toward health-related fitness and AMC (Salin et al., 2021). Furthermore, the relation between higher cardiorespiratory fitness and combining multiple sports in the present study does not indicate a particular causal direction. It may be that children have a higher fitness level due to participating in multiple sports, but it may well be that their fitness levels allow them to better cope with new and challenging environments of different (multiple) sport contexts.

Our results also revealed that being involved in multiple sports was related to higher PMC levels when compared to children participating in a single sport. To the best of our knowledge, no previous studies have investigated the association between this OSP feature and children's PMC. However, according to Côté et al. (2009) and Côté & Vierimaa (2014), children who combine multiple sports will gain psychosocial benefits, such as developing a healthy identity, which may affect how they perceive themselves. In addition, being involved in a single sport rather limits children's interaction to the peer group within the context of OSP. Since peers are an important source of information to develop accurate PMC (True et al., 2017), it might be beneficial to have diverse peer groups to assess oneself against. Moreover, the PMC tool that was used in the present study (i.e., the SPPC; Harter, 2012) explicitly asks children to compare themselves to other children. It is possible that children who are involved in only one sport compare themselves with their (most likely very skilled) sports team mates, while children involved in multiple sports, use different frames of reference and as such perceive themselves as being below average.

As noted by Barnett et al. (2013) and Henrique et al. (2016), the effect of sports participation on AMC development may depend on the **type of sports**. Indeed, our results revealed that the type of sports being practiced across childhood is a crucially important OSP feature for children's level of AMC. Indeed, children participating in more object control-oriented sports scored higher on AMC when compared to those involved in more locomotor-oriented sports, which is in line with previous findings reported by Coppens, Rommers, et al. (2021). It is possible that object control-oriented sports, like field hockey, may provide more opportunities to develop both object control and locomotor skills compared to predominantly locomotor-oriented sports, like dancing. This assumption is in line with our results on the overall sports type index, where the calculations within this sample ranged between -0.9 to +0.3, indicating less extreme values to the object control side of this continuum. Moreover, earlier studies demonstrated an advantage of object control skill over locomotor skill development in childhood due to continued and more varied participation in sports and games (Barnett et al., 2011; Stodden et al., 2014). The importance of object control skills is further highlighted by the study of Barnett et al. (2009), which demonstrated that competence in object control skills during childhood significantly predict physical activity levels during adolescence. Notwithstanding, the systematic review of Bolger et al. (2021) revealed that with (increasing) age children consistently exhibited higher levels of locomotor skills compared to object control skills, indicating that greater instruction and practice are needed for object control skills due to greater perceptual demands and complexity involved during performance (Morgan & Barnett, 2013). In addition, locomotor skills can be practiced anytime and anywhere, whereas object control skills are more time- and context-specific (e.g., equipment, players), making it somewhat less accessible.

Average weekly amount of OSP across childhood also explained variance in AMC, indicating that time spent in OSP is an important feature of OSP , which was also previously established by Fransen et al. (2012) and Vandorpe et al. (2012). Surprisingly though it was not found to be the most important predictor of AMC when the full model was considered. One potential explanation for not finding a greater association of average weekly amount of time spent in OSP on AMC is that the aforementioned studies only took into account the amount of OSP at the time of testing. In the current study, however, the average weekly amount of OSP across childhood was based on children's training history (from the age of two years onwards), providing a broader picture of their average weekly amount of time spent in OSP over their developmental years. Another reason might be the principal of 'reduced additional gain', which means that once a certain threshold of OSP is exceeded, additional profit may no longer be achieved. Following this reasoning, the mean values of the OSP group's AMC across childhood were checked, indicating that these children's level of AMC was indeed slightly above average

(MQKTK3+ = 105.67 ± 10.38) when compared to the KTK3+ test battery's reference value of 100 (± 15). In addition, the average weekly amount of OSP in our sporting subsample was found to be higher than in another study including participants within the same age range (2.49 ± 0.99 hours/week vs. 1.56 ± 1.90 hours/week; De Meester et al., 2020), thus supporting the hypothesis of reduced additional gain. Moreover, in previous studies, other OSP features were not taken into account, leading to a potential overestimation of the amount of practice compared to the type of sport.

None of the aforementioned OSP features significantly predicted children's **autonomous motivation toward sports**. Apparently, children value and enjoy sport to similar degrees independent of whether they engage in multiple of single sports, or whether they are involved in more object control or locomotor-oriented sports. Also, their average weekly amount of time practicing sports did not relate to their autonomous motivation. This is perhaps surprising given that children and adolescents spending less time in OSP typically show lower levels of autonomous motivation toward sports (Bardid et al., 2016; De Meester et al., 2016). Yet, in the current study children's' training history was also taken into account, while their motivation may be more closely related to their current participation in sports. Moreover, Coppens, De Meester, et al. (2021) previously distinguished a group of children with lower levels of OSP who still had high AMC and PMC levels and who were still autonomously motivated for sports. Furthermore, it should be noted that the variation in autonomous motivation in the current study was quite limited, partly because the questioned children were all OSP participants, whom are likely to all have a relatively high autonomous motivation for sports. Indeed, the distribution of the scores on autonomous motivation toward sports was found to be skewed to the left, with 87% of the participants scoring above 4 and 61% even above 4.5 on a 5-point scale.

In view of our findings regarding these OSP features, the question arises what OSP should entail to achieve the most benefit in view of children's physical and psychosocial outcomes. While it is not totally clear which types of sports should be best combined for optimal results, our findings highlight that being involved in multiple sports and participating in object control-oriented sports is associated with higher AMC, PMC and cardiorespiratory fitness. Apart from the demonstrated short-term physical and psychosocial benefits, there is also a possible long-term advantage since involvement in multiple sports is associated with continued engagement in sports participation later in life (Côté & Vierimaa, 2014). While it has been suggested that these effects are due to more enjoyment and intrinsic motivation for sports (Wall & Côté, 2007), such findings were not confirmed in our study with children engaged in multiple sports being equally autonomously motivated to those practicing single sports. However, as stated by Crane & Temple (2015), having fun is the most commonly reported intrinsic motivator for sport participation among children and youth. Moreover, enjoyment of sport (i.e., fun and pleasure; Weiss and Williams, 2004) has been previously associated with motivation to sports participation (McCarthy & Jones, 2007) and the desire and willingness to continue participation (Weiss and Ferrer-Caja, 2002; Crane & temple, 2015). Therefore, it is crucial to encourage children to participate in any sport they like.

Strengths, limitations and future research

A major strength of the present study is the use of a wide spectrum of information regarding participants’ OSP, including their training history across childhood from 2 years up to their age at the time of data collection, thus providing a broader understanding of the role of OSP than previous studies. Moreover, to the best of our knowledge, this is the first study that investigates the combined impact of three different OSP features in relation to children’s AMC, cardiorespiratory fitness, PMC and autonomous motivation, using validated assessment tools. Despite the strengths of this study, some limitations need to be addressed. First, the original research protocol was revisited due to the COVID-19 pandemic; that is, the study duration and the scope of data collection were limited due to stringent measures and logistic restrictions. Because of applying a cross-sectional study design, the present results do not provide any causal evidence regarding significant relationships that were found among study variables. Second, only 37.7% of the included OSP group participants completed the OSP questionnaire, so there is a chance of non-random failure in the data. Third, OSP data were collected retrospectively through parent-proxy report, which is subjective and prone to recall bias since the received information relies on respondent’s report (Raphael & Cloitre, 1994). Many factors relate to recall errors (Coughlin, 1990; Van Den Brink, 2001), one of them being the length of time between the occurrence of an event and the recall of that event (Van Den Brink, 2001). In our study, parents were asked to shed a light on their children's engagement in organized sports across childhood, which might have led to an overestimation or underestimation of the OSP of their child (Biemer et al., 1991; Van den Brink, 2001). While our approach was not gold standard like the detailed retrospective interview procedure of Côté et al. (2005), the collected information regarding the overall sports type index was verified with the governing body overarching all Flemish sports federations, allowing us to check whether or not the children were actually and thus officially enrolled in these types of organized sports. It should be noted that cross-checking information with governing sports bodies did not enable us to check children's actual attendance and/or level of engagement during training sessions. Moreover, no information regarding children's unstructured active leisure time physical activity was registered. Therefore, there is a change that some children are categorized in the non-organized sports group while being active in non-organized activities. Finally, the binary allocation to the single vs. multisport category at the moment of testing does only take into account whether the child currently was involved in one or more sports. It does not take into account if the child combined multiple sports earlier in life. The results of the present study clearly underscore the need for longitudinal and experimental research investigating the effect of OSP features on physical and psychosocial outcomes such as children's AMC, PMC, weight status and autonomous motivation. Future studies should track OSP in a more objective manner across developmental time so (recall) bias in data collection can be minimized. In doing so, a close collaboration with the government and/or sports federations might be a promising strategy to gather this information.

Conclusion

OSP can be considered beneficial for children's AMC, cardiorespiratory fitness and PMC, which is in agreement with the positive spiral of engagement in physical activity as suggested by Stodden and colleagues (2008). The current study indicates that participating in more object control-oriented sports and spending more time in OSP is associated with higher AMC levels. Moreover, encouraging children to participate in multiple sports - preferably including a sufficient share of object control-oriented sports - seems advantageous since it may promote both physical and psychosocial outcomes, including higher levels of cardiorespiratory fitness and PMC.

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PART III: GENERAL DISCUSSION

The general aim of this dissertation was to gain more insight into individual, environmental and task-related determinants of children's AMC and its development. In doing so, the conceptual model of Stodden and colleagues (2008) was combined with Newell's model of constraints (1986). While all of these determinants influence and are influenced by AMC, the focus of this dissertation was not on scrutinizing the reciprocal relationships, model pathways or mediating mechanisms, but on children's AMC and its development as the main outcome of interest.
The *first objective* was to gain more insight in children's individual change in AMC across childhood and the variability in developmental trajectories (STUDY 1 & 2). In doing so, we moved beyond the traditional analysis at group level. Using a person-centered approach was also the way to achieve our *second objective* to provide a deeper understanding of previously identified motor competence based profiles (STUDY 3). The importance of moving beyond the group level, and thus applying a more person-centered approach, will be highlighted based on the available literature and the findings from my original research (STUDY 1, 2 & 3). A *third objective* was to address some of the perceived shortcomings in the literature concerning motor competence assessments (STUDY 3 & 4). Finally, a *fourth objective* was to explore different features of OSP during childhood in relation to AMC (STUDY 2, 3 & 5),
on which will be reflected when discussing the environmental determinants.

Accordingly, the third and final section of this dissertation starts with a summary of the main findings resulting from each of these original research studies, representing the core of the present dissertation. By means of a schematic overview (see Figure 1), the results regarding each of the investigated individual, environmental, and task-related determinants in relation to AMC and its development are discussed. Subsequently, an adapted model is proposed based on the original conceptual model of Stodden and colleagues (2008) and Newell's model of constraints (1986; see Part I of this doctoral thesis for a description of these models). Besides, a reflection is provided on the findings regarding individual variability and applying a person-centered approach. Following a summary of the main findings and discussion, the strengths and limitations of the included studies are discussed, along with some directions for future research. Lastly, some practical implications are considered and a final conclusion is formulated.

1 - OVERVIEW OF THE MAIN FINDINGS -

In an attempt to gain more insight in children's AMC development *(*i.e., *the first objective)*, two longitudinal studies with a focus on individual variability and developmental change were conducted (STUDY 1 & 2). In both of these studies, LGCA were run since it affords the examination of observed as well as latent variables, allowing to account for changes in individual differences that are not reflected in a group's mean or average effect. Moreover, multiple individual and environmental determinants were taken into account while using different AMC assessments considered as a task-related determinant.

The purpose of STUDY 1 was to investigate differences in AMC developmental trajectories across childhood and the potential influence of five individual determinants (i.e., sex, age, baseline AMC, baseline physical fitness and baseline weight status) on this developmental change over a 2-year timespan. In doing so, the KTK4 was used to objectively measure AMC from a product-oriented perspective in 558 children, aged between 6 and 9 years at baseline. Results demonstrated a general positive change in AMC over time with significant inter-individual variability in AMC development. While some children demonstrated a linear improvement of AMC over the two years of study, others showed only an increase in year 1 followed by little to no progress in year 2. Moreover, the level of AMC at baseline did not determine the change in AMC over time, indicating that each child can improve his/her level of AMC level regardless of the starting point. At baseline, no sex differences in AMC level occurred, but boys were found to make more progress in AMC over a 2-year timespan when compared to girls. In addition, children who were older at baseline displayed higher AMC levels at baseline but demonstrated less improvement over time. Interestingly, baseline physical fitness was only significantly associated with children's AMC level at baseline, but not with its change over time. Finally, children's baseline weight status was found to be inversely associated with their baseline AMC level as well as the change in AMC, indicating that children with a less optimal weight status (i.e., a higher body mass index) are at greater risk to become less motor competent across developmental time, which is strongly in line with the conceptual model (Stodden et al., 2008).

The research presented in **STUDY 2** investigated to what extent two individual determinants (i.e., sex and age) as well as different environmental determinants (i.e., features of participation in organized sports) are explanatory for children's improvement in AMC over a period of six years. More specifically, the long-term effectiveness of 'Multimove for Kids', a policy-based FMS intervention funded by the Flemish Government, was examined in this second study taking into account the potential influence of sex, age and multiple features of children's OSP. As the main outcome of interest, children's (N = 399; mean $_{age}$ = 11.3 ± 1.33) AMC was evaluated using the process-oriented TGMD-2. A significant positive change in AMC over time was found with significant inter-individual variability in change in AMC. The intervention group demonstrated higher AMC levels at post-measurement (i.e., after the intervention period of 30 weeks) when compared to the control group. Interestingly, the control group caught up with the intervention group during the retention period of 6 years, indicating no long-term effect of the earlier FMS intervention. At baseline, boys outperformed girls on object control skills and overall AMC, but no differences were found regarding locomotor skills. However, it should be noted that sex did not influence change in AMC over developmental time. Being older was associated with higher initial AMC scores In addition, younger children showed a more pronounced improvement in AMC over time. This study also revealed that individual trajectories of change in AMC were positively influenced by OSP, clearly indicating that OSP benefits children's AMC development (i.e., *the fourth objective*). More specifically, children with less experience in OSP (i.e., less years involved in OSP) showed a steeper evolution in locomotor skills, whereas no influence of OSP experience was found on progress in object control skills or overall AMC. In addition, children spending more time in OSP displayed a more pronounced improvement in AMC over time. Furthermore, children practicing predominantly object control-oriented sports during the 6 year follow-up period displayed a slightly better evolution in AMC over time. However, the effect of type of sports was only found to be marginal.

Next to mapping a number of determinants governing children's level of AMC and its development, our research also aimed at acquiring a deeper understanding of previously identified motor competence based profiles *(*i.e., *the second objective)* by including OSP as an additional cluster variable next to AMC and PMC. To this end, **STUDY 3** examined how these three cluster variables interact with each other in 206 children (aged between 9 and 13 years) while using aligned AMC and PMC test instruments, which also added to *the third objective* (i.e., addressing some of the perceived shortcomings in literature concerning AMC assessment). A second purpose of this third study was to compare the identified AMC-PMC-OSP profiles in terms of children's weight status and autonomous motivation toward sports, being two individual determinants. Cluster analyses identified three profiles with completely convergent levels of AMC, PMC and OSP, and three profiles with partially convergent levels thereof. The most optimal profiles were the ones with average to high levels of all three cluster variables as they combined a healthier weight status with elevated levels of autonomous motivation, while the opposite was true for children with low levels on all three cluster variables. Furthermore, the identified partially convergent profiles revealed that children with relatively low levels of AMC and PMC showed the least favorable weight status - independent of their OSP levels - which is strongly in line with the conceptual model (Stodden et al., 2008).

AMC assessment was subject of the original research described in **STUDY 4**, examining the level of AMC among typically developing Flemish children and adolescents aged between 6 and 19 years. To this end, the widely used KTK3 was combined with an EHC task, resulting in the so-called KTK3+ that addresses the three FMS categories (i.e., locomotor, object control and stability skills). The aim of this fourth study was to validate the combined KTK3+ test battery as well as to provide reference values for 6- to 19-year-old boys and girls *(*i.e., *the third objective)*. Therefore, 2271 children and adolescents took part in this study. The results revealed that the KTK3+ was a valuable tool for measuring AMC in Flemish children and adolescents. A significant increase in test scores was found for each age consecutive group (i.e., 6-7.99, 8-9.99, 10-11.99, 12-13.99, 14-15.99, 16-17.99, 19-19.99 years) on the four test items of the KTK3+. Participants in the older age groups scored significantly better than their younger counterparts, resulting in providing separate age-related normative values. Moreover, boys systematically outperformed girls on the MS, JS and EHC tasks, while girls outperformed boys on the BB task. Therefore, normative values of the KTK3+ test battery were provided separately for boys and girls at all ages, since the observed sex differences remained present over time or with increasing age, even after puberty. In addition, participants who were not involved in any organized sport activities scored systematically lower on all motor tasks included in the KTK3+ test battery when compared to peers who were involved in organized sports on a weekly basis. The fact that the KTK3+ test battery can be used in children and adolescents from 6- to 19-year-old makes it a tool of high practical value, especially for the longitudinal follow-up of motor competence since few AMC assessment tools have been developed for use in both children and adolescents.

