Early childhood motor development

Measuring, understanding and promoting motor competence

Farid Bardid

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Supervisor

Prof. Dr. Matthieu Lenoir (Ghent University)

Co-supervisor

Prof. Dr. Jan Seghers (Katholieke Universiteit Leuven)

Supervisory board

Prof. Dr. Matthieu Lenoir

Prof. Dr. Jan Seghers

Prof. Dr. Kristine De Martelaer (Vrije Universiteit Brussel)

Prof. Dr. Frederik Deconinck (Ghent University)

Prof. Dr. Jacqueline Goodway (The Ohio State University)

Examination board

Prof. Dr. Els Clays (Ghent University)

Prof. Dr. Dirk Declercq (Ghent University)

Prof. Dr. Eva D'Hondt (Vrije Universiteit Brussel)

Prof. Dr. Leen Haerens (Ghent University)

Prof. Dr. David Stodden (University of South Carolina)

Prof. Dr. Hilde Van Waelvelde (Ghent University)

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Summary

Motor development is considered a crucial factor in children's overall growth, and is related to other aspects of health such as social and cognitive development. The ability to perform a variety of motor skills in a proficient manner, also described as motor competence, underpins engagement in physical activity. Moreover, gaining competency in fundamental motor skills (FMS; e.g., hopping, kicking and throwing) during early childhood is important to be successful in sports, games and other types of physical activity. The aim of this thesis was to gain more insights into motor development and motor competence in young children.

One of the challenges researchers and practitioners face when assessing motor competence, is the adoption of reliable and valid measures with known relationships to other assessments. The first two studies in this thesis investigated the measurement of motor competence. The first study (Chapter 2) compared the Body Coordination Test (KTK) and the Motor Proficiency Test for 4- to 6-year-old Children (MOT 4-6), two frequently used assessments in Europe. The results provide evidence of convergent validity between both tests but the moderate to low levels of classification agreement do suggest the need to use more than one assessment when detecting motor difficulties or identifying talented children. The second study (Chapter 3) investigated the construct of motor competence in three- to six-year-old children using the large set of items in the MOT 4-6 to test the general motor ability hypothesis. This hypothesis states that various skills are related and underpinned by a general motor competence. The findings reveal a one-dimensional and homogenous structure for motor competence, supporting the general motor ability hypothesis in early childhood. In addition, it supports the use of composite scores in practice.

The following two studies examined the cultural context of motor competence. The third study (Chapter 4) compared the motor competence of Australian and Belgian children using the KTK. The results indicate that Belgian children demonstrated higher scores than the Australian children. Nearly twice as much Australian children were categorized as scoring below average. The motor performance of both groups was nonetheless lower than the German reference population. In the fourth study (Chapter 5), we investigated the FMS of three- to eight-year-old Belgian children using the Test of Gross Motor Development, Second Edition (TGMD-2), and compared the scores with the United States reference group. The findings show that FMS performance increased with age from three to six years for locomotor skills (running, galloping, hopping, leaping, jumping and sliding) and from three to seven years for object control skills (striking, dribbling, catching, kicking, throwing and rolling). Furthermore, Belgian boys scored higher on object control skills than Belgian girls. In addition, Belgian children generally demonstrated lower motor competence levels than children from the United States, especially for object control skills. These findings indicate that researchers and practitioners need to be cautious when using reference norms from culturally distinct populations.

The last study (Chapter 6) evaluated the effectiveness of the Multimove for Kids intervention, a FMS program for young children aged three to eight years. The results show that the intervention had a positive effect on children's motor competence. Additionally, sex differences were found, i.e. boys made more gain in object control skills while girls made more gain in locomotor skills. The study highlights the value of sustainable interventions that involve collaborations with existing organizations (sports clubs, sports councils, schools and day care centers) and local instructors.

In conclusion, the research in this thesis provides evidence of a one-dimensional structure in motor competence and convergent validity between existing assessments in early childhood. We also found cultural differences in motor competence but future research is needed to determine the role of factors such as physical activity and physical fitness. Finally, the present research underscores the value of diversified movement initiatives organized and implemented in existing child settings.