As the final original research study in this dissertation, **STUDY 5** examined to what extent different OSP features (i.e., practicing a single sport vs. multiple sports, weekly amount of practice and type of sports practiced across childhood), all of which considered as environmental determinants, might play a role in terms of aspects related to children's physical (i.e., AMC, cardiorespiratory fitness) and psychosocial (i.e., PMC and autonomous motivation toward sports) outcomes *(*i.e., *the fourth objective)*. To this end, AMC was measured with the newly composed and validated KTK3+ in 346 children, aged between 8 and 12 years at baseline. A predominant involvement in object control-oriented sports and spending more time in sports across childhood were found to be associated with higher AMC levels. In addition, multiple sports participation was associated with higher levels of both cardiorespiratory fitness and PMC as compared to single sport participation. However, the different OSP features under investigation did not influence the participants' autonomous motivation toward sports. The findings of this fifth study indicate that OSP is an important resource to support children's AMC, PMC and cardiorespiratory fitness. Participating in more object control-oriented sports and spending more time in OSP is recommended given its positive association with higher AMC levels. Moreover, encouraging children to participate in multiple sports - preferably including a sufficient share of object control-oriented sports - seems advantageous since it may promote both physical and psychosocial health outcomes including higher levels of cardiorespiratory fitness and PMC.

All studies being part of the original research in this dissertation (**STUDY 1, 2, 3, 4 & 5**) contribute to the same overall objective, which is refining the picture of the individual, environmental and task-related determinants of children's AMC and its development. Our research findings regarding this general and overarching aim are presented in Figure 1.

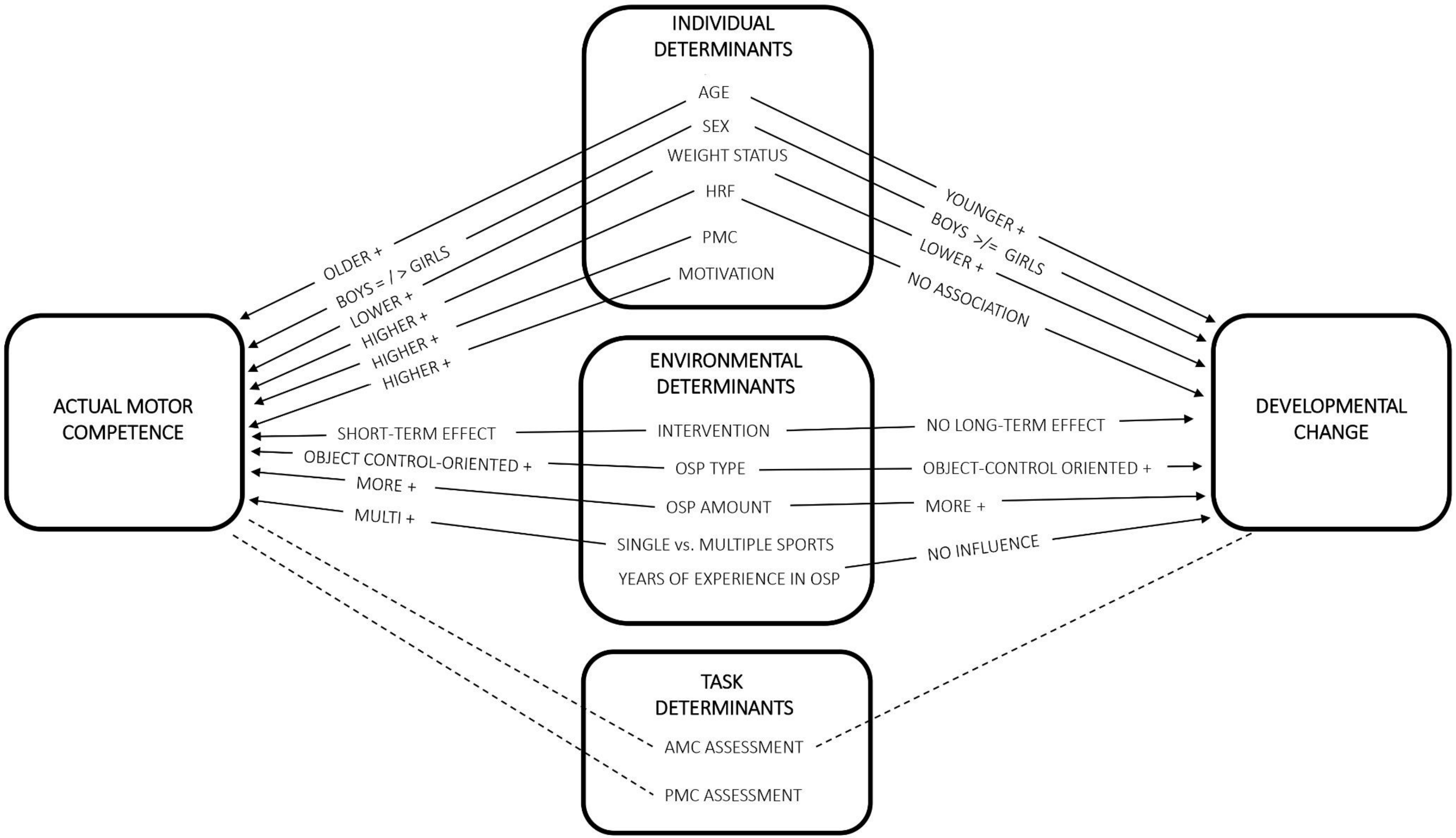


FIGURE 1 - Schematic overview of the research findings regarding actual motor competence and its development (i.e., improvement over time) across childhood and in (young) adolescence.
(HRF: health-related fitness; PMC: perceived motor competence; OSP: organized sports participation; AMC: actual motor competence). An arrow represents the relation between two constructs in this doctoral thesis. A dotted line means that the way AMC and PMC are defined, operationalized, and measured might influence the outcome.

2 - OVERALL DISCUSSION -

In the next section, resultant cross-study reflections based upon the presented findings are provided regarding the general aim and each of the four objectives.

2.1 DETERMINANTS AFFECTING ACTUAL MOTOR COMPETENCE AND ITS DEVELOPMENT

As highlighted in the introduction of this doctoral thesis, motor development is influenced by factors that originate within the individual, but also from the environment and the task. Therefore, the *general aim* of the present dissertation was to take some of these determinants into account when investigating AMC and its development across childhood. Our research findings regarding these determinants are presented in Figure 1, serving as the starting point to guide you through the overview of results in the following section. In doing so, the effect of each determinant on AMC will be presented, followed by the impact of that determinant on the development of AMC, after which the findings regarding the next determinant are discussed.

2.1.1 INDIVIDUAL DETERMINANTS INFLUENCING ACTUAL MOTOR COMPETENCE AND ITS DEVELOPMENT

2.1.1.1 AGE

Table 1 presents an overview of the age of the participants in each of the original research studies, in which the impact of this particular individual determinant was examined.

TABLE 1 - Overview of the age of the participants in each of the studies being part of this dissertation

	AGE AT BASELINE	AGE AT FOLLOW-UP
STUDY 1	6-9 years	9-12 years
STUDY 2	3-8 years	9-14 years
STUDY 4	6-19 years	/
STUDY 5	8-12 years	/

The results regarding age were straightforward. Older children obtained higher AMC scores when compared to their younger counterparts, independent of the test battery being used (i.e., KTK4 in

STUDY 1, TGMD-2 in **STUDY 2**, KTK3+ in **STUDY 4 & 5**) and age ranges within the independent studies. In addition, **STUDY 4** showed an overall significant increase in test scores across consecutive age groups (i.e., 6- to 19-year-olds) on the four test items of the KTK3+ test battery. This is in line with previous studies also revealing a positive relationship between children's age and their AMC level (Barnett et al., 2016; Bolger et al., 2021; Niemistö et al., 2020), affirming the obvious role of age as an individual determinant (Robinson et al., 2015; Stodden et al., 2008). This age-related association may result from a combination of maturation and practice opportunities across the lifespan (Charlesworth, 2016). While Barnett et al. (2016) also observed a positive relation between age and AMC after adolescence, this finding was less pronounced in our **STUDY 4** where the increase in BB performance with age was less accentuated after puberty. This could indicate that dynamic balance meets the mature performance level around the age of 12 years (Largo et al., 2001). In addition to this ceiling effect for the BB task, a floor effect was observed in the EHC task among 6- to 7-year-olds, which is in line with findings reported by Platvoet et al. (2018) and Rizzo et al. (2017).Therefore, the EHC test might be rather challenging for this young(er) age group since a complex spatial-temporal relationship between our visual system and manual motor system is needed to successfully complete this task.

Aligned with previous studies of Ahnert et al. (2009), dos Santos et al. (2018) and Vandorpe et al. (2011), results of our longitudinal studies revealed an average positive change in AMC over time (**STUDY 1 & 2**). In addition, in both of our prospective studies younger children showed a more pronounced improvement of AMC when compared to older peers, which may be attributed to more rapid changes in motor development at a younger age during childhood (Gallahue & Ozmunn, 2005). Also, it is known that with aging children express their motor skills in higher levels of mature performance. Therefore, identifying change in AMC is more difficult in older (and already more skilled) children, especially when the chosen instrument (i.e., task determinant) or one of its test items encounters a ceiling effect as was the case in **STUDY 2**, where a process-oriented and thus criterion-referenced test battery with a theoretical maximum total raw score was used (i.e., TGMD-2; Ulrich, 2000). In addition, the majority of participants in the second study was older than the upper limit of the TGMD-2 (i.e., 10 years) at follow-up (given the time interval of 6 years relative to baseline) making it even more difficult to identify developmental change. This highlights the need to ensure the instrument has been validated among the age group it purports to assess (Barnett et al., 2016).

Summarizing the age-related findings, our studies clearly indicate a positive relationship between children's age and their AMC level. Considering the development of AMC, younger children showed a more pronounced improvement of AMC over a 2- and 6-year timespan when compared to older peers. If younger children can improve their AMC more easily when compared to their older counterparts, promoting AMC development as early as possible is considered critical to improve both the AMC levels of current and future generations Furthermore, since young children adopt new behavioral habits more easily (Gliebe, 2011), AMC interventions provided at an earlier age will more likely result in greater positive and sustained effects (Lubans et al, 2010).

2.1.1.2 SEX

Results regarding sex were somewhat more equivocal. Most of the previously conducted studies have reported sex differences in AMC with boys usually obtaining higher scores, although different results have been reported across specific motor skill domains (i.e. gross motor coordination vs. FMS categories). Table 2 provides an overview of our findings regarding sex as an individual determinant affecting AMC (i.e., instantaneous; **STUDY 1, 2, 3, 4 & 5**) and its development (i.e., improvement over time; **STUDY 1 & 2**), together with the used AMC assessment tool (i.e., task-related determinant) and how the scores were used in the analyses (i.e., raw scores vs. using standardized scores adjusted for sex (and age)).

TABLE 2 - Overview of the sex-related findings affecting AMC (i.e., instantaneous) and its development

		AMC				AMC DEVELOPMENT
		LOCOMOTOR SKILLS	OBJECT CONTROL SKILLS	STABILITY SKILLS	OVERALL AMC	
STUDY 1	KTK4 (raw)	/	/	/	Boys = girls	Boys > girls (2-year timespan)
STUDY 2	TGMD-2 (raw)	Boys = girls	Boys > girls	/	Boys > girls	Boys = girls (6-year timespan)
STUDY 3	KTK4 (MQ)	/	/	/	Boys = girls	/
STUDY 4	KTK3+ (raw)	Boys > girls	Boys > girls	Boys < girls	Boys > girls	/
STUDY 5	KTK3+ (MQ)	Boys = girls	Boys = girls	Boys = girls	Boys = girls	/

AMC: Actual motor competence; KTK4: KörperkoordinationsTest für Kinder; TGMD-2: Test of Gross Motor Development – Second Edition; KTK3+: KörperkoordinationsTest für Kinder + eye-hand coordination task; MQ: motor quotient.

In light of our findings, it is important to highlight that three different test batteries for AMC assessment were used in our original research (i.e., KTK4, TGMD-2, KTK3+). A validity study revealed that the KTK4 and TGMD-2 measure discrete aspects of AMC (Rudd et al., 2016), with the KTK4 not covering the broad spectrum of AMC since object control skills are not taken into account in this latter assessment tool. Additionally, Niemistö et al. (2020) who assessed AMC with both the TGMD-3 and the KTK4 revealed that sex differences were found in both assessment tools, indicating that these assessment tools measure different aspects of AMC (i.e., FMS categories vs. gross motor coordination, respectively; Cools et al., 2009; Ré et al., 2018). Moreover, both the KTK4 and KTK3+ are product-oriented assessment tools whereas the TGMD-2 is a process-oriented one. Previous studies suggested that product-oriented and process-oriented assessment tools provide different information (Hulteen, True et al., 2020; Ré et al., 2018), which makes comparing results across studies hard (da Luz et al., 2017; Stodden et al., 2008). Another important notion is that in three studies raw scores were used (i.e., STUDY 1, 2 & 4), while MQ's were used in STUDY 3 & 5. Using MQs means that the raw performance scores are converted into standardized values adjusted for sex (and age). Therefore, it is not surprising that no sex differences were established in these latter two studies. Moreover, this could also explain the different findings regarding sex in STUDY 4 - where raw scores were used - and STUDY 5 - using MQs. Taken this into account, we will now only focus on the studies that used raw scores (i.e., STUDY 1, 2 & 4).

Considering *object control* tasks, sex differences were observed with boys outperforming girls, which is in line with the systematic review of Barnett and colleagues (2016) and Bolger and colleagues (2021). One explanation might be that boys participate more in object control-oriented activities, while girls tend to participate more in locomotor related activities (Bardid, Huyben, Lenoir, et al., 2016), indicating that boys and girls seem to have different preferences when it comes to (organized) sports participation. Indeed, many researchers agree that sex differences in AMC during early childhood are not based on biological factors (Donnelly et al., 2016) but are more likely related to environmental factors and the sociocultural context (Iivonen & Sääkslahti, 2014; Spessato et al., 2013). It is interesting to note that our results seem to indicate that when boys had higher object control scores, they also seem to outperform girls in *overall AMC*. In this respect, the systematic review of Bolger et al. (2021) revealed that across age, children exhibit higher levels of locomotor skills compared to object control skills, indicating that greater instruction and practice are needed for object control skills due to greater perceptual demands and complexity of object control skills (Morgan & Barnett, 2013). These aforementioned issues may not only explain the sex-related differences in object control skills but also in overall AMC, since leisure time activities may considerably differ between boys and girls (Barnett et al., 2013; Spessato et al., 2013).

Our results seem to indicate no clear sex differences regarding *locomotor tasks*, which is in line with the systematic review of Barnett, Lai and colleagues (2016). However, boys reached significantly higher levels on JS, which is considered a locomotor performance task, and this finding was even more pronounced among the older age groups. As suggested by Platvoet et al. (2018), this could be explained by an underlying physical and physiological factor as strength and/or endurance are underlying requirements for a good performance on the JS as a specific KTK4 and KTK3+ test item.

Our findings regarding sex and developmental change were also inconclusive. In **STUDY 1**, boys made more progress in AMC over a 2-year timespan when compared to girls. Surprisingly, dos Santos et al. (2018), who also used KTK4 raw scores to assess children's AMC, found differences in developmental change favoring girls. These authors stated that this contrasting finding needs further exploration. In **STUDY 2**, when AMC was measured with the TGMD-2, our results indicated that sex did not influence change in AMC over a 6 year timespan, which is in line with the findings of Rodrigues et al. (2016). However, these authors used a test battery that mainly focused on physical fitness. In light of these contrasting findings, there is need for more research into how sex relates differently to various aspects of AMC evolution and how this might be moderated by other (environmental) factors like OSP. It seems that leisure time activities, which are proven to differ between boys and girls, are also influencing AMC and its development.

Summarizing the sex-related findings, boys seem to have a (slight) advantage over girls in terms of AMC and its development over time although not consistent across all of our studies. However, since boys and girls tend to participate in different physical activities, the type of activities they are involved in may also influence the relationship between sex and AMC (development). This is important information in light of developing interventions targeting AMC, since boys and girls seem to need a differently oriented approach.

2.1.1.3 WEIGHT STATUS

Our results regarding weight status were unambiguous. A lower weight status (i.e., a lower BMI) was systematically associated with higher levels of AMC (**STUDY 1 & 3**), which is in agreement with previous research on the topic (Cattuzzo et al., 2016; D'Hondt et al., 2013; D'Hondt et al., 2014; Estevan et al., 2019; Lopes et al., 2012; Martins et al., 2010; Rodrigues et al., 2016). Next to AMC, also PMC and the environmental determinant OSP seem important when it comes to weight status. Indeed, **STUDY 3** revealed that children with average to high levels of AMC, PMC and OSP combined a healthier weight status with elevated levels of autonomous motivation, while the opposite was true for children with low levels on all three cluster variables. Furthermore, partially convergent profiles revealed that both AMC and PMC levels are crucial for weight status as profiles with relatively low levels thereof displayed the highest weight status, independent of children's OSP levels. Our findings thus highlight the importance of promoting AMC, PMC and OSP simultaneously in achieving a healthy weight status and higher levels of autonomous motivation toward sports, both essential cornerstones in achieving and maintaining a healthy and active lifestyle. Additionally, previous research revealed that also the assessment tool or test instrument being used might accentuate the effect of weight status on AMC (D'Hondt et al., 2011; Lopes et al., 2020). It seems that when a greater proportion of body mass is involved in the action and thus needs to be moved under time constraints or against gravity, the detrimental effect of an unhealthy weight status becomes more prone, which is especially the case when using product-oriented assessment tools like the KTK4 or KTK3+ (D'Hondt et al., 2011). It is not surprising when using the process-oriented TGMD-2, where most of the object control tasks do not require to move the majority of body weight, an unhealthy weight status is less decisive on the AMC test result (Lopes et al., 2020). Interestingly, previous studies revealed that this mechanical point of view is not the only factor causing a lower AMC level in children with a high BMI. Having an unhealthy weight status also seems to negatively impact fine motor skills, involving less parts of the body (D'Hondt et al., 2008; Gentier et al., 2013). In addition, reduced AMC levels in children with an unhealthy weight status may also be related to neurological factors (Augustijn et al., 2018).

Considering developmental time, our results indicate that a lower weight status at baseline was associated with more progress in AMC over a 2-year timespan (**STUDY 1**), which is in agreement with the findings of Barnett et al. (2021), D'Hondt et al. (2014), dos Santos et al. (2018), Lima et al. (2021), Lopes et al. (2020) and Rodrigues et al. (2016). The latter also observed that children with a steeper AMC progression were less likely to become overweight or obese at the end of primary school when compared to children with a less positive AMC development over time. Furthermore, Lima et al. (2021) examined the relationship between children's weight status at preschool age and their AMC scores in early and middle childhood, and found that children who changed their weight status category from high (i.e., overweight or obese) to normal or low (i.e., underweight) presented similar AMC scores compared to children who maintained a low or normal weight status within the same time frame. All of this previous research partly supports the postulated 'positive spiral of engagement' of Stodden and colleagues (2008), where children with an optimal weight status end up in becoming more motor competent over time, which was also the result in our STUDY 1. Altogether, this demonstrates the importance of targeting weight status from a young childhood age onwards. Although there is strong evidence for a (reciprocal) relationship between AMC and weight status over developmental time (see Barnett et al., 2021 for a recent systematic review), we are still not sure whether lower AMC should be considered a precursor or consequence of a higher weight status. However, it is clear that future interventions should not only target AMC but should consider children's weight status as an outcome to be evaluated since this might be beneficial for their AMC level as well as for their health-related fitness, PMC, motivation, self-concept and other (health-related) outcomes.

> *In summary, our results revealed that a lower weight status was systematically associated with higher levels of AMC at the moment of testing as well as with a steeper development of AMC over time. Therefore, future interventions aiming to stimulate children's AMC should not focus solely on AMC, but should consider weight status as an outcome to be evaluated since this might be beneficial for their (future) AMC level as well as for health-related fitness, PMC, motivation, self-concept and other (health-related) outcomes.*

2.1.1.4 HEALTH-RELATED FITNESS

Health-related fitness, which is considered an important marker of current and future health in children, adolescents and adults, was taken into account in STUDY 1 (i.e., cardiorespiratory fitness, musculoskeletal fitness and flexibility) and **STUDY 5** (i.e., cardiorespiratory fitness). Our results indicated that both cardiorespiratory and musculoskeletal fitness were significantly related to momentary AMC levels (**STUDY 1 & 5**). These findings are in line with the recently published meta-analysis of Utesch et al. (2019) and earlier reviews on this topic (Cattuzzo et al., 2016; Lubans et al., 2010; Robinson et al., 2015). Our findings also highlight the supportive role of OSP on children's AMC and cardiorespiratory fitness, since our sporting subsample in **STUDY 5** (i.e., OSP group) significantly outperformed those children not involved in OSP (i.e., non-OSP group), which is consistent with previous research (Drenowatz & Greier, 2019; Fransen et al., 2012; Vandorpe et al., 2012). Considering flexibility (**STUDY1**), no association with AMC was found, which is in contrast with the study conducted by Lopes et al. (2017), who observed that children needed adequate levels of flexibility to attain proper AMC. However, the meta-analysis of Utesch and collleagues (2019), revealing moderate-to-large positive associations between AMC and overall health-related fitness from early childhood into early adulthood, also demonstrated that more research is warranted to further understand the association between AMC and flexibility as there is currently limited evidence available on this particular relationship (Cattuzzo et al., 2016; Utesch et al., 2019).

Limited research has been conducted on the developmental perspective of health-related fitness and AMC, which was also stated as a shortcoming in current literature in the meta-analysis of Utesch et al. (2019). In **STUDY 1**, we investigated how children's baseline physical fitness related to AMC development over a 2-year timespan. Surprisingly, none of the three components of physical fitness (i.e., cardiorespiratory fitness, musculoskeletal fitness and flexibility) were significantly associated with changes in AMC over developmental time. This observation is in contrast with other studies also investigating the pathway of health-related fitness to AMC (Antunes et al., 2016; dos Santos et al., 2018; Henrique et al., 2018; Jaakola et al., 2019; Lima et al., 2019). Indeed, cardiorespiratory fitness was a found to be a predictor of AMC in the studies of dos Santos et al. (2018), Henrique et al. (2018), Jaakola et al. (2019) and Lima et al. (2019). The same holds true for musculoskeletal fitness (Antunes et al., 2016; dos Santos et al., 2018) and flexibility (Antunes et al., 2016). It should be noted, however, that our study particularly focused on to what extent physical fitness at baseline influenced change in children's AMC over time. In light of the limited longitudinal evidence on this topic, there is a need for more research investigating the role that different health-related fitness components may have on

AMC development (and vice versa) across childhood and adolescence, something that was also highlighted in the recently published systematic review of Barnett and colleagues (2021).

Although it was not the focus of our research, it is important to note that AMC and health-related fitness are separable, yet interrelated constructs. This is particularly apparent in the fact that some test items of (mainly product-oriented) motor assessment tools require a certain fitness level to achieve a good level of performance on these tests (Bardid, Huyben, Deconinck, et al., 2016; Fransen, D'Hondt, et al., 2014). In addition, some tasks (e.g., standing broad jump) are used as either a fitness or AMC measure (Utesch et al., 2019), which proves the close relationship between these two constructs showing a certain degree of overlap

In summary, our results indicate a positive relationship between health-related fitness and initial AMC. While the influence of baseline fitness did not significantly influence AMC development, it is clear that further longitudinal research is needed examining the dynamics between health-related fitness and AMC across developmental time.

2.1.1.5 PERCEIVED MOTOR COMPETENCE

The relationship between AMC and PMC is already extensively examined in the literature, revealing divergent results. A recently published systematic review and meta-analysis of De Meester et al. (2020), including data from 69 studies, endorsed a positive relationship between AMC and PMC in children and adolescents as hypothesized in the conceptual model of Stodden and colleagues (2008), indicating that higher AMC levels will coexist with higher PMC levels. However, while this systematic review revealed a positive relationship between AMC and PMC in children, adolescents and young adults (until 24 years of age), the strength was only low to moderate (De Meester et al., 2020). Furthermore, most of the studies included in this meta-analysis relied on a variable-centered approach, which does not provide insight into how differently AMC and PMC may be combined at the individual level (Bardid, De Meester, et al., 2016). Therefore, a person-centered approach is needed which may result in different motor competence based profiles (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Weiss & Amorose, 2005), with some of them combining convergent levels of AMC and PMC, and others combining divergent levels of AMC and PMC. Another reason for finding generally low correlations as reported in the systematic review of De Meester and colleagues (2020) may be the fact that the AMC and PMC assessment tools being used were not always aligned (i.e., the items in the PMC questionnaire did not directly correspond to tasks to be performed upon the AMC assessment), making it harder for children to provide additional relevant information about their self-perceived level of skill (True et al., 2017). This can be considered an implicit issue that might influence the interpretation and discussion of the results (Robinson et al., 2015). The use of aligned assessment tools could help in this regard because otherwise there is a possibility that children could perceive their AMC differently from their competence in other types of physical skills and activities. Therefore, Estevan and Barnett (2018) suggested to use aligned AMC-PMC assessment tools since it could result in a stronger relationship between both constructs of motor competence and also to make more correct statements about how well children can assess their own AMC. Surprisingly, this hypothesis could not be verified by the meta-analysis of De Meester et al. (2020), since most of the studies in this meta-analysis that used aligned instruments were conducted in young children, and young children are supposed to still have a decreased cognitive ability to accurately self-assess their competence (Harter, 1999) As such, De Meester et al. (2020) suggested that future research regarding the alignment between test instruments and its potential impact on the strength of the relationship between AMC and PMC is still needed. Following these suggestions, and to provide a more refined understanding of the AMC-PMC relationship *(i.e., the second objective)*, a person-centered approach was implemented while using aligned AMC and PMC assessment tools in STUDY 3. The results showed moderately strong correlations between both constructs. Moreover, the majority of the children (83.9%) showed convergent levels of AMC and PMC, which is much higher when compared to previous studies using the same approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Weiss & Amorose, 2005). One explanation may be that the PMC questionnaire was directly aligned with the test items of the AMC assessment tool. Not only the alignment, but also the nature of the assessment tools, which were both product-oriented, may have resulted in a stronger relationship between AMC and PMC in our study as compared to earlier work. It is possible that children have less difficulties with feeding product-oriented information back to themselves (e.g., *"How many steps did I walk backwards on the balance beam?"*) when compared to process-oriented information (e.g., *"Did I extend my arm while reaching for the ball as it* *arrives?"*; True et al., 2017), resulting in a stronger correlation between the aligned AMC and PMC in the current study when compared to earlier research also using a person-centered approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Pesce et al., 2018).

The aforementioned explanations regarding alignment and the nature of assessment tools could also explain the contrasting findings in STUDY 5, where no significant relation between children's AMC and PMC was observed. In this study, the assessment tools being used were not aligned (i.e., KTK4 and SPPC). Additionally, the SPPC explicitly asks children to compare themselves to other children. However, children may have different frames of reference (e.g., peers of the same sex versus peers of both sexes, or class mates versus sports team mates; De Meester, 2017). It is also worth noting that the participants in STUDY 5, who completed the PMC questionnaire, were all currently involved in OSP, making it plausible that they compared themselves with their (most likely very skilled) sports team mates and as such perceive themselves as being below average. Interestingly, children who combined multiple sports at the moment of testing demonstrated an association with higher perceptions regarding their AMC when compared to single sport participants. Since peers are an important source of information to develop accurate PMC (True et al., 2017), it might be beneficial to have diverse peer groups to assess oneself against.

Our cluster analyses also revealed that children with high(er) levels of AMC and PMC (and OSP) displayed the most optimal profiles with healthier weight status, which is in line with the recent findings of Estevan and colleagues (2021).

Summarizing our findings regarding PMC, using aligned assessment tools resulted in higher correlations with AMC. Contrastingly, when less aligned evaluation tools were used in children participating in organized sports, we did not find evidence for a significant positive association between AMC and PMC. It seems that that the evaluation tool being used (i.e., a questionnaire involving peer comparison) resulted in lower perceptions in this specific population engaged in OSP. However, our results also pointed out the importance of not only targeting AMC but also PMC as children with higher levels of both constructs revealed a better weight status.

2.1.1.6 AUTONOMOUS MOTIVATION TOWARD SPORTS

The final individual determinant that was investigated in the context of this dissertation encompassed children's autonomous motivation toward sports (**STUDY 3 & 5**). Both studies including this particular determinant revealed significant yet negligible to low positive correlations in a sample of 9- to 13- year-old children (**STUDY 3**, $r = 0.302$, $p < 0.001$) and a sporting subsample of 8- to 12-year-old children (**STUDY 5**, $r = 0.158$, $p < 0.05$). These findings indicate that AMC relates to autonomous motivation, albeit to a limited extent, suggesting that if children are better performers in the KTK (**STUDY 3**) or KTK3+ (**STUDY 5**), they will also be more likely to enjoy and value sports. Interestingly, **STUDY 3** helped us in understanding whether and how various profiles based on AMC-PMC-OSP differently relate to autonomous motivation for sports in order to stimulate healthy development. Our results revealed that children with average to high levels on all three cluster variables displayed the most optimal profile as they had higher levels of autonomous motivation toward sport in addition to a better weight status, while the opposite was true for children with low levels of all three cluster variables. These findings align with previous studies revealing that a combination of low(er) levels of AMC and PMC among children is the least optimal in view of their autonomous motivation (Bardid, De Meester, et al., 2016; De Meester, Maes, et al., 2016). Our research also adds to the existing literature as it is the first time that these three constructs were combined in identifying motor competence based clusters or profiles. Moreover, our results also point toward the importance of promoting average to high levels of all three cluster variables simultaneously since the group with average levels of AMC and low levels of PMC and OSP also displayed lower levels of autonomous motivation, indicating they were less likely to value and enjoy OSP. On the other hand, *s*ome children might be optimally motivated toward sports, but not have access to (organized) sports because of several reasons (e.g. socio-economic status, social support, economic resources and sex; Eime et al., 2013; Vandendriessche et al., 2012). Regarding economic resources, policy makers, sports federations and sports clubs should all be aware that children (and their parents) perceive 'cost' and 'time' as key barriers to participation in sport. More local sports opportunities are needed where costs are reduced (Somerset et al., 2018). One solution might be a collaboration between schools and local sports clubs to provide more affordable local opportunities to increase children's participation in sport.

In summary, our results reveal a positive association between AMC and autonomous motivation. Moreover, targeting not only AMC but also PMC and OSP seems beneficial in terms of children's autonomous motivation toward sports. When doing so, children's perceived barriers to OSP should also be taken into account (Somerset & Hoare, 2018).

Altogether, our results indicate a great role of the examined individual determinants on AMC and its development. The recurring role of environmental factors (e.g., leisure time activities, OSP) on the individual child and its development is striking. This proves again that an individual is in constant interaction with its environment from which motor development arises.

2.1.2 ENVIRONMENTAL DETERMINANTS INFLUENCING ACTUAL MOTOR COMPETENCE AND ITS DEVELOPMENT

In order to more comprehensively understand children's motor development, we should not only take into account the individual and his/her structural and functional characteristics. From an ecological point of view, motor development is also influenced by various factors that do not originate within the individual but that are extrinsic in nature, including environmental determinants. The environmental determinants that were investigated in the context of this dissertation are on the one hand related to interventions targeting and promoting children's AMC and on the other hand related to OSP, both of which are offering unique practice opportunities enabling children to develop their AMC.

2.1.2.1 INTERVENTIONS

While most AMC intervention studies provide evidence of short-term positive effects on children's level of AMC (Bardid et al., 2017; Brian et al., 2019; Logan et al., 2012; Morgan & Barnett, 2013; Riethmuller et al., 2009; Van Beurden et al., 2003), studies investigating the long-term impact are scarce (Morgan & Barnett, 2013). In STUDY 2 of our original research, we added to the literature by investigating the long-term impact of 'Multimove for Kids', which is an FMS intervention for typically developing children between 3 and 8 years. This 30-week program, consisting of weekly 1-hour sessions and focusing on 12 FMS themes, was found to significantly improve both locomotor and object control skills (Bardid et al., 2017). Our results indicated that the Multimove program boosted the AMC level of the participating children (*N* = 228, mean age = 5.80 ± 1.46 years) since these children outperformed the control group after following the 30 week FMS intervention at the post-measurement. This reflects the need of providing structured opportunities to young children so they can develop their FMS to an adequate standard, which is important for policy and practice. Indeed, it seems that the Multimove intervention supports the finding that FMS do not naturally occur through free play or maturation (Brian et al., 2017a; 2017b; Goodway & Branta, 2003; Logan et al. 2011; Riethmuller et al., 2009; Robinson & Goodway 2009). In doing so, we might have to focus more on object control skills since these skills need more instruction and practice (Brian et al., 2017a; Gallahue et al; 2012; Goodway & Branta, 2003), and have more predictive value when it comes to engagement in PA (Barnett et al., 2009a).