Samenvatting

Motorische ontwikkeling is van cruciaal belang in de algemene groei van kinderen, en hangt samen met andere gezondheidsaspecten zoals sociale en cognitieve ontwikkeling. Het kunnen uitvoeren van diverse motorische vaardigheden op een efficiënte manier, ook wel motorische competentie genoemd, is een determinant van fysieke activiteit. Daarbij is het ontwikkelen van fundamentele motorische vaardigheden (FMS; bv. hinken, trappen en werpen) in de vroege kindertijd belangrijk voor succeservaring in sport, spelen en andere vormen van fysieke activiteit. Het doel van dit proefschrift was om meer inzicht te verkrijgen in de motorische ontwikkeling en motorische competentie bij jonge kinderen.

Een van de uitdagingen waarmee onderzoekers en praktijkmensen geconfronteerd worden, is het gebruik van betrouwbare en valide meetinstrumenten voor de evaluatie van motorische competentie. De eerste twee studies in dit proefschrift onderzochten de psychometrische aspecten van motorische testen. In de eerste studie (hoofdstuk 2) werden de Körperkoordinationstest für Kinder (KTK) en de Motoriktest für 4- bis 6-jahrige Kinder (MOT 4-6) vergeleken, twee vaak gebruikte testen in Europa. De resultaten geven aan dat er convergente validiteit is tussen beide testen, maar de matige tot lage overeenkomst tussen de classificatiesystemen toont aan dat er mogelijk fouten kunnen gemaakt worden wanneer men de motorische competentie van een kind enkel beoordeelt op basis van de KTK of de MOT 4-6. Daarom wordt aangeraden om meer dan één test te gebruiken bij het opsporen van kinderen met motorische problemen of het identificeren van motorisch begaafde kinderen. De tweede studie (hoofdstuk 3) onderzocht het construct van motorische competentie bij drie- tot zesjarige kinderen met behulp van de items van de MOT 4-6 om de *general motor ability* hypothese te testen die stelt dat verschillende motorische vaardigheden verwant zijn en onderbouwd worden door een algemene motorische competentie. De bevindingen tonen een één-dimensionele en homogene structuur in motorische competentie en ondersteunen daarmee de *general* *motor ability* hypothese in de jonge kindertijd. Bovendien ondersteunt de studie het gebruik van somscores in de praktijk.

De volgende twee studies onderzochten de culturele context van motorische competentie. In de derde studie (hoofdstuk 4) werd de motorische competentie van Australische en Belgische kinderen vergeleken met behulp van de KTK. De resultaten geven aan dat Belgische kinderen hoger scoren dan Australische kinderen. Bijna twee keer zo veel Australische kinderen scoren onder het gemiddelde. De motorische competentie van beide groepen is niettemin lager dan die van de Duitse referentiepopulatie. De vierde studie (hoofdstuk 5) onderzocht de FMS van drie- tot achtjarige Belgische kinderen met behulp van de Test of Gross Motor Development, Second Edition (TGMD-2) en vergeleek de scores met de Amerikaanse referentiegroep. De resultaten tonen een leeftijdsgebonden stijging in de scores voor locomotie (lopen, galopperen, hinken, loop- en vertesprong, en bijtrekpas) bij kinderen van drie tot zes jaar, en voor objectcontrole (slaan, dribbelen, vangen, trappen, werpen en rollen) bij kinderen van drie tot zeven jaar. Daarbij scoren Belgische jongens hoger op objectcontrole dan Belgische meisjes. In vergelijking met de Amerikaanse referentiegroep scoren Belgische kinderen lager op FMS, voornamelijk op objectcontrole. Deze bevindingen tonen aan dat men voorzichtig moet zijn bij het gebruik van referentienormen afkomstig van landen met een andere culturele achtergrond.

De laatste studie (hoofdstuk 6) evalueerde de effectiviteit van de Multimove interventie, een breed bewegingsprogramma voor kinderen van drie tot acht jaar. De resultaten tonen aan dat de interventie een positief effect heeft op de motorische competentie. Daarbij zijn ook geslachtsverschillen aangetoond waarbij jongens meer vooruitgang hebben geboekt in objectcontrole en meisjes meer vooruitgang in locomotie. De studie onderstreept de meerwaarde van duurzame interventies, georganiseerd door bestaande actoren (sportclubs, sportdiensten, scholen en kinderopvangen) en geïmplementeerd door lokale lesgevers.