During the 6-year follow-up, the control group caught up in terms of their AMC level with their peers of the intervention group, indicating no long-term effect of the earlier intervention, which is partly in line with the study of Zask et al. (2012). These authors evaluated movement skills at three time points (i.e., at baseline, 10 months later, three years later) in a sample of children that were respectively four, five and eight years old) and only found lasting differences in object control skills between the intervention and control group three years after the intervention. Girls in the intervention group maintained their object control skill advantage when compared to the control group, but boys did not. In the years following the intervention, children of the control group also caught up to intervention children in locomotor skill ability, regardless of their sex. On the other hand, Barnett and colleagues (2009b) investigated the long-term impact of a primary school-based motor skill intervention 6 years after the intervention took place. At post-measurement, the children were 8- to 12-year-old, with a mean age of 10.1 years, which is comparable with the children in our study sample. In contrast with our findings, the intervention group maintained their advantage in 3 skills (i.e., catch, side gallop and jump) and lost their advantage in two other skills (i.e., kick and overhand throw). However, while the study of Barnett et al. (2009b) used a one year multi-strategic approach aiming to increase both FMS and PA, the Multimove intervention only focused on boosting FMS development and lasted for 30 weeks. Considering the dose, it is known that time spent in exploring and practicing FMS in various ways is of great importance in improving children's AMC (Morgan & Barnett, 2013). It is possible that the Multimove intervention program was not long or intensive enough to accomplish sustained effects. Additionally, in subsequent years following the intervention, environmental factors such as (non)engagement in OSP may have influenced the further development of motor skills both among intervention and control children. Moreover, while the study of Zask et al. (2012) and Barnett et al. (2009b) were school-based interventions (with some long-term effects), Multimove was a community-based one in collaboration with local sports clubs, local councils and schools. Since education is compulsory in most countries (e.g., in Belgium from age five till eighteen), virtually all children (independent of their background) and adolescents attend school, making it an ideal setting for health promoting interventions by reaching the majority of the target population involved. It is, therefore, not surprising that a recently published systematic review on the topic noted that schools are also an effective setting for motor skill interventions, with 89% of the included studies reporting significant benefits on at least one aspect of motor skill (Eddy et al., 2018). Indeed, embedding motor skill interventions within schools has a number of advantages such as integrating interventions into the routine of the school curriculum to create more sustained and frequently dosed treatment regimens, which are important factors in moderating the effectiveness of motor skill interventions (Yu et al., 2018). However, huge differences in educational systems and physical education across countries and continents arise (Bardid et al., 2015; Brian et al., 2018; D'Hondt et al., 2019). In some European countries, children are generally enrolled in preschool earlier and at a higher frequency when compared to children in Saudi Arabia and US (D'Hondt et al., 2019). Moreover, the disparity in attention for physical education in the curriculum of preschoolers is striking. In Belgium, physical education is compulsory in the intra-curricular medium through which children and adolescents are stimulated to engage in moderate-to-vigorous PA (Haerens et al., 2010; 2011). Also in preschool, Belgian children receive structured physical education classes as part of the curriculum and many of them receive these classes from trained physical education teachers (D'Hondt et al., 2019; Van Cauwenberghe et al., 2012; Van Waelvelde et al., 2008). In contrast, preschoolers in US do not receive this structured opportunity for motor development (Brian et al., 2018). Based on the Active Start Guidelines, which provides a framework for early childhood educators to implement PA with their students (National Association for Sport and Physical Education [NASPE, 2009]), early childhood centers generally provide 20-60 min of well-equipped daily free play as the typical standard of practice aimed at fostering gross motor skill development and providing PA (Brian et al., 2017a, 2017b). Although free play is important for children, Brian et al. (2017a; 2017b) revealed that the control children's FMS remained delayed in spite of daily free play movement opportunities when compared to the intervention children who received an 8-week teacher-led intervention. While previous studies have shown that motor skill interventions can be effective when implemented in schools(Brian et al., 2017a; 2017b; Goodway & Branta, 2003; Taunton et al., 2017), gaining more insight into cross-cultural differences in AMC is imperative to counteract the general decay in AMC around the globe.

In summary, while the implicit goal of interventions is to counteract the secular decline in AMC by stimulating children's motor development, it remains unclear how the short-term effects of such intervention programs can be made more sustainable. However, embedding these motor skill interventions in schools seems a promising strategy. Further investigations are needed to determine the optimal characteristics of FMS / AMC intervention programs, including dose (i.e., program duration, frequency and intensity), as well as to strengthen the response evidence for long-term developmental success.

2.1.2.2 OSP FEATURES

One of the goals of this dissertation was to gain more insight in the different OSP features being associated with AMC and its development *(*i.e., *the fourth objective)*. Therefore, we took children's training history into account upon data collection in longitudinal STUDY 2 and cross-sectional STUDY 5. Besides, the average weekly amount of time spent in OSP at the moment of testing was also included in STUDY 3. Overall, four different OSP features were considered in these three studies: that is, weekly amount of practice (in STUDY 2, 3 & 5), experience in OSP (in STUDY 2), type of sports being practiced (in STUDY 2 & 5), and single sport vs. multiple sports participation (in STUDY 5). In addition, being involved in OSP was also taken into account in STUDY 4, where it was investigated if the KTK3+ was able to discriminate between OSP-participants and non-OSP participants.

In general, our results across studies clearly indicate that OSP benefits AMC development, given that it results in better AMC scores regardless of the AMC assessment tool being used (i.e., TGMD-2 in STUDY 2, KTK4 in STUDY 3 and KTK3+ in STUDY 4 & 5). This is in agreement with previous studies also suggesting that sports related leisure time is beneficial for children's AMC (Lubans et al., 2010; Niemistö et al., 2020; Queiroz et al., 2014).

While previous research already investigated the role of OSP at the moment of testing (Fransen et al., 2012; Vandorpe et al., 2012), the latter studies did not include long-term training history (i.e., over a period of several years), incorrectly assuming little change in children's OSP over developmental years. Moreover, most of the studies investigating the role of OSP only took into account one aspect of OSP, not covering the full picture with respect to this particular environmental constraint. To the best of our knowledge, the present research represents the first attempt to investigate the role of multiple OSP features with regard to children's AMC and its development in such an encompassing way. In doing so, two OSP features (i.e., type of sports and time spent in OSP) were considered across childhood (i.e., from the age of 2 years onwards), thus providing a wider and more comprehensive picture of OSP in general.

Our findings showed that the four OSP features were all associated with AMC to some extent. Two of these OSP features focused on the *amount of practice*: the average weekly amount of time spent in OSP and years of experience in OSP. In agreement with previous studies of Fransen et al. (2012) and Vandorpe et al. (2012), our results revealed that children who spent more time in OSP across childhood reached higher levels of AMC (**STUDY 5**) and a more pronounced AMC improvement over time (**STUDY 2**). The latter study also showed that children with more years of experience in OSP at baseline (i.e., number of seasons enrolled in OSP) reached higher initial AMC scores. However, the years of experience in organized sports at baseline did not influence the evolution in overall AMC or object control during the 6-year follow-up period. Interestingly, children with less years of experience in organized sports, showed a more pronounced progress in locomotor skills. This might be due to a greater margin for improvement in children with less expertise in OSP, scoring lower at baseline. The other two OSP features focused more on *OSP content*: type of sports and single sport vs. multiple sports participation. Regarding type of sports, children practicing predominantly object control-oriented sports were found to score higher on AMC (**STUDY 5**) and also displayed a slightly better evolution in AMC over time (**STUDY 2**). One explanation might be that predominantly object control-oriented sports, such as basketball, may provide more opportunities for children to develop both object control and locomotor skills compared to predominantly locomotor-oriented sports, like swimming for instance. This idea seems to be confirmed by the newly developed sports type index itself (going from -1 for predominantly locomotor-oriented sports to +1 for predominantly object-control-oriented sports; see p.89), as it clearly encloses less extreme values to the object control side of the continuum. In addition, object control skills are more context-specific (e.g., specific equipment, number of players), making it somewhat less accessible when compared to locomotor skills. Considering the development of AMC, the influence of type of OSP was less prone when the progress in locomotor and object control skills were considered separately during the 6-year follow-up in **STUDY 2**. With regard to the OSP feature single sport vs. multiple sports participation revealed that being involved in multiple sports was also found to be related to higher levels of cardiorespiratory fitness and PMC compared to single sport participation (**STUDY 5**). To the best of our knowledge, no previous studies have investigated the association between this particular OSP feature and children's PMC.

In summary, our findings underline the importance of OSP during childhood in view of AMC and its development, which is in agreement with the 'positive spiral of engagement' as suggested by Stodden et al. (2008). The four OSP features examined were all associated with AMC to some extent. Type of sports being practiced (predominantly object control-oriented), average weekly amount of time spent in OSP (more) across childhood, and experience in OSP (more) are positively determining AMC. In addition, being involved in multiple sports was also found to be related to higher levels of cardiorespiratory fitness and PMC compared to single sport participation. Taking together these findings, the question arises which type(s) of organized sports should be best combined to achieve the most benefit in view of both physical and psychosocial outcomes during childhood. However, while the answer to this question is not yet totally clear, our findings highlight that encouraging children to combine multiple sports - preferably including a sufficient share of object control-oriented sports - seems advantageous, since it may promote both physical and psychosocial development including higher levels of cardiorespiratory fitness and PMC. The latter is also an important finding considering that the systematic review of Crane & Temple (2015) revealed that PMC occurs to be a protective factor against dropout from OSP among children and youth. In addition, apart from the demonstrated short-term physical and psychosocial benefits, there is also a possible long-term advantage, as involvement in multiple sports is associated with continued engagement in sports participation later in life (Côté & Vierimaa, 2014), due to more enjoyment and intrinsic motivation for sports (Wall & Côté, 2007). However, combining multiple sports might have a downside as well, given *that - in Belgium - it comes with higher registration fees, making it less approachable for all children. Policy and practice (i.e., sports federations and sports clubs) should take into account children's (and their parents') perceived barriers to OSP. These barriers can be practical (i.e., time, location, cost) or personal (Somerset & Hoare, 2018). Personal barriers to children's OSP include either external (e.g., peer disapproval, gender stereotype, competiton) or internal factors (e.g., fear of judgement, self-conscious, sporting ability; Somerset & Hoare, 2018). Future initiatives should bear in mind these barriers in order to improve and increase OSP opportunities for children.*

2.1.3 TASK-RELATED DETERMINANTS THAT INFLUENCE ACTUAL MOTOR COMPETENCE AND ITS DEVELOPMENT

In the context of this doctoral thesis, the task determinants were approached entirely from a methodological point of view and, as such, represent the different assessment tools used to measure participants' AMC and PMC across the included studies. Throughout the discussion of the individual and environmental determinants, we have repeatedly pointed out that the way both constructs are defined, operationalized and measured has an undeniable impact on the findings. In the next section, I discuss the gathered information regarding the different levels at which assessment tools can differ from one another. I end the discussion of the task determinants by some conclusions on potential improvements in motor competence assessment.

2.1.3.1 ACTUAL MOTOR COMPETENCE ASSESSMENT TOOLS

Regarding AMC assessment tools, both product-oriented (i.e., the KTK4 and KTK3+ as used in **STUDY 1, 3, 4 & 5**) and process-oriented (i.e., TGMD-2 as used in **STUDY 2**) assessment tools were administered for this research. Studies examining the relationship between these product- and process-oriented AMC assessments reveal mixed results (Hulteen, Barnett, et al., 2020; Logan et al., 2017; Niemistö et al., 2020; Ré et al., 2018). Two of these studies compared product-oriented and process-oriented assessments at the level of the total test-battery: KTK4 vs. TGMD-2 (Ré et al., 2018) and KTK4 vs. TGMD-3 (Niemistö et al., 2020). These authors concluded that product- and process-oriented assessment tools measure different aspects of AMC (i.e., gross motor coordination vs. FMS categories), which was clear from the low-to-moderate correlations that were found between the KTK4 and TGMD-2 (Ré et al., 2018). Two other studies examined the process-oriented and product-oriented assessments at skill level. On the one hand, Logan and colleagues (2017) examined associations between the product-oriented score of the standing long jump, hop and throw with the process-oriented validated developmental sequences that exist for these three skills. On the other hand, Hulteen, True, et al. (2020) investigated the association between the run, jump, throw and kick from the process-oriented TGMD-2 with the product-oriented assessments of these skills, respectively (i.e., run time, jump distance, throw and kick speed). Both of these latter studies found positive significant correlations, ranging from weak to strong, indicating that the strength of the association depends upon the skill that is evaluated, the child's age, and the type of assessment (Hulteen, True, et al., 2020; Logan et al., 2017). Taking into account these findings, it seems that product-oriented and process-oriented assessment tools measure different aspects of AMC and, therefore, provide unique (but potentially complementary) information (Cools et al., 2009; Hulteen, True, et al., 2020; Ré et al., 2018), which makes comparing results across our studies less evident. However, since the baseline measurements of **STUDY 2** were already performed before the start of my PhD trajectory, using the same test battery was necessary to allow longitudinal follow-up and analysis. Nevertheless, in the present research, only widely used AMC assessment tools with good reliability and validity indicators were used, which was one of the key statements in the systematic review of Hulteen, Barnett, et al. (2020). Therefore, further examining the existing tools is important, especially in adolescents as the majority of studies investigated AMC in children (Hulteen, Barnett, et al., 2020). This advice was implemented in **STUDY 4**, where the KTK3 short form was combined with the EHC task, revealing excellent factor structure and good construct validity of the KTK3+. This newly composed AMC assessment tool was based on existing tools and measures the whole range of gross motor domains, including aspects of locomotion, object control and stability. The validation of the KTK3+ also adds to the literature as it involves a test battery that can be used in both children and adolescents, making it a valuable tool for longitudinal follow up of AMC. However, using a combination of both product-oriented and process-oriented assessment tools might have offered even more information about children's AMC (Palmer et al., 2021; Robinson et al., 2015; Rudd et al., 2016).

Understanding whether process- and product-oriented assessments provide the same and/or cumulative information is important from the perspective of monitoring and promoting AMC for health outcomes (Hulteen, True, et al., 2020). Indeed, AMC assessment allows for the informed development of interventions by identifying various skill deficiencies in movement execution and/or outcome, which highlights the need for continued research related to the use of both process- and product-oriented assessments (Hulteen, True, et al., 2020).

2.1.3.2 PERCEIVED MOTOR COMPETENCE ASSESSMENT TOOLS

With respect to PMC, two different assessment tools were applied in this dissertation, which might reveal different findings in relation to the perception(s) of one's AMC. In **STUDY 3**, the PSCS was used (McGrane et al., 2016), which is a self-report questionnaire that does not include peer comparison. In **STUDY 5**, we used the SPPC (Harter, 2012), representing a self-report questionnaire that has been developed based on comparing yourself with others. We believe that different perceptions might occur when children use different frames of reference, which is the case when using the SPPC in **STUDY 5**. Without defining the frame of reference, children are asked to compare themselves with "others", but a child may compare him/herself with only the children in his/her class or only with children of the same sex (vs. both) or only peers (vs. broader) or only children from the sports club. This lack of frame of reference may result in other self-perception reports, which was also highlighted by De Meester (2017). It is, therefore, difficult to assess the extent to which children correctly estimate themselves. Moreover, children use different sources of information to build their perceptions. External sources of information include feedback from significant adults or peers such as coaches, parents, peers, role models, and classmates' performance (Weiss, Horn & Ebbeck, 1997). Children up to 10 years of age would see parental feedback as the primary source of information to form perceptions around their own AMC. On the other hand, internal sources of information refer to the internal processes within the child to modify the picture about his/her own AMC. Some examples of internal sources of evaluation are determining whether predetermined goals have been achieved, the degree of skill improvement in a given time, the outcome of a sports competition,... The importance of these internal sources of information was addressed by Harter (1978) in her competence-motivation theory. The author described that when children do not realistically assess their AMC this can have major consequences for their motivation. For example, children who overestimate themselves will never achieve their internal goals, whereas children who underestimate themselves will never maximize their performance because they think "they cannot do it anyway". In both cases, this leads to disappointment in a child. Harter (1978) concludes that it is important for parents, coaches and teachers to adjust the child's perceptions so that he/she can count back on his/her internal sources of information. The switch from the primary use of external to internal sources of information is age-related and does not appear until late adolescence (Horn & Weiss, 1991; McKiddie & Maynard, 1997; Shapiro & Ulrich, 2001; Weiss & Amorose, 2005). The most important information sources for each age group are briefly listed in Table 3.

TABLE 3 - Sources of information for each age group

AGE	SOURCES OF INFORMATION
5-8 years	Task control, effort, feedback from parents (Weiss & Amorose, 2005)
8-10 years	Evaluative feedback from parents, the extent to which they are attracted to a sport (Horn & Weiss, 1991)
11-12 years	Evaluative feedback from significant adults, attraction to sport (Mckiddie & Maynard, 1997)
10-13 years	Peer comparison and peer evaluation

Children also use other sources of information depending on their experience with the sport, which can also relate to their age. In this respect, a study of Amorose & Weiss (1998) revealed that young(er) children (i.e., 6-8 years of age) use more different sources of information to estimate an athlete's skill such as the effort the athlete made or the outcome of the stroke (e.g., did the ball go far and high). In contrast, the older age group (i.e., 12-14 years of age) used a narrower range of information sources in which the "athlete's technique" was found to be very important. The fact that older children place more importance on technique may be explained by the fact that they already have some more movement experience compared to younger children.

Another reason that might explain the different findings in relation to the perception(s) of one's AMC, may have to do with the uniqueness of the AMC test battery being used (i.e., product-oriented vs. process-oriented). In this regard, it is possible that children have less difficulties with feeding product-oriented information back to themselves (e.g., *"How many steps did I walk backwards on the balance beam?"*) when compared to process-oriented information (e.g., *"Did I extend my arm while reaching for the ball as it arrives?"*; True et al., 2017) as highlighted in **STUDY 3**.

2.1.3.3 THE ASSOCIATION BETWEEN ACTUAL AND PERCEIVED MOTOR COMPETENCE

The association between AMC and PMC can be examined by perfectly or less aligned instruments. In this regard, Estevan and Barnett (2018) suggested to use aligned AMC-PMC assessment tools since it could result in establishing a stronger relationship between both constructs. While this could not be confirmed in the meta-analysis of De Meester et al. (2020), the authors also suggested that future research should investigate the alignment between AMC and PMC measurement instruments and its potential impact on the strength of the relationship between AMC and PMC in different age groups more closely. This suggestion was followed in **STUDY 3**, where aligned AMC and PMC assessment tools were used, showing stronger correlations between both constructs in the current study when compared to earlier research also using a person-centered approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Pesce et al., 2018). In addition, we also ran cluster analyses revealing that almost 84% of the children showed convergent levels of AMC and PMC, which is much higher when compared to previous studies using the same statistical approach (Bardid, De Meester, et al., 2016; De Meester, Stodden, et al., 2016; Estevan et al., 2019; Weiss & Amorose, 2005). However, we only used one instrument to measure AMC and PMC while it has been suggested to measure AMC with both a process-oriented and a product-oriented assessment tool (Palmer et al., 2021), which might provide complementary information. Therefore, and to gain more insight in whether different motor competence based profiles could be identified based on different assessments of both constructs, we used a more direct approach to test this hypothesis by combining two AMC and PMC tools that were or were not aligned in the same study sample (**STUDY 2**). Children's AMC was measured using the product-oriented KTK4 as well as the process-oriented TGMD-2. Their PMC was also measured with two different instruments, namely the PSCS and the SPCC. Two separate cluster analyses were conducted post-hoc to identify different profiles. A cluster variable (i.e., AMC, PMC) was labelled as high when the z-score was above 0 and as low when the z-score was below 0. The first one combined two <u>optimally aligned instruments</u> of AMC and PMC: the TGMD-2 and PSCS. The five-cluster solution was found to be the best fit for the data with a Cohen's kappa of 0.67 and explained 76.4 % and 64.3 % in variance in AMC and PMC, respectively. The second cluster analyses combined two <u>mediocrely aligned instruments</u>: the KTK and SPCC. Again, the five-cluster solution was found to be the best fit for the data with a Cohen's kappa of 0.83 and explained 65.9 % and 78.4 % in AMC and PMC variance, respectively. In both five-cluster solutions, two groups were characterized by similar, relatively high or low levels of both AMC and PMC (i.e., low-low & high-high). In addition, two groups were characterized by divergent levels of AMC and PMC (i.e., low-high & high-low). The fifth group was different in both cluster solutions (see Figure 2). Where the cluster analyses with optimally aligned instruments (i.e., the right-hand of Figure 2) revealed an extra high-high profile, the cluster analyses with mediocrely aligned instruments (i.e., the left-hand of Figure 2) revealed an additional low-high profile (see black circles). Accordingly, it can be concluded that the choice of measurement actually impacts the relationship between AMC and PMC, which was previously indicated by De Meester and colleagues (2020) and Estevan & Barnett (2018). Therefore, future research should explore more in depth whether associations will be stronger when the used AMC instrument aligns with the PMC instrument.

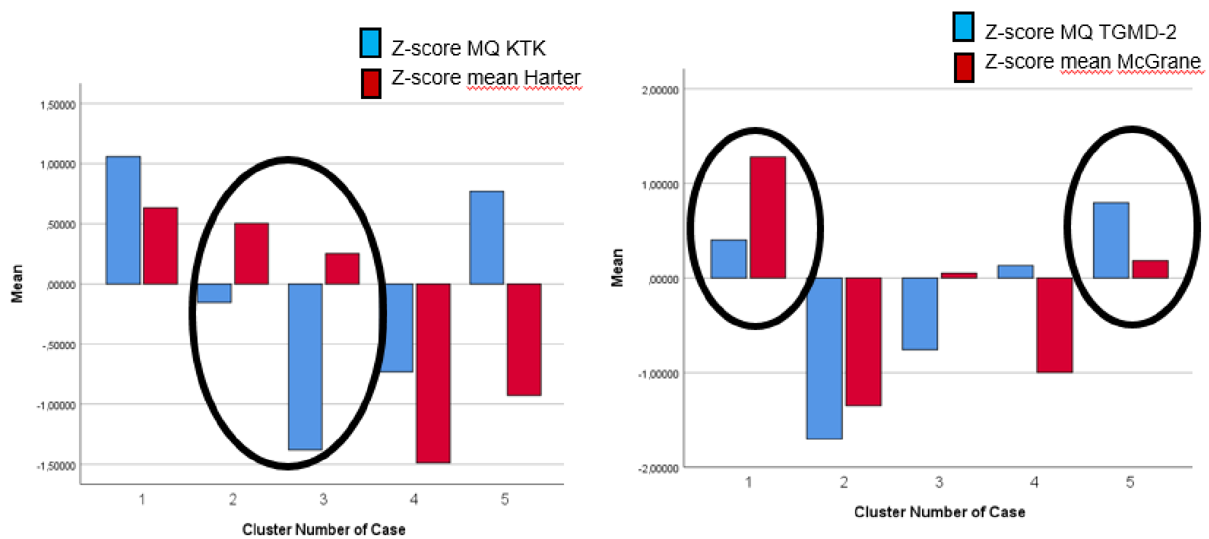


FIGURE 2 - Different motor competence based profiles resulting from using different assessment tools.

Summarizing the results regarding the task determinants, it is clear that, when choosing an appropriate AMC assessment tool, it is important to keep in mind the purpose of the assessment (e.g., identifying motor skill deficiencies vs. understanding current levels of AMC; Bardid et al., 2019) and the established validity and reliability of the assessment tool (Hulteen, Barnett, et al., 2020). Moreover, understanding how and why the strength of associations between AMC assessments may change across developmental time is imperative because some assessments are developed to identify motor skill deficiencies while others have the purpose to map current *and future levels of AMC across childhood and adolescence (Hulteen, Barnett, et al., 2020; Logan et al., 2017). Considering PMC, it is important to realize that the perceptions of one's AMC may be different when the self-report questionnaire includes peer comparison (i.e., SPPC) or not (i.e., PSCS). The present original research also revealed that the choice of measurement actually impacts the relationship between AMC and PMC, since the use of aligned assessment tools revealed other motor competence based clusters/profiles as compared to using less aligned assessment tools.*

2.1.3.4 TOWARD A GOLD STANDARD TO ASSESS MOTOR COMPETENCE

The gold standard for AMC assessment should unify the three domains of fundamental motor skills (locomotion, object control, and stability) in one and the same test battery. To the best of my knowledge, the first test battery that covered all of the abovementioned domains was the Motor Competence Assessment (MCA; Rodrigues et al., 2019). In the MCA, locomotion is measured through the standing vertical jump and 4x10m shuttle run, object control through speed of ball catching and ball kicking, and stability through jumping and moving sideways (two tests that are also part of the KTK3+). Due to the large age range (3-23 years) and the use of the exact same tests for each age group, the MCA seems ideal to measure the development of AMC over time. The test battery also includes normative values specific to age and gender. In 2021, the same authors published a study verifying that the construct of motor competence as measured by the MCA was stable across age groups (Rodrigues et al., 2021), with a positive outcome as the final result. The same holds true for the KTK3+. However, a disadvantage of both the MCA and the KTK3+ is that only the product or (performance) outcome of the movement execution is measured. The advantage is that it is easy to assess the different tests, which is different in process-oriented test batteries where the quality of the movement execution has to be assessed by an evaluator. Although this is done using imposed criteria, there can still be (subjective) differences in ratings between different evaluators (or even within the same evaluator who would evaluate a movement execution more than once). While I would like to put the norm-referenced KTK3+ forward as a very complete (i.e., locomotion, object control and stability skills), easy to administer and not time consuming test battery, we must also recognize that a one-sided focus on product or process may provide different and limited information about motor competence (Logan et al., 2017). A gold standard AMC assessment tool should provide a more complete picture of motor competence, and in doing so, the use of both process- and product-based test batteries can be significant. While a few studies have already combined multiple motor test batteries (Logan et al., 2017; Niëmisto et al., 2020; Ré et al., 2018), to my knowledge there is no test battery that combines both process and product (with the exception of the Movement ABC, which focuses on identifying children with motor problems and thus serves a different objective). Therefore, adding qualitative information for strong(er), moderate and weak(er) movers (i.e., criterion referenced information) to the validated KTK3+ would be of great value, an idea for which a pilot study has been started in our lab by incorporating movement analysis techniques. For example, one child may achieve the highest score on balance beam (i.e., 72) without performing additional movements with the arms or accelerations on the beam, while another child does need these adaptations in order to reach the highest score. In doing so, wearable motion capture devices using Visual 3D (Qualisys) might be helpful. The system consists of a number of motion capture cameras, usually about 8 to 12 cameras, placed in a space around the moving subject, recording the path of the markers that are applied on the body of the subject. A group of markers together represent a segment of the body, such as the lower leg or upper arm. Two segments together represent a joint. Based on the markers, a 3D model is created (see Figure 3). The marker information from the recordings is used together with body dimensions of the subject to calculate kinematic variables like joint angles. Because the system is calibrated, the system "knows" where the cameras are positioned in relation to each other and to the subject.

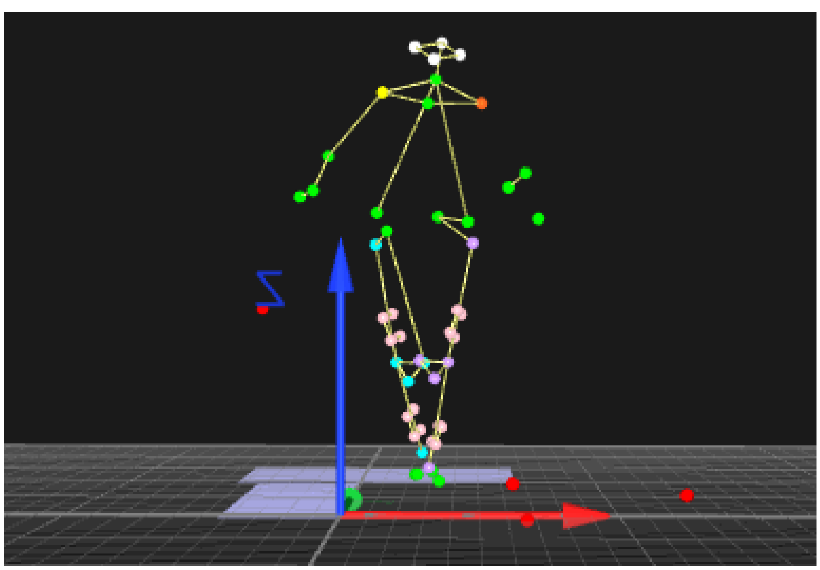


FIGURE 3 – Dynamic balance in visual3D (Qualisys) during our pilot study

With respect to PMC, future research would benefit from using a tool that is aligned with the AMC assessment tool (De Meester et al., 2020). For the purpose of STUDY 3 , four items were added to the PSCS questionnaire, in alignment with the four KTK subtests (i.e., *"How well can you perform walking backwards on a balance beam?", "How well can you perform moving sideways as fast as possible with the aid of two wooden boards?", "How well can you perform jumping sideways over a slat as fast as possible?", "How well can you perform hopping for height on one leg over an increasing number of foam squares?"*). That way, the AMC and PMC assessment tool were perfectly aligned.

Finding a measurable set of skills that can provide a representative picture of children's general AMC is clearly a challenge. As Bardid et al. (2019) noted in their hitchhikers' guide, a gold standard for AMC for any setting does not exist. However, unifying a product- and process-oriented assessment tool for AMC in one test instrument as suggested above with the KTK3+, in combination with a perfectly aligned PMC questionnaire (without peer comparison, as in STUDY 3), might be a promising strategy in order to get a better insight in the development of motor competence across a wide age range.

2.1.4 CONCLUSION REGARDING THE DETERMINANTS AFFECTING AMC AND ITS DEVELOPMENT

Our results regarding the determinants of AMC and its development revealed some interesting findings. Combining the schematic overview of these findings (see Figure 1 of the general discussion) with the theoretical framework underlying this dissertation (see Figure 8 of the general introduction) resulted in the graphical representation below (Figure 2), which is based on the conceptual model of Stodden et al. (2008) as well as Newell's model of constraints (1986).

From our work, it can be concluded that the <u>individual determinants</u> age (increasing), sex (boy), weight status (lower), health-related fitness (higher), PMC (higher), autonomous motivation toward OSP (higher) all impacted upon children's momentary AMC. Moreover, being younger, being a boy, and having a lower weight status were associated with a steeper evolution and thus a more pronounced improvement in children's AMC level across developmental time. It also appeared that particularly overweight/obese children are at higher risk of becoming less motor competent over time, which partly supports Stodden and colleagues' (2008) notion of a 'negative spiral of disengagement'.

With respect to the <u>environmental determinants</u>, despite the previous reporting of a short-term positive impact, our results revealed no long-term effect on AMC of a specific FMS intervention (i.e., Multimove for Kids) when children were reassessed six years later. Notwithstanding, our findings did reveal and thus highlight the importance of OSP with regard to childhood AMC and its development: type of sports being practiced (predominantly object control-oriented), weekly time spent in OSP (more) across childhood years, and years of experience in OSP (more) seem beneficial for momentary levels of AMC. Moreover, being involved in object control-oriented activities and spending more time in OSP was also beneficial for AMC development. In addition, being involved in multiple sports was related to higher levels of cardiorespiratory fitness and PMC.

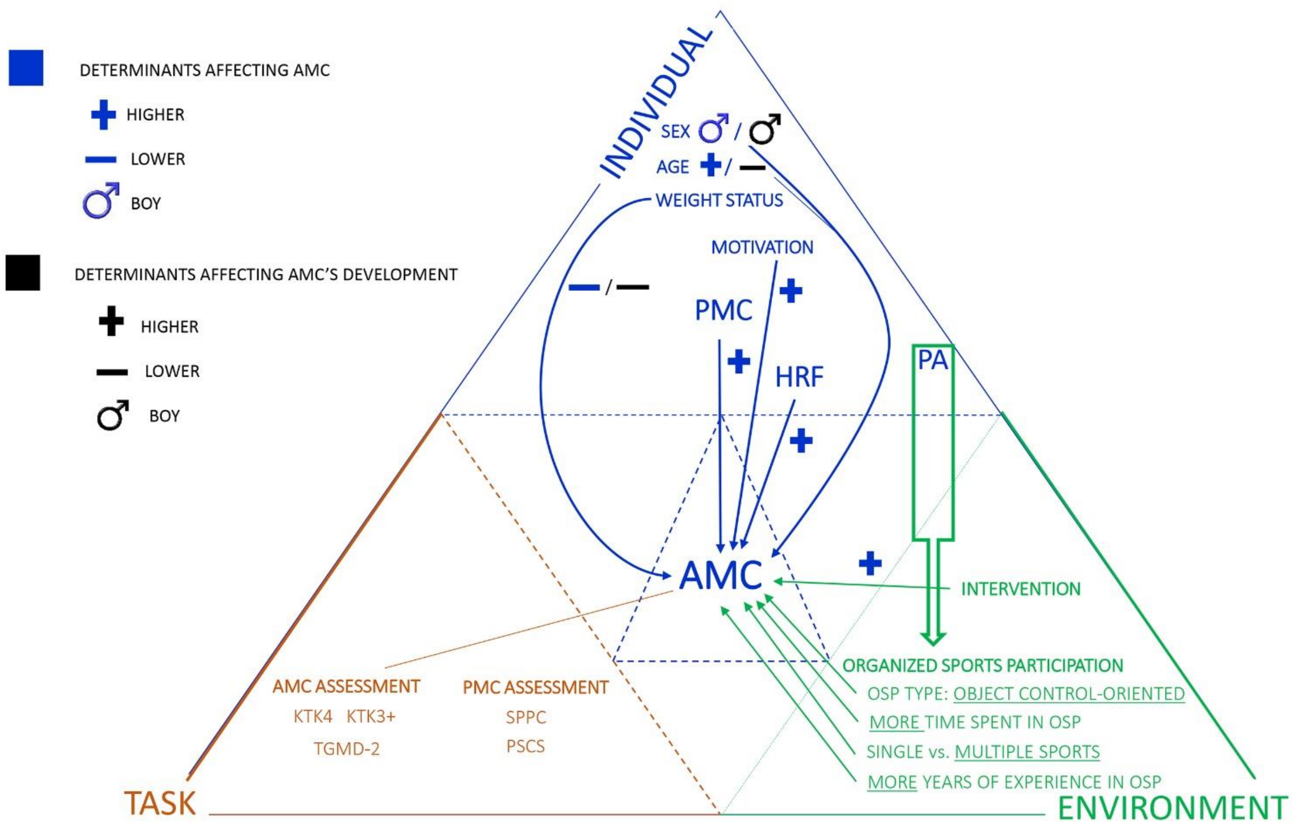


FIGURE 4 – Visual representation of individual, environmental and task-related determinants affecting a child's AMC and its development as being part of this dissertation, based on combining the constraints model of Newell (1986) and the conceptual model of Stodden et al. (2008). The blue arrows represent the reciprocal relationships between the constructs as hypothesized in the original conceptual model of Stodden et al. (2008). The green frame around PA indicates the relationship between PA and OSP.
(AMC: actual motor competence; PMC: perceived motor competence; HRF: health-related fitness, PA: physical activity; KTK4: KörperkoordinationsTest für Kinder; KTK3+: KörperkoordinationsTest für Kinder + eye-hand coordination task; TGMD-2: Test of Gross Motor Development – Second Edition; SPPC: Self-Perception Profile for Children; PSCS: Physical Self-Confidence Scale; OSP: organized sports participation)

Our findings regarding the task determinants highlight the importance to take into account the purpose of measuring AMC when choosing an AMC assessment tool (Bardid et al., 2019), as certain AMC assessments may be able to adequately discriminate levels of proficiency in typically developing children while others are not able doing so (Logan et al., 2017). Moreover, it is important to bear in mind the measurement properties and the established validity and reliability of the assessment tool (Bardid et al., 2019; Hulteen, Barnett, et al., 2020). Considering PMC, different perceptions might occur when children use different frames of reference. It is clear that the choice of assessment tool may impact the results on children's AMC (development) and (its relationship with) their PMC.

2.2 INDIVIDUAL VARIABILITY AND PERSON-CENTERED APPROACH

While discussing the findings regarding the different determinants affecting developmental change, we did not yet reflect on the inter-individual variability that was found in our studies. Therefore, this will be discussed at length in the next section. Moreover, reflections are provided on the difference between examining AMC and its development at group vs. individual level on the one hand, and by using a variable-centered vs. a person-centered approach on the other hand.