Samengevat levert het onderzoek in dit proefschrift bewijs voor een één-dimensionale structuur in motorische competentie en convergente validiteit tussen bestaande testen in de vroege kindertijd. Er werden ook culturele verschillen gevonden in motorische competentie, maar verder onderzoek is nodig om de invloed van factoren zoals fysieke activiteit en fysieke fitheid te bepalen. Eveneens wordt het belang aangetoond van initiatieven met een gevarieerd bewegingsaanbod die georganiseerd worden in lokale settings zoals sportclubs, scholen en kinderopvangen.

Contents

Chapter 1

General introduction

Motor development is an important part of children's health and growth, and is associated with other areas of development such as cognitive and social development (Gallahue, Ozmun, & Goodway, 2012; Hill, 2010). The development of motor skills is essential for daily life activities and underpins children's engagement in physical activity, sports and games (Stodden et al., 2008). This chapter provides an overview of the literature on motor development and motor competence. In Section 1.1, we briefly discuss the definitions and concepts of motor development and motor competence, prominent motor development models and the dynamic relationship of motor competence with physical activity and other health-related factors. In Section 1.2, we describe the different purposes and types of motor assessment and conclude with a brief review of widely used test batteries in early childhood. Section 1.3 sketches the main instructional approaches adopted in motor skill programs, and provides current evidence in the literature relating to motor skill interventions.

1.1 Motor development and motor competence

1.1.1 Definitions and concepts

Motor development is described as the continuous change in motor behavior across the lifespan that is driven by an interaction of constraints in the individual, the task and the environment (Gallahue et al., 2012; Haywood & Getchell, 2009). Motor development also refers to the development of motor skills which are goal-oriented activities or tasks that require voluntary movement of one or more body parts (Gallahue et al., 2012). It should be noted that motor skills and movement skills are used interchangeably in literature.

Motor competence is defined as the ability to perform a wide range of gross and fine motor skills in a proficient manner (Haga, 2008). It relies on motor coordination and physical fitness. Motor coordination involves the cooperation between muscles or muscle groups to produce a purposeful action or movement (Magill, 2011). Physical fitness pertains to the capacity to perform physical activity and involves different components including endurance, flexibility, speed, strength and aspects of motor coordination (Ortega, Ruiz, Castillo, & Sjöström, 2008). Different terms have been used in literature analogous to motor competence, such as motor skill competence, motor function, motor performance, motor proficiency, movement competence and movement skill competence.

During early childhood (defined as ages 3 to 8 years for the purpose of this thesis), motor competence can be reflected by the ability to proficiently execute fundamental motor skills (FMS). FMS are generally categorized into locomotor skills and object control skills executed in a bipedal position (Burton & Miller, 1998). Locomotor skills involve movement of the body through space and include skills such as running and jumping. Object control skills involve manipulation of objects and pertain to skills such as catching and kicking. Similarly to motor competence, FMS have been used interchangeably with various terms such as fundamental movement skills and fundamental movement patterns.

1.1.2 Motor development models

FMS are considered the ABC of movement as they are important for daily life activities and form the building blocks of later specialized skills (Gallahue et al., 2012). The development of these basic motor skills during early childhood is commonly depicted as the FMS phase in motor development models, which are rooted in theories of motor development. Across the 20th century, the theoretical approach to motor development research has shifted from a maturational perspective to an ecological perspective. According to the maturational perspective, motor development is a function of maturational processes (specifically, the central nervous system development) from birth through childhood and controlled by hereditary factors rather than environmental factors. In contrast, the ecological perspective views motor development as a lifelong process and a product of individual, task and environmental factors (see Haywood & Getchell, 2009, for an overview). Following models have been used to describe motor development across the lifespan and the importance of FMS in early childhood, and will be further discussed: (1) hierarchical model of motor development (Seefeldt, 1980), (2) triangulated hourglass model of motor development (Gallahue et al., 2012), and (3) mountain of motor development model (Clark & Metcalfe, 2002).

1.1.2.1 Hierarchical model

In 1980, Seefeldt introduced a motor development model using a hierarchical approach (see Figure 1). This pyramid shaped model sketches the development of motor skills in four sequential phases. The transition from one phase to the next occurs over time as a consequence of biological maturation and environmental experiences.