2.2.1 GROUP vs. INDIVIDUAL LEVEL

Although studying change in motor development at group level provides valuable information regarding age-related trends (Getchell et al., 2020), it does not take into account the individual progression or change over time within each single individual within a group or population. If we want to gain more insight in inter-individual variability of AMC development, we should move beyond group outcomes and reject the assumption that the entire population is homogenous with respect to how variables influence each other (Laursen & Hoff, 2006) as every person thrives in his/her unique ecological system. This was suggested by Malina (2014) and further supported by Rodrigues and colleagues (2016), who showed that the development of AMC and health-related fitness during childhood is identified by a high degree of inter-individual variation, which brings me back to the *first objective* of this dissertation. That is, gaining more insight in the individual variability in children's AMC development (**STUDY 1 & 2**).

To illustrate how studying change over time at group level differs from studying change at a more individual level, two figures were produced based on the data collected for the purpose of **STUDY 1**. In this study, 558 children aged between 6 and 9 years at baseline were assessed three consecutive times (i.e., in 2007, 2008 and 2009). Figure 5 presents the mean AMC level for the entire study sample at each time point, indicating an overall positive development of AMC at group level (see the dotted trend line). In this figure, the variability in the sample is presented by the standard deviations provided with the annual group means.

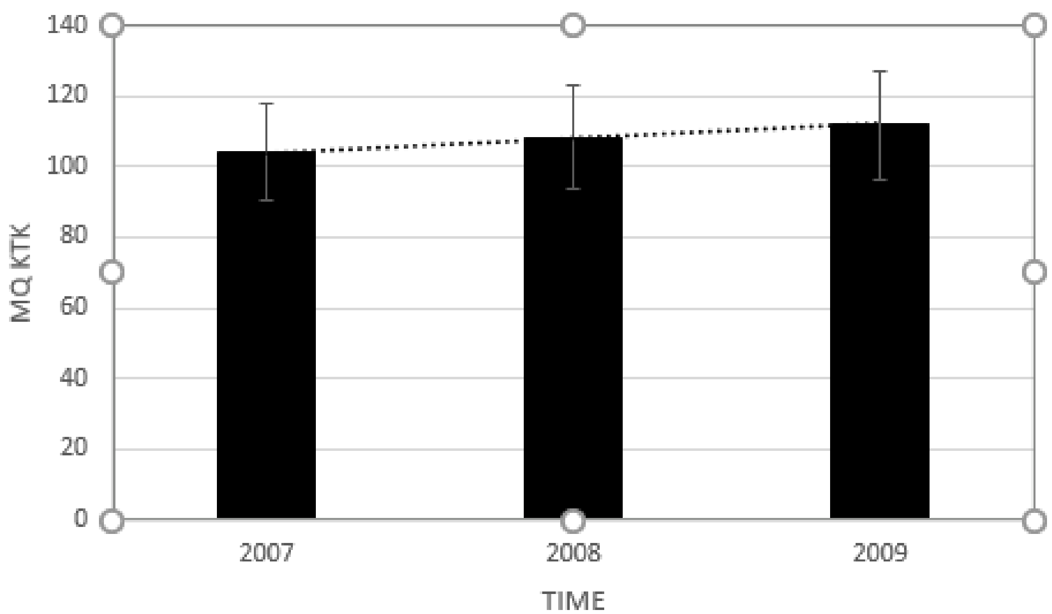


FIGURE 5 - Representing AMC development at group level

This presentation shows that AMC improves with time, and implicitly feeds the idea that this will hold for each child of the study sample. In contrast, Figure 6 illustrates a more individual-centered approach, where individual trajectories of change in AMC among that same study sample are presented. Every line or trajectory represents a single child's development over the 2-year timespan of the study at hand. Children were divided into three groups based on their change in AMC over time as a shared particular characteristic, making this approach more person-centered. These three groups include the low rate of change group (Panel A), the average rate of change group (Panel B), and the high rate of change group (Panel C), as based on the associated percentiles (i.e., < P25 (= low), P25 - P75 (= average), > P75 (= high), respectively). The thick black lines always represent the average AMC developmental trajectory in each of these rate of change groups. Visual inspection of Figure 5 shows a large variability even within the different rate of change groups, indicating that not all children improved their AMC level from one time point to the next. As a matter of fact, a number of children stagnate (1.1%) or demonstrate delayed AMC development (14.7%) over time and with increasing age when compared to the test battery's reference sample (Kiphard & Schilling, 2017). Interestingly, it can also be noted that each rate of change group includes children with a high(er) or low(er) level of AMC at baseline indicating that every child can change (and preferably improve) his/her level of AMC over time which is important information considering interventions targeting AMC.

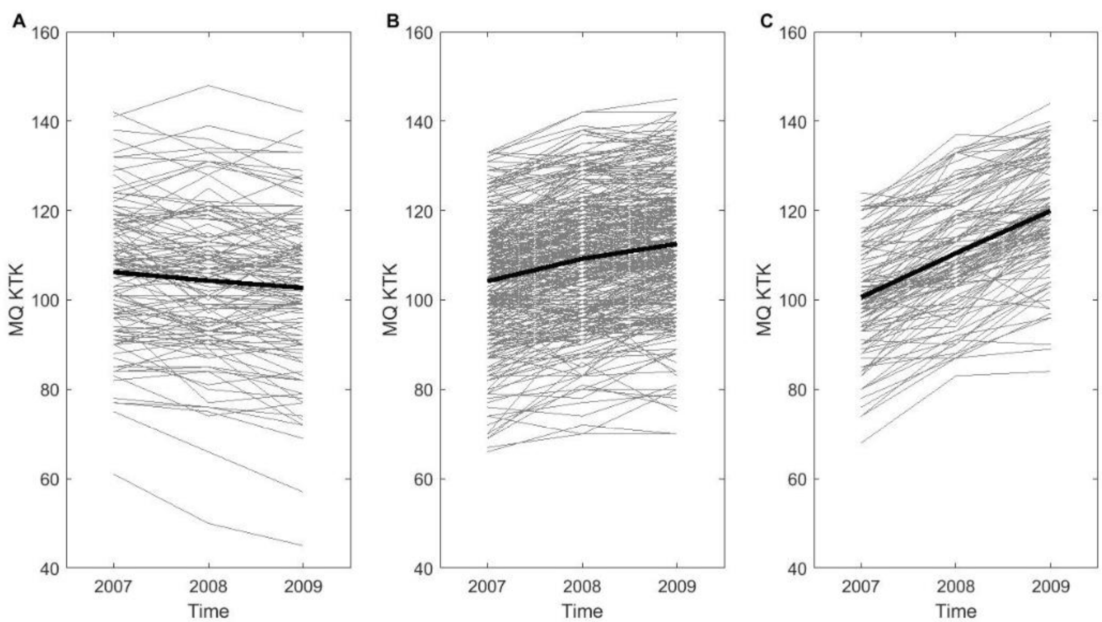


FIGURE 6 - Representing AMC development at the individual level

To study individual developmental change, LGCA was used in **STUDY 1** and **STUDY 2** because its focus is on the description of individual change as a function of time, resulting in a curve shape that indicates the trajectory of change. Moreover, a fully expanded LGCA takes into account both factor means and variances, which correspond with individual differences. In addition, LGCA can also be used to study predictors of individual differences to answer questions about which variables have important effects on the rate of development (Duncan & Duncan, 2009). Using LGCA allows for the estimation of inter-individual variability in intra-individual trajectories of change over time, which is beneficial in order to gain more insight in AMC development between the individuals and within the person. Moreover, considering inter-individual variation within the population is useful since this may help in developing interventions that make optimal use of differentiation in order to support all children, including those children who lag behind (Niemistö et al., 2020).

2.2.2 VARIABLE-CENTERED vs. PERSON-CENTERED APPROACH

Another way of gaining more insight in individual differences is using data clustering techniques. Whereas a variable-centered approach is well suited for addressing questions that concern the relative contributions that predictor variables make to an outcome, a person-centered approach identifies groups of individuals who share particular characteristics or relations among characteristics (Laursen & Hoff, 2006). Related to our predefined *second objectiv*e, it should be noted that a variable-centered approach would not provide insight into how different AMC and PMC levels may be combined at the individual level. Accordingly, by assuming subgroups of individuals within a sample of children, a person-centered approach can help to detect those groups where the mutual associations among AMC and PMC are most striking. Therefore, a person-centered approach is needed to examine whether children with similar AMC levels may differ in the degree to which they perceive themselves as motor competent.

Both approaches will be illustrated and compared, based on the data of STUDY 3. In this study, cluster analysis (i.e., one possible way of performing a person-centred approach) was used to provide a deeper understanding of previous identified AMC and PMC profiles. To this end, OSP as an additional extrinsic cluster variable was included next to both aforementioned intrinsic cluster variables as combined in previous studies. In this respect, Table 4 represents the Spearman's rank correlation coefficients between the three cluster variables (i.e., AMC-PMC-OSP) and the outcome variables of interest (i.e., children's weight status or BMI and their autonomous motivation toward sports). These correlations describe the association between the cluster and/or the outcome variables in the overall sample. For example, a positive association between AMC and OSP (moderate strength) and a positive correlation between AMC and OSP (low strength) were found. Whereas this information provides an overall picture of the average association between the cluster variables included in this study, it does not contribute to gaining more insight in their association at the individual level. Indeed, the overall correlations do not indicate whether children with similar AMC levels may differ from each other in their PMC and OSP levels.

TABLE 4 - Correlations among cluster (i.e., 1-3) and outcome (i.e., 4-5) variables

		1	2	3	4
	Cluster Variables				
1	Actual motor competence *(MQ)*				
2	Perceived motor competence *(scale 1-10)*	0.502**			
3	Organized sports participation *(hours/week)*	0.308**	0.137		
	Outcome Variables				
4	Body mass index z-score	-0.292**	-0.197*	0.057	
5	Autonomous motivation *(scale 1-5)*	0.302**	0.333**	0.405**	-0.079

MQ: motor quotient; ** $p < 0.001$; * $p < 0.01$

Using a person-centered approach by means of cluster analysis allows to investigate how the cluster variables (i.e., AMC, PMC, OSP) are combined within individuals and to examine whether children with similar AMC levels may differ in their PMC and OSP. Accordingly, six different profiles could be identified in STUDY 3 as visually presented in Figure 7. Three of these profiles had completely convergent levels of AMC, PMC and OSP, representing 52.2% (*n* = 104) of the total sample. Furthermore, three profiles with partially convergent levels of AMC, PMC and OSP were found, representing 47.8% (*n* = 95) of the entire study sample. Children in the convergent profiles with average to high levels of AMC, PMC and OSP had the most optimal profile as they combined a healthier weight status with elevated levels of autonomous motivation toward sports, while the opposite was true for children with low levels on all three cluster-variables. Partially convergent profiles showed that AMC and PMC appear crucial for weight status as profiles with relatively low levels of AMC and PMC had the highest weight status, independent of children's OSP levels.

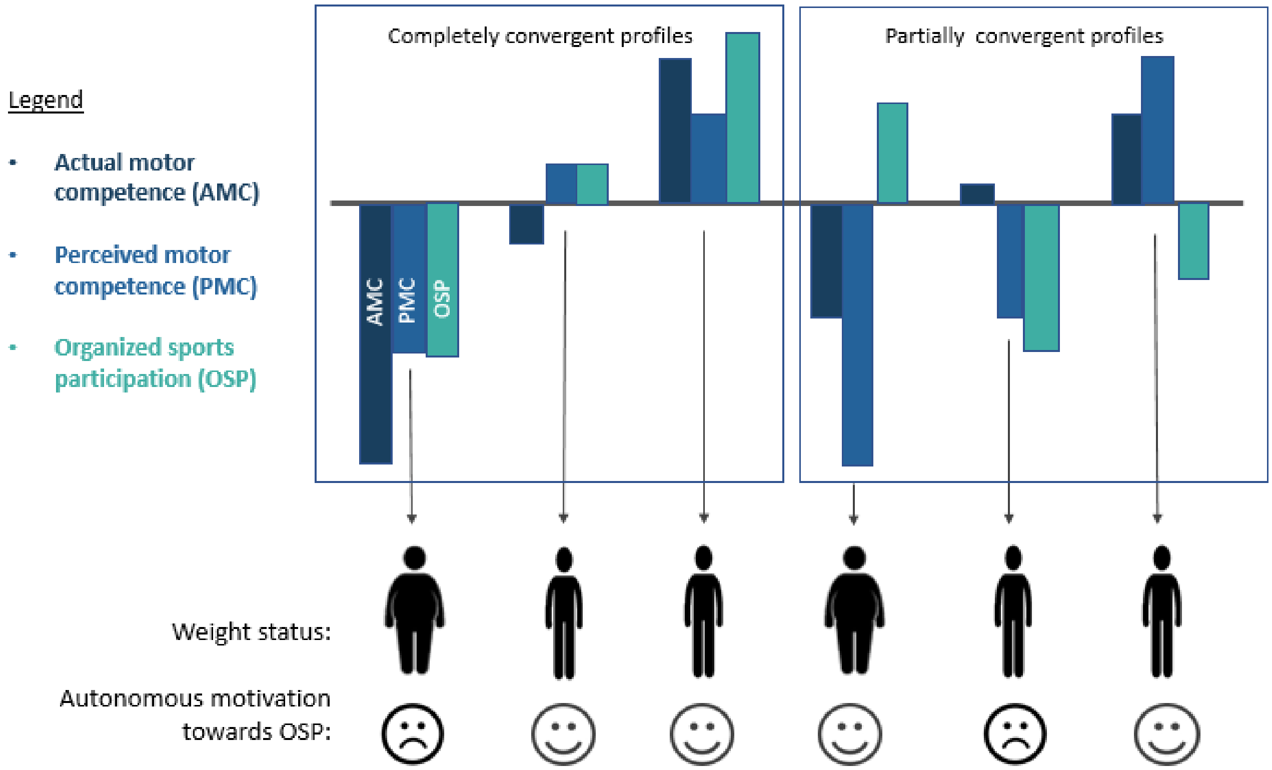


FIGURE 7 - Identification of six profiles based on actual motor competence (AMC), perceived motor competence (PMC) and organized sports participation (OSP) linked to differences in children's weight status and autonomous motivation toward OSP.

It is important to note that variable-centered and person-centered strategies should not be considered as competing but as complementary approaches. As stated by Laursen & Hoff (2006): "Variable strategies are more appropriate for questions concerning relations among variables; person strategies are more appropriate for questions concerning differences among individuals." In light of our *first objective* (i.e., gaining more insight in children's individual change in AMC across childhood and the variability in developmental trajectories) and *second objective* (i.e., providing a deeper understanding of previously identified motor competence based profiles), choosing to move beyond reporting and analyzing findings at group level and to apply a person-centered approach was extremely helpful. We can conclude that the combined use of variable- and person-centered approaches in motor development research is a worthwhile gateway to truly understand developmental trajectories, design successful interventions, and tailor these interventions to the characteristics of subgroups within the target population.

3 - STRENGTHS, LIMITATIONS AND FUTURE DIRECTIONS -

The general aim of this dissertation was to gain more insight into some specific individual, environmental and task-related determinants of children's AMC and its development. In doing so, several strengths and limitations can be attributed to the original research conducted. While the five included studies allowed to answer a number of research questions, other questions remained unanswered or more questions arose. Therefore, suggestions and recommendations for future research are provided alongside the cited strengths and limitations of our work.

3.1 STRENGHTS

3.1.1 THE ECOLOGICAL PERSPECTIVE ON MOTOR DEVELOPMENT

In order to gain more insight in motor development, this dissertation originated from a holistic point of view. It was suggested that optimal motor development is related to the degree to which practice opportunities are tailored with the individual (Haywood & Getchell, 2019). From an ecological perspective, AMC development is thus influenced by the so-called individual factors as well as by factors that do not originate within the individual, like environmental and task determinants. Therefore, we did not only take into account the individual and his/her characteristics by using the model of Stodden and colleagues (2008). We also placed this individual-oriented developmental model in the broader ecological framework of Newell (1986). To this end, we focused on investigating some environmental determinants, which seems to be important when it comes to general individual development. In addition, attention was given to the task-related determinants as well. All of this resulted in an adapted / combined model which was used as the theoretical foundation of this research. This overarching model was helpful in structuring, reporting and discussing our findings, and may encourage further discussion on motor development research.

3.1.2 LONGITUDINAL DESIGN

In the field of AMC a lot of evidence relies on cross-sectional studies which might create bias, since potential associations and relationships between study variables may be identified without indicating direct causation. Moreover, cross-sectional data offer a picture of a specific point in time without considering what happens before or after the picture is taken. Therefore, more longitudinal studies are needed to truly test the associations between constructs over time. This dissertation added to the literature since a longitudinal research design was used in the first two studies being included in the original research, involving a 2-year (i.e., **STUDY 1**) and 6-year follow-up (i.e., **STUDY 2**). This prospective approach allowed us to examine true developmental change in AMC and to provide insights into causal mechanisms and variable patterns of its evolution over time. These studies are considered highly valid for determining long-term changes and are unique in themselves when it comes to providing useful data about individual developmental changes. However, exploring individual change in AMC across childhood is also important in order to develop more effective movement programs and to better support all children's motor development. In doing so, future studies are needed to determine the optimal characteristics of AMC interventions or movement programs (e.g., type of approach, amount of instruction time, frequency, duration, differentiation) to be successful in maintaining its intervention effects in the long run. This can help us in order to provide guidelines for a more efficient program design to facilitate an effective long-term impact of AMC interventions. In addition, this advancement will help to support positive health trajectories across childhood and adolescence (Robinson et al., 2015), and it will inform decision making in policy and practice.

3.1.3 STATISTICAL APPROACH

Our findings highlight the importance of exploring individual change in AMC across childhood. Accordingly, we used LGCA to move beyond analyses performed at the group level. LGCA is a statistical technique to study change in AMC and how these developmental changes differ between persons (i.e., **STUDY 1 & 2**). Using LGCA is distinguished from more traditional methods for analyzing change over time because it affords the examination of both observed and latent variables, allowing to account for changes in individual differences that are not reflected in a group's mean or average effect and to separate true variance from measurement error (Kline, 2011; McArdle & Nesselroade, 2003). Moreover, a person-centered approach was also applied in **STUDY 3** to enable a deeper understanding of how AMC, PMC and OSP are combined within youngsters and in turn relate to their weight status and autonomous motivation toward sports. This approach resulted in identifying six unique profiles of AMC-PMC-OSP in childhood, supporting the idea that measures related to AMC work in an integrative manner to produce differences in children' s physical and psychosocial health outcomes. However, we did not combine both innovative approaches in one study, which implies that children's possible temporal shifts among profiles were not taken into account (Estevan et al., 2021). Nevertheless, a combination of both methods seems an ideal strategy to gain even more insight in children's individual developmental change. Therefore, future research is recommended using a person-centered approach applying longitudinal study designs.

3.1.4 ORGANIZED SPORTS PARTICIPATION FEATURES AND SPORTS TYPE INDEX

Another strength of the research presented in this dissertation is the wide spectrum of information regarding OSP as a forward shifted environmental determinant (i.e., STUDY 2, 3, 4 & 5), including training history across childhood from 2 years up to the current age of the child, and thus providing a broader understanding of each child's OSP across developmental time. To the best of our knowledge, this is the first study that investigates the impact of four different OSP features in relation to AMC (i.e., STUDY 2, 3 & 5) and other health-related outcomes (i.e., STUDY 5). One of the investigated aspects of OSP was the type of sports being practiced as suggested by Barnett et al. (2013) and Henrique et al. (2016). Based on experts' opinion, a novel tool was developed to determine the type of sports in which children were predominantly involved. This tool was first validated and then used in two studies included in this dissertation (i.e., STUDY 2 & 5). Based on the input of these experts from the field of motor development (all with a master degree and/or PhD in movement science), an averaged value between -1 (i.e., purely locomotor-oriented sports) and +1 (i.e., purely object control-oriented sports) was obtained for all reported sports, which resulted in a sports type index (see STUDY 2, p.91-92). This index adds to the existing literature as the same approach can be adopted in other research, making it easier to compare findings regarding the effect of type of sports.

The results of the present study clearly highlights the need for longitudinal and experimental research investigating the effect of OSP features among children on physical and psychosocial outcomes like their AMC, PMC, weight status and autonomous motivation. Future studies should track OSP in a more objective manner so (recall) bias in data collection can be minimized. In doing so, a close collaboration with the government and/or sports federations might be a promising strategy to gather this information.

3.1.5 VALIDATION OF A MOTOR TEST BATTERY FOR CHILDREN AND ADOLESCENTS

As pointed out in a recent review, it is better to enhance the measurement properties of existing assessments instead of developing new ones (Hulteen, Barnett, et al., 2020). These authors also suggested to investigate the measurement properties of tools developed specifically for evaluating older children's and adolescents' levels of AMC. In the context of this dissertation, the short form of the widely used KTK was combined with an object control task in order to cover the whole spectrum of FMS (i.e., locomotor skills, object control skills, and stability), resulting in the KTK3+. This makes this product-oriented tool of high practical value, especially for the longitudinal follow-up of AMC given that the tasks to be performed are similar regardless of a child's momentary age. The large age range, the easy test protocol and quick set up are major strengths of the KTK3+ test battery. Moreover, new AMC normative values were provided and validated in a Flemish reference sample of 2271 6- to 19-year-old participants (**STUDY 4**). These updated norms allow a better monitoring of the evolution of (Flemish) children's AMC development over time while taking into account changes in behavioral patterns, which impact this development through the course of time (Lenoir & Vandorpe, 2013).

3.1.6 ALIGNMENT IN ASSESSMENT TOOLS

The use of aligned assessment tools to simultaneously measure AMC and PMC (**STUDY 3**) adds to the existing literature as it helps to gain more knowledge on children's self-perceptions and to assess the extent to which children correctly estimate themselves. Moreover, an additional cluster analysis comparing fully aligned and mediocrely aligned assessment tools revealed different clusters/profiles, which confirms that the used assessment tools actually impact the strength of the relationship between AMC and PMC (De Meester et al., 2020; Estevan & Barnett, 2018). However, different questionnaires to measure PMC were used in this dissertation, so more research is required. In this respect, the field of motor development would benefit from conducting more longitudinal studies to investigate the relationship between AMC and PMC across developmental time while using aligned instruments.

3.1.7 LARGE SAMPLE SIZES

Each study sample consisted of a collection of diverse subgroups (e.g., children from different organized sports clubs and from different schools; children from different areas in Flanders and schools in different Flemish provinces), ranging from more than 200 (i.e., STUDY 3) up to more than 2000 (i.e., STUDY 4) participants. While our sample sizes were indeed reasonably large, they all relied on convenience sampling. Future studies should ideally use stratified random samples so it can be assumed with greater certainty that the study participants mirror the aspects of the broader population from which they were selected, and that the study results are thus fairly representative of the respective target populations.

3.2 LIMITATIONS

Inevitably, there are also some limitations that have to be acknowledged together with suggestions and recommendations for future research.

3.2.1 PARENTAL PROXY-REPORT

Probably the biggest limitation of our work relating to the environmental constraints is the use of parental proxy-report for the OSP features (**STUDY 2 & 5**), which requires the ability to retrieve information from long-term memory (Van den Brink, 2001). Unfortunately, this approach is subjective and prone to recall bias since the received information relies on respondent's report (Raphael & Cloitre, 1994). Personal factors shown to be related to recall errors are age, gender, socioeconomic status, the respondent's psychological state (e.g., his or her mood), motivation of the respondent and social desirability (Coughlin, 1990; Van Den Brink, 2001). Other factors are the length of time between the occurrence of an event and the recall of that event, the salience of the event and interference (Van Den Brink, 2001). Interference occurs when an individual experiences an increasing number of events. As a result, the probability of recalling any one of those events specifically declines. All these factors can lead to an overestimation or underestimation of the event, which is dependent on their mutual coherence (Biemer et al., 1991; Van den Brink, 2001). A better approach would have been to use the detailed retrospective interview procedure of Côté et al. (2005). Such an interview consists of three general content areas: measured and description of current and past levels of performance, engagement in domain-related activities and factors limiting the quality and quantity of training. The aim of the interview is to examine how performance changes over time and if differences in performance can be predicted. While this approach is of great value, due to the large amount of children in our studies in combination with time constraints (i.e., one interview takes two to three hours per participant), we only asked for rudimentary information, which is perhaps the least likely to be affected by recall bias. That is, most parents will remember when their children were enrolled in organized sports, which types of organized sports their children practiced and how many hours per week each of these activities was scheduled for. In addition, we verified the received information with the governing body overarching all Flemish sports federations (i.e., Sport Vlaanderen), allowing us to check whether or not the children were actually enrolled in organized sports. However, we could not check whether and, if so, how often the child attended the organized sports sessions in the clubs in which they were assumed to participate. Therefore, future studies are encouraged to include more detailed and preferably objectively collected information about participants' OSP.

The present research is a first attempt to capture OSP in a more detailed and systematic manner using specific questions on type and frequency of participation across the developmental years. Understanding the potential differential effects of OSP on AMC and other health-related outcomes, might also enhance our understanding about sustained OSP across childhood.

3.2.2 DIFFERENT ACTUAL MOTOR COMPETENCE ASSESSMENT TOOLS

The use of two different product-oriented (i.e., KTK4 & KTK3+) and one process-oriented (TGMD-2) assessment tool for AMC, is a second limitation because it makes comparison of the results across studies somewhat more difficult. These assessment tools do not only measure a different number of skills (i.e., KTK4 and KTK3+ (N = 4) vs. TGMD-2 (N = 12)), they also provide different information regarding AMC assessment (Cools et al., 2009; Hulteen, True, et al., 2020; Ré et al., 2018). Moreover, in **STUDY 2**, the age of our study sample at follow up ranged between 9 and 14 years, which implies that the majority of the children was already older than the upper limit of the TGMD-2 (i.e., 10 years and 11 months). However, we did not originally intend to follow-up this cohort of children after such a long time, but the Flemish government explicitly asked us to investigate the long-term effects of the 'Multimove for Kids' intervention since this was a policy-based initiative. So, to allow for a longitudinal analysis we were tied to use the TGMD-2 again for the re-assessment of children's AMC at follow-up. When choosing an AMC assessment tool, it is important to ensure the tool has been validated among the age group it purports to assess (Barnett et al., 2016). Moreover, the tool should be representative for the competence a child needs at a particular period in his/her life, covering the broad spectrum of AMC from overall motor coordination to FMS.

3.2.3 NO INFORMATION REGARDING PHYSICAL ACTIVITY

While previous research suggested a reciprocal relationship between AMC and PA (De Meester, 2017; Logan et al., 2015; Robinson et al., 2015; Stodden et al., 2008), we did not investigate PA as a determinant influencing children's AMC and its development, nor did we investigate the determinants affecting PA. General data on PA are thus lacking in this doctoral thesis. Worldwide, the majority of youth (11-17 years of age) do not meet the current international recommendation of at least 60 min of moderate-to-vigorous PA per day (Aubert et al., 2018; Sallis et al., 2016) while the positive physical, psychological, developmental, cognitive and social health effects of sufficient PA in the short- and long-term in this age group are prone (Biddle et al., 2011; Donnelly et al., 2016; Janssen et al., 2010; Poitras et al., 2016; Reiner et al., 2013, Strauss et al., 2001). Therefore, it is essential to understand which factors might influence youngsters' PA behavior. Based on the Health Belief Model (Strecher & Rosenstock, 1984), it has already emerged that perceived advantages and disadvantages influence an individual's behavior significantly. Subsequently, demographic and psychological background variables also exert an impact on behavior. Furthermore, it emerged from the Theory of Planned Behavior (Ajzen, 1991) that behavior is best predicted by behavioral intention, which in turn is influenced by attitude, subjective norm and perceived behavioral control. In addition to the influence of these intra-individual factors, the ecological model of PA and sedentary behavior (Sallis et al., 2015) also identified the importance of environmental factors in relation to PA and sedentary behavior. Based on these models, the influencing factors of PA can be divided into three main components: the demographic factor (including age, gender, and SES), the psychosocial factor (including self-efficacy, social influence, attitude and perceived (dis)advantages) and the physical environment (including factors such as the movement friendliness, safety, aesthetics and availability of facilities). While investigating the determinants of PA was not subject of the current dissertation, it is important to highlight that the relationship between AMC and PA might also be influenced by (some) of these aforementioned factors. For example, socialization figures such as physical education teachers, youth sports coaches, and parents, can stimulate youngsters' engagement in PA, which might also affect their OSP.

In the current dissertation, we only focused on children's OSP, as a specific type of leisure-time PA, which is a part of the umbrella term 'PA' as stated by Corbin (2000). In doing so, some children will be categorized in the non-organized sports setting while they might be active in non-organized activities (e.g., active transport, active leisure time like going for a run on a regular basis or jumping on the trampoline in the backyard). However, previous research established that OSP contributes to achieving children's and adolescents' daily recommended PA level (Guagliano et al., 2013). OSP thus only represents a part of the sport participation pattern, and by extension the total amount of PA.

OSP does contribute to achieving children's and adolescents' daily recommended PA level (Guagliano et al., 2013), but future research might pay more attention to disentangling OSP, non-OSP, and PA, and their respective associations with MC development.

3.2.4 A REAL ECOLOGICAL PERSPECTIVE ON AMC?

In addressing the role of individual, environmental and task-related determinants in view of children's AMC and its development – as the main goal of this dissertation – a selection of determinants was investigated. However, that selection was not conclusive, meaning that a range of other individual, environmental and task-related determinants were not taken into account in this dissertation. In this respect, a limitation is the lack of information regarding participants' socio-economic status, which could also affect AMC and its development (Barnett, Lai, et al., 2016; Cools et al., 2011). Especially since children from socio-economically disadvantaged settings are vulnerable to delays in their FMS (Brian et al., 2017a; 2017b; Goodway et al., 2010; Goodway & Branta, 2003; Robinson & Goodway, 2009). With respect to OSP, it would have been of great value to know this information, since previous studies have shown that several factors play a role in OSP (e.g., sex, socio-economic status, social support from parents and friends, and economic resources; Eime et al., 2013; Vandendriessche et al., 2012). For example, children with a lower socio-economic background may have less access to OSP (Eime et al., 2013), particularly those that require expensive equipment (e.g. ice hockey) or private classes (e.g. horse riding) and major time commitments from one of their parents (i.e., parental support).

Parental support is another uninvestigated determinant that might have biased my results since it relates to OSP. Indeed, a longitudinal study of Basterfield and colleagues (2016) revealed that parental support is vital with respect to OSP as the children may be considered too young to travel independently to their activities. The parental involvement is also necessary with respect to financial resources and permission (Basterfield et al., 2016). Children may also have to choose between sports as there may not be enough money and/or time for them to do all sports they would like to do, especially considering transportation and practice time that parents may not be able to provide (Holt et al., 2011; Wetton et al., 2013). The importance of parental support was also highlighted in the systematic review of Somerset & Hoare (2018) regarding barriers to children's OSP. Therefore, future studies are recommended to take these additional factors (i.e., SES, parental support) into account when examining the determinants of AMC and its development.

Future studies are recommended to take these additional factors (i.e., SES, parental support) into account when examining determinants affecting AMC and its development. Moreover, exploring to what extent the physical and social environment (including factors such as (traffic) safety, attractiveness and availability of facilities) impact on (the development of) AMC would be interesting.

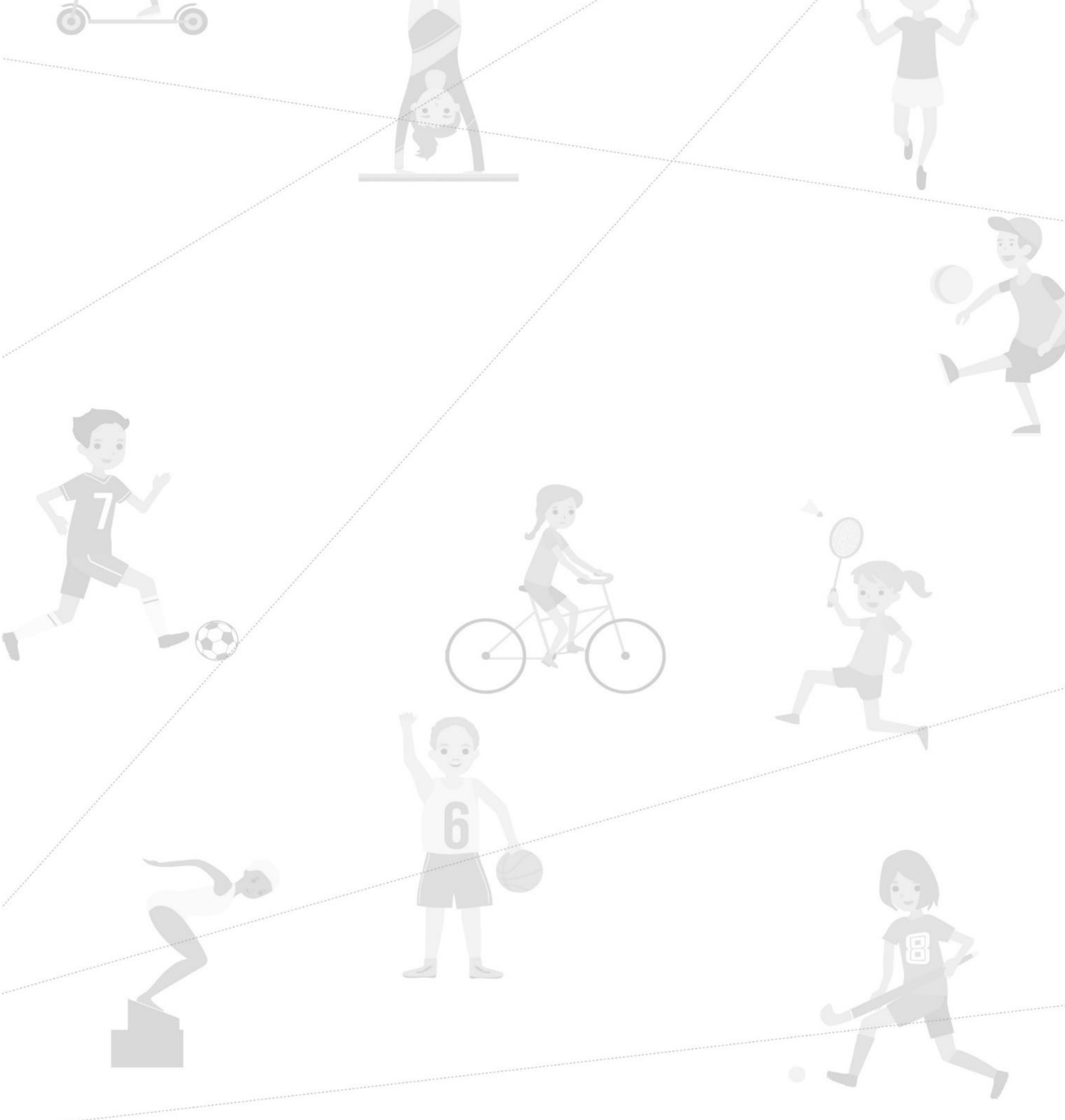
3.2.5 IMPACT OF COVID-19

While we intended to investigate the developmental model of Stodden and colleagues (2008) longitudinally with two time points in **STUDY 5,** we were obliged to amend the original research plan due to the COVID-19 pandemic. The stringent measures and logistic constraints in our country (e.g., school and sports club closures) did impact the data collection tremendously. For this reason, the original research questions of **STUDY 5** were adapted to a predominant focus on OSP. While the focus on different OSP features is definitely a strength of the current research, we could no longer investigate whether the direction of relationships as suggested in the conceptual model of Stodden et al. (2008) changed over time as children developed. In light of the *general aim* (i.e., gaining more insight into the determinants that influence children's AMC and its development) and the *first research objective* (i.e., gaining more insight into children's individual change in AMC across childhood) of this dissertation, future studies should conduct more longitudinal research while including all the variables in the conceptual model of Stodden et al. (2008).