The first phase consists of reflexes during infancy; these involuntary movements are stereotypical motor reactions to specific stimuli and are regarded as the base for all future movement. This reflexive phase is followed by the fundamental motor skills phase during early childhood in which children start to develop FMS including locomotor skills and object control skills. The importance of these basic motor skills is highlighted by the notion of a proficiency barrier. Seefeldt hypothesized that an adequate level of competency in FMS is required to break through this barrier and allow children to move to the next phases of the pyramid (i.e., the transitional motor skills phase and the specific sports skills and dances phase) from middle childhood into adulthood. In the transitional skills phase, children engage in lead-up sports and small-sided games (e.g., tag rugby, T-ball).

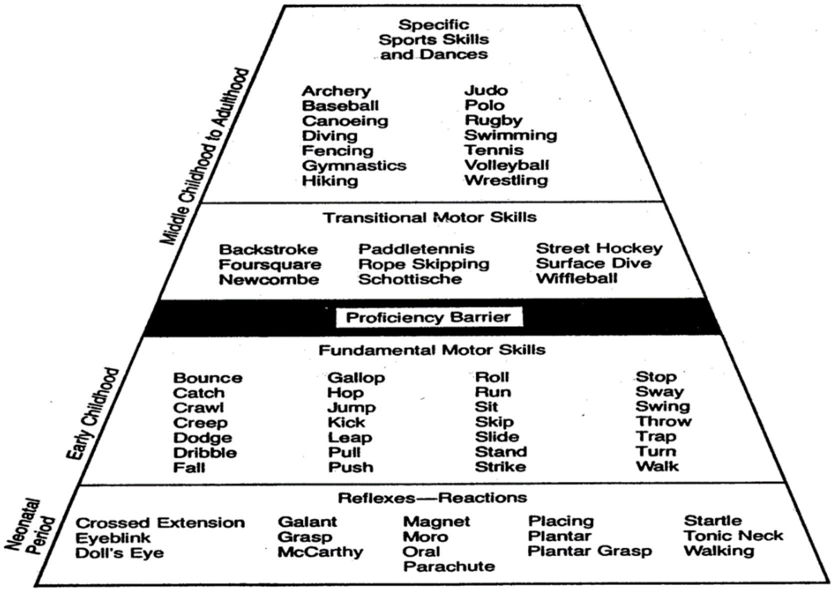

Figure 1. Hierarchical model of developmental motor patterns (reprinted from Seefeldt, 1980)

By means of the proficiency barrier, Seefeldt's model emphasizes that children need to develop and master FMS in order to engage and be successful in sports, games and other types of physical activity.

1.1.2.2 Triangulated hourglass model

Gallahue proposed a motor development model in the form of an hourglass and an overlapping (inverted) triangle (see Figure 2). This model includes four phases and is nested in the frameworks of phase-stage theory and dynamic systems theory to describe products (hourglass) and processes (inverted triangle) of motor development across the lifespan (Gallahue et al., 2012). The development of motor skills is represented by the sand that falls into the hourglass through biological and environmental factors. As shown in Figure 2, the contribution of biological factors is considered fixed (i.e., hereditary container with closed lid) as opposed to the contribution of environmental factors (i.e., environmental container with no lid). As individuals move through the different movement phases to obtain and maintain motor control and competence, the rate and extent of motor skill development will be influenced by constraining factors denoted by the inverted triangle: individual, environment and task.

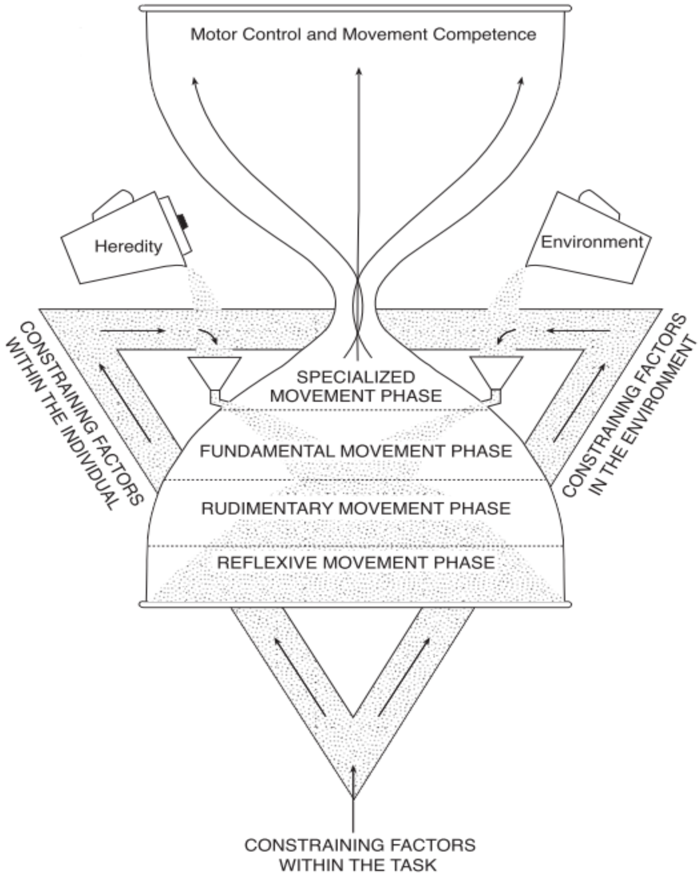

Figure 2. Triangulated hourglass model of motor development (reprinted from Gallahue et al., 2012)

The first phase is the reflexive movement phase during infancy, characterized by reflexes. These involuntary movements are generally divided into primitive reflexes (e.g., rooting reflex and palmar grasping reflex) and the postural reflexes (e.g., labyrinthine righting reflex and parachute reflex). Gallahue points out that these reflexes (specifically the postural reflexes) can be considered as a neuromotor testing apparatus for stability, locomotor and object control mechanisms in later voluntarily movement. During the rudimentary movement phase, the developing cortex causes the inhibition and gradual disappearance of reflexes as infants start to develop basic voluntarily movements including head and trunk control (stability), reaching and grasping (object control), and crawling and walking (locomotion). Following this phase is the fundamental movement phase that occurs during early childhood. In this phase, young children are actively exploring and experimenting with body movement and developing FMS. The fundamental movement phase is categorized into the initial stage (± 2-3 years), the emerging elementary stages (± 3-5 years) and the proficient stage (± 5-7 years). The progression through these stages is characterized by an improvement in biomechanical efficiency, coordination and control of FMS patterns. In the specialized movement phase, individuals begin to refine and extend these FMS to develop and master complex skills required in sports, games and other types of physical activity. According to the model, the hourglass turns over around the start of young adulthood, and the sand (i.e., motor control and competence) starts to pour out. However, the rate at which the sand falls, is determined by the hereditary filter and the lifestyle filter. While the hereditary filter is fixed, the lifestyle filter is determined by factors such as physical fitness and physical activity.

Gallahue et al. (2012) consider FMS as an important component in daily living for both children and adults. Like Seefeldt's model, the triangulated hourglass model underlines the importance of attaining FMS competence during early childhood as it allows successful development and application of complex skills in sports, recreation and daily living.

1.1.2.3 Mountain of motor development model

Clark and Metcalfe (2002) used a mountain metaphor in their model to describe the development of motor skills across childhood and adulthood. The mountain of motor development model consists of six phases and is embedded within the framework of dynamic systems theory. This theoretical approach is a branch of the ecological perspective and defines motor development as a non-linear and self-organizing process where motor behavior is influenced at each moment in time by changing constraints in the individual, environment and task (Kugler, Kelso, & Turvey, 1980, 1982; Newell, 1986). Both the triangulated hourglass model and the mountain of motor development model adopt the dynamic systems theory as a framework to conceptualize motor development.

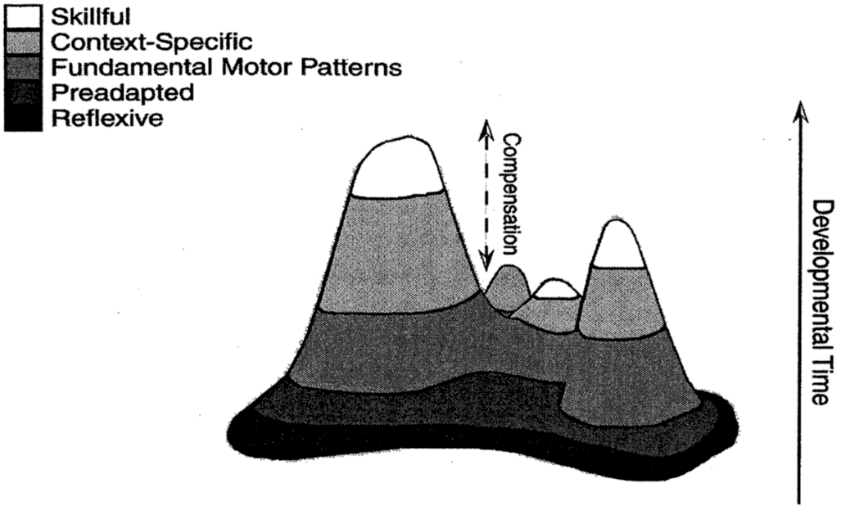

Figure 3. Mountain of motor development (reprinted from Clark & Metcalfe, 2002)

In the reflexive phase, infants demonstrate spontaneous and reflexive movements. Unlike reflexive movements, spontaneous movements refer to movements that are not evoked by specific stimuli in the environment (e.g., arm swinging). Both movements are important for infants to survive and to engage with the environment; the reflexive phase is also considered a necessary step to familiarize children with the mountain. Following is the preadapted phase in which toddlers start to develop rudimentary movements such as rolling and grasping with the goal to achieve independent function. In the next phase, children start to develop their

FMS and build a sufficiently diverse motor skill repertoire. Clark and Metcalfe consider the FMS phase as the basecamp of the mountain from which children can apply FMS to specific tasks and adopt these basic motor skills as building blocks to develop specialized skills during the context-specific phase. Skill development during the context-specific phase is characterized by specific peaks in the mountain. A person can then continue to climb up the mountain, building on context-specific experience, and achieve high levels of performance (i.e., skillfulness phase). This model acknowledges that an individual does not achieve skillfulness over a wide range of activities but rather establishes efficiency and effectiveness in certain motor skill domains. This is reflected by the peaks in the motor development mountain of which the heights or levels of performance differ for each person depending on hereditary and environmental factors. Finally, the compensation phase indicates the period where individuals adapt their motor behavior due to aging-associated or injury-induced changes.

Similar to previous models, the importance of FMS development by the age of seven as a base for later specialized skills is highlighted in Clark and Metcalfe's model. Children who master these basic skills are more equipped to develop skillfulness and be successful in later sports and other types of physical activity.

1.1.3 Motor competence, physical activity and other health-related factors

The aforementioned models have contributed to a better understanding of the motor development process and imply that motor competence, specifically FMS competence in early childhood, is an important factor underlying engagement in current and future physical activity. However, research on physical activity has generally adopted a social cognitive, expectancy-value or mixed social learning approach, and has focused on children's perceived competence and social influences with regard to physical activity (Brustad, 1993; Eccles & Harold, 1991; Harter & Pike, 1984; Harter, 1978; Klint & Weiss, 1987). For instance, Harter developed the competence motivation theory and proposed that perceptions of competence affect children's effort to master skills and their task persistency; this entails that children's perceived competence determines to what extent they engage and persist in an activity (see Harter, 1999; Weiss & Ferrer-Caja, 2002, for literature reviews on the linkage between perceived competence and motivational processes). Eccles and colleagues proposed that perceived competence in relation to task difficulty, subjective task value and expectation of success determines children's engagement in an activity, and included the role of contextual influences on children's motivation and engagement (Eccles & Harold, 1991; Eccles et al., 1983; Eccles, Wigfield, & Schiefele, 1998). Adopting Eccles' expectancy-value model, Brustad (1993) and Trost et al. (2003) identified parental participation, enjoyment and perceived importance in terms of physical activity as predictors for parental support which in turn affects children's perceived competence; in addition, parental support and children's perceived competence influence children's physical activity engagement (see also Fredericks & Eccles, 2004). Although these frameworks have provided new insights into physical activity and its psychosocial factors, they do not sufficiently address the role of actual motor competence as an underlying mechanism of physical activity.

It is essential for children to be competent in movement in order to feel competent and engage in physical activity. One model by Stodden et al. (2008) describes the relationship between actual motor competence and physical activity across childhood, and the interrelations with perceived motor competence, physical fitness and weight status (Figure 4; see also Robinson et al., 2015). The authors also addressed the role of motor competence in the development of a positive spiral of engagement or negative spiral of disengagement in physical activity. The positive spiral of engagement indicates that children with higher levels of actual motor competence will show higher levels of perceived competence and will be more likely to engage in physical activity which will in turn reduce the risk of developing an unhealthy weight status. This outcome provides positive feedback to the model and supports children's continued physical activity engagement and motor competence development.

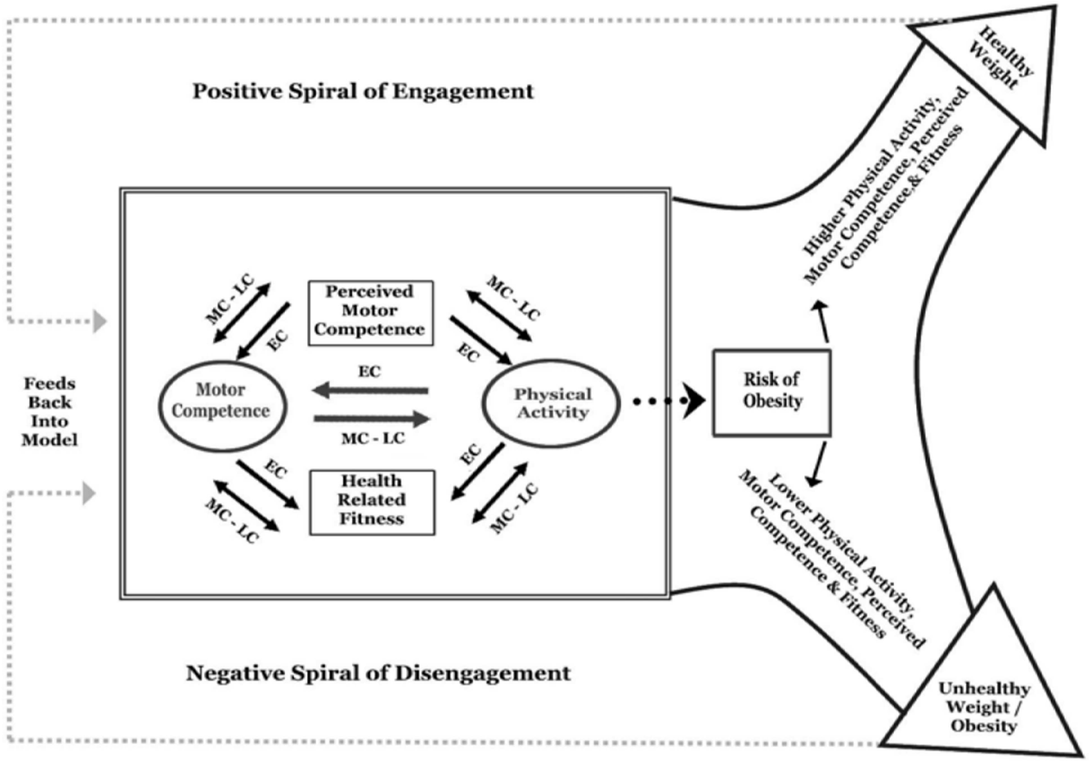

Figure 4. Conceptual model on mechanisms influencing physical activity trajectories (reprinted from Stodden et al., 2008; EC = 3-5 years, MC = 6-9 years, LC = 10-13 years)

The opposite negative spiral of disengagement will occur in low skilled children who will demonstrate lower levels of perceived competence and be less likely to participate in physical activity which will result in a higher risk of overweight and obesity. This outcome will negatively respond to the model and negatively impact children's motivation to be physically active and develop motor competence. Using this model as a guide, we will briefly discuss the relationships between motor competence and these health-related factors.

1.1.3.1 Motor competence and physical activity

In their model, Stodden et al. (2008) proposed that the development of motor competence is initially promoted by physical activity during the preschool years (ages 3-5). Physical activity provides opportunities for young children to develop their FMS. Due to variability in development in early childhood and environmental factors (e.g., school-based and community-based structured physical activity, free play, parental support), motor competence and physical activity are expected to be weakly related. This weak relationship becomes stronger and more reciprocal when children reach the age of 6-7 and start to participate in sports, games and other types of physical activity. Proficiency in FMS will support participation in physical activity as children adopt their skills to be successful in a variety of activities while physical