3.2.6 EVOLVING INTERPRETATION OF MOTOR DEVELOPMENT DURING THIS DISSERTATION

While the same definition for AMC was used across the five studies being part of this dissertation, my own interpretation and conceptualization of motor development evolved over the past four years. My present conception of motor development is that each individual develops one-self in its unique ecological system, which is discussed in this doctoral thesis. While this is a positive reflection, this ecological perspective was not taken into account in **STUDY 1**.

Assessing a child's AMC does not take into account the child's environment that may have determined their AMC at the moment of testing. It only pictures the performance of a child on a specific point in time. While we added to the existing literature by extending the age range of the widely used KTK4 and KTK3, making it a more valuable tool for picturing long-term AMC development, the ecological validity of the assessment tool was not taken into account. However, previous research revealed that motor skills being assessed should correspond to the experiences of the children (Tamplain et al., 2020; Vinçon et al., 2017), which reinforces the need for further research in this area.



4 - PRACTICAL IMPLICATIONS -

Based on the findings of the current dissertation, some implications can be presented. However, since the theoretical implications have been addressed extensively in the overall discussion, only the practical implications are discussed in the next section.

The *general aim* of this dissertation was to gain more insight into some specific individual, environmental and task-related determinants of children's AMC and its development. A multitude of factors influence AMC and its development in children, of which some associations were confirmed in this work, while adding a broader view of the importance of different OSP features.

4.1 REACHING CONSENSUS ON AMC ASSESSMENT

A common thread throughout this dissertation is that the influence of the AMC assessment tool – being considered as a task-related determinant here - is often pointed out. This highlights the need to achieve consensus and uniformity in view of which instrument to use in specific circumstances, which is also linked to consensus on what constitutes AMC, something that was already stated in previous research in this field (Barnett et al., 2016; Hulteen, Barnett, et al., 2020; Tamplain et al., 2020). While each AMC assessment tool has his own characteristics, strengths, limitations and practical considerations for using it, some key considerations for selecting appropriate methods are the included age, sample size, assessment time, and available budget (Bardid et al., 2019). These latter authors developed a guide to support researchers and practitioners in selecting an appropriate AMC assessment tool depending on the purpose of assessment (e.g., screening for motor delay, talent identification, efficacy of intervention programs, etc.), population characteristics (e.g., age, disability), administrative properties (e.g., cost, required time, user friendliness) and measurement quality (e.g., test-retest reliability, construct validity).

Finding a measurable set of skills that can provide a representative picture of children's general AMC is clearly a challenge. A combination of both product- and process-based tests in one AMC assessment tool can be significant and might be a promising strategy in order to get a better insight in the development of motor competence, which was discussed at length in the earlier section entitled 'toward a gold standard to assess motor competence'.

4.2 SUSTAINABILITY OF AMC INTERVENTIONS

Our findings highlight that AMC benefits from interventions focusing on improving motor skills. Interestingly, while interventions aimed at improving FMS are successful in the short-term, no long-term effect could be found with respect to children's AMC development. To further tailor AMC programs, more knowledge is required to determine the optimal characteristics of such movement programs (e.g., type of approach, amount of instruction time, frequency, duration) to be successful in maintaining its intervention effects in the long run. This can help us in view of providing guidelines for a more efficient program design to facilitate an effective long-term impact of FMS interventions, such as the 'Multimove for Kids' program.

Such widely deployable and effective initiatives, in turn, will help to support positive health trajectories across childhood and adolescence among the broader society (Robinson et al., 2015), and to inform decision making in policy and practice toward that crucial goal. Ideally, these initiatives should be sustainably embedded in the local community, stimulating partnerships between sports clubs, municipalities, schools and daycare centers. As such, all actors should understand the importance of AMC as a developmental field that is essential to an active and healthy (later) life. Our findings once again underline the importance of coordinating structures and joining forces to promote motor development. Moreover, a varied range of physical activities should be offered, combined with well-educated coaches and a network of collaborating local actors (municipalities, sports clubs, schools, childcare, and social partners). To allow everybody to participate, financial or logistical barriers should be minimized in order to engage in such a program. Youth organizations can also be addressed from this perspective, as the entry threshold to participate in their activities - which are also organized on a regular basis - is often lower than in a sports club.

With respect to Multimove, a critical reflection on the program, and the implementation thereof in Flanders, is needed in order to adapt the current training course for Multimove instructors appropriately. This course is embedded in the Flemish Training School, a collaboration between the governing body overarching all Flemish sports federations, the Flemish Sports Federation itself and the universities offering physical education and sports sciences. In this Multimove course, the instructors receive a 3h training session with a focus on theory and 13h of practice (i.e., microteaching, making a lesson plan,…). However, when the intervention was implemented in 2012, the Multimove instructors only received a one-day training workshop (i.e., ½ day theory and ½ day practice). This might not be enough to ensure that knowledge learned in the workshop will be optimally transferred to the field (Patton & Parker, 2014). *Were the local Multimove instructors able to effectively deliver structured motor programming to the children? And if they did, where they also able to deliver the program as it was originally intended and did they meet the needs of the individual learning child?* The lack of fidelity measures on the Multimove curriculum implementation in 2012 (Bardid et al., 2017) might be one reason why the intervention effect did not last in the long term. Therefore, it would be of great value to examine the intervention fidelity of Multimove - a common standard of practice within the motor skill and broader educational intervention literature (Kaderavek et al., 2010) - like Brian and colleagues (2017a) have done. In this respect, the newly trained local instructors have to complete a procedural check sheet after each session provided. The trainers also have to note any deviations from the intervention procedure as described in the lesson plan. The procedural check sheet serves as a documentation log and helps providing dosage of intervention and getting more insight in the optimal characteristics of an intervention. Based on the procedural check sheet of Brian et al. (2017a; 2017b), local instructors have to check off what time they started and ended each session, what materials were used during that session, what tasks they implemented, if they deviated from the prescribed session's content, and if they provided any skill corrections to the children (i.e., differentiation). They are also asked to include a roster of all children present and participating in the Multimove-session provided. A research staff member should randomly complete a program delivery process check sheet and would have to do so for 10-30% of sessions across the newly trained Multimove instructors. The process check sheet includes similar items to the procedural check sheet, serves as triangulation / reliability and helps to reduce bias inherent with Multimove trainers' self-report. Further, the process check sheet can also include an area for comment(s) regarding whether any skill corrections and/or deviations were appropriate (e.g., were they provided when necessary, did they occur when they were not necessary, or were they necessary but not provided). Moreover, Brian et al. (2017a; 2017b) established that coaching and support from an expert was necessary because the teachers failed to deliver the intervention adequately at the start of the program. Therefore, providing coaching and support sessions for the newly trained Multimove instructors might help them in order to deliver the Multimove intervention with more fidelity.

Worldwide, huge differences in educational systems and physical education across countries and continents exist (Bardid et al., 2015; Brian et al., 2018; D'Hondt et al., 2019). For example, while preschoolers in US do not receive structured physical education classes (Brian et al., 2018), Belgian preschoolers receive these classes and mostly from trained physical education teachers (D'Hondt et al., 2019; Van Cauwenberghe et al., 2012; van Waelvelde et al., 2008). Despite these differences, it seems that embedding motor skill interventions within schools might be one way to counteract the deterioration in AMC in early childhood. Indeed, Yu and colleagues (2018) concluded that integrating interventions into the routine of the school curriculum might create more sustained and frequently dosed treatment regimens (Yu et al., 2018). This is in line with the two studies that investigated the long-term impact of a school-based movement skill intervention, respectively over three (Zask et al., 2012) and six years (Barnett et al., 2009b), revealing some long-term effects. Since education is compulsory in most countries, virtually all children and adolescents attend school (independent of their background), making schools an ideal setting for health promoting interventions by reaching the majority of the target population involved.

4.3 IMPORTANCE OF ORGANIZED SPORTS PARTICIPATION

The present research also demonstrates that being involved in OSP is beneficial for children's AMC and its development. Interestingly, children being involved in predominantly object control-oriented sports reached higher levels of AMC and showed a slightly steeper evolution in AMC over time. Moreover, from the perspective of motor competence and physical fitness, there are no arguments in our research for participating in just one sport from an early age onwards. Instead, participating in multiple sports was associated with higher levels of cardiorespiratory fitness and self-perceptions of AMC. In addition, being involved in more hours of OSP across childhood was associated with a higher level of AMC. While it is important to keep in mind that OSP in itself is something positive as being a particular form of PA - no matter which type of sports it concerns or how many sports are being practiced - some interesting practical relevance can be highlighted regarding these OSP related findings.

Participating in organized sports is popular in Belgium, with most of the participants being involved in only one sport (Sport Vlaanderen, 2021). Also, most of the sports clubs in Flanders focus on one specific sport. While combining multiple sports is associated with better physical outcomes, it also comes with more financial and/or logistical barriers for children and their parents. Therefore, policy and practice should raise more awareness on the topic and support sports federations and clubs in developing training sessions aiming to improve broad AMC development through coach education, conferences, workshops, and sharing good practices, among others. Paying more attention to broad AMC development can be done in many ways, even in the 'unisport' context. For example, devoting a portion of time during each practice session to motor skills that are complementary to the specific sport, providing a weekly practice where members are offered (with or without obligation) a multisport session, using the off-season to engage in multisport, etcetera. Moreover, many locomotor-oriented sports, do not require object control. However, our results highlight that participating in predominantly object control-oriented sports is stimulating the development of AMC more when compared to participating in predominantly locomotor-oriented sports. Locomotor skills are usually needed in most of the object control-oriented sports (e.g., hockey requires running, volleyball requires jumping, etc.). Therefore, children who practice object control-oriented activities during leisure time may have an advantage over their peers who do not. For this reason, it is advisable to ask the coaches of locomotor-oriented sports to add object control-oriented activities to their training sessions.

Raising more awareness regarding the influence of type of sports and the importance of broad motor development among coaches and parents should be one of the future goals of policy makers. While it will take some time and effort to convince coaches to adapt their training sessions, I am convinced that it is necessary for the current and future generations. Meanwhile, I am writing a book chapter (in Dutch) as an extension of my dissertation with both content background and good practices for sports clubs. This book will be distributed to all sports federations in Flanders and an evidence-based workshop will be compiled. For this workshop, I am currently working together with the overarching Flemish Sports Federation. However, 'the icing on the cake' would be to develop a training course for the 'multisport coach' in Flanders.

4.4 TARGETTING OTHER OUTCOMES IN ADDITION TO AMC

Our findings also highlight that maintaining OSP throughout childhood may not only be achieved by improving children's AMC, but also by focusing on strengthening/reinforcing their levels of PMC, which might positively contribute to their weight status. Our results indicate that particularly overweight children are at a higher risk of becoming less motor competent over time. Moreover, it was observed that children with average to high AMC-PMC-OSP levels displayed the most optimal profile as they had a healthier weight status as well as higher levels of autonomous motivation toward sports, while the opposite was true for children with low levels of all three variables. A key factor for the development of PMC is providing structure, by means of six cornerstones: creating clarity, showing confidence and providing challenge, consistent monitoring, providing appropriate assistance, giving motivating feedback, and encouraging self-reflection. Sports coaches can achieve these goals by using autonomy and competence supportive teaching practices and applying differentiated instruction (De Meester, 2017; Vansteenkiste & Soenens, 2015).

In view of the abovementioned practical implications, it is clear that the knowledge and expertise to boost AMC and its development is available, so are the organizations, places and materials. In Flanders, there are 41 sports federations focusing on one specific sport (i.e., 'unisport' federations) and 7 sports federations who combine multiple sports in their operation (i.e., 'multisport' federations). In total, there are more than 28.000 sports clubs in Flanders (Sport Vlaanderen, 2021), all of them striving to achieve the Flemish government's goal of 'a sports offer tailored to every stage of life' (Muyters, 2014). The question is not IF but HOW we should join forces in order to achieve this justified goal. In doing so, we should pay attention to the individual child, its own characteristics and the ecological system in which each child is developing. A multicomponent approach is thus needed to better support children's motor and general development, by not only targeting AMC but also their PMC. That way, children might become more autonomously motivated towards OSP and participate more in organized sports, which might positively influence their weight status. Since virtually all children and adolescents attend school (independent of their background), schools may serve as an ideal setting to target AMC and PMC development. Moreover, a large proportion of toddlers not yet attending (pre)school are taken care of and spend a lot of their awake time in daycare centers. This might also provide a unique context for the development, implementation and upscaling of AMC targeted initiatives.

5 - CONCLUSION -

The *general aim* of this dissertation was to gain more insight in some specific individual, environmental and task-related determinants regarding children's AMC and its development. Age (increasing), sex (boy), weight status (lower), health-related fitness (higher), PMC (higher), autonomous motivation toward OSP (higher) were all affecting children's momentary level of AMC. Moreover, being younger, being a boy, and having a lower weight status was associated with a steeper evolution and thus a more pronounced improvement in AMC across developmental time. Being involved in more object control-oriented sports, spending more time in OSP, and having more years of experience in OSP seemed beneficial for AMC and/or its development. In addition, being involved in multiple sports was also related to higher levels of cardiorespiratory fitness and PMC. However, it should be noted that the way AMC and PMC are defined, operationalized, and measured may impact the results. This may lead to slightly altered outcomes as to the individual's AMC performance and his/her self-perception thereof.

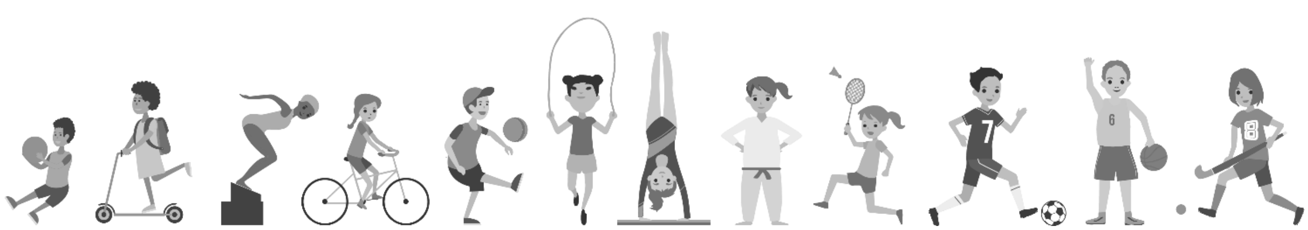
Our novel findings highlight the importance of exploring individual developmental trajectories of change in AMC across childhood, since the development of AMC during childhood is identified by a high degree of inter-individual variation. This will help to support positive and more tailored health trajectories across childhood and adolescence (Robinson et al., 2015), and it will inform decision making in policy and practice.

Altogether, our findings indicate that each individual child develops in its own ecological model, which is influenced by several individual, environmental and task-related determinants. In this respect, it is important to better support children's (motor) development by using a multicomponent approach with attention for the individual child. Therefore, future interventions or movement programs should not only focus on improving children's AMC but also on PMC, which might positively influence their weight status and autonomous motivation toward OSP. This, in turn, may be beneficial for their general development.

This brings me all the way back to the start of this dissertation. Individual differences in AMC exist and each child develops differently and at different paces. Moreover, motor development is associated with physical, cognitive, emotional, and social development (Gallahue et al., 2012).

Do you remember the boy on the birthday party of your 7-year-old nephew being scared of the ball and the deeper water? Just imagine that, soon after that birthday party, the same scared boy starts to go to a swimming pool and rides his (bigger) bike more often. He also becomes a member of one or more local sports club(s) where he starts playing ball games and performing various sporting activities. In the organization(s) he enrolled in, they pay specific attention to each individual child and his/her ecological system. The scared boy gets time to get used to the new environment, the interactions with the sports equipment and team members during the training sessions and games. Due to increased OSP, he gets more in shape and starts enjoying being active and part of the team.

How would he feel about your nephew's next birthday party?



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LIST OF PUBLICATIONS AND PRESENTATIONS

A 1 – INTERNATIONAL PEER-REVIEWED JOURNAL ARTICLES

Coppens, E.*, Bardid, F.*, Deconinck, F. J. A., 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]. https://doi.org/10.3389/fphys.2019.01273 *These authors share first authorship. (IF 3.3367 - Q1 - 20/81 – Physiology)

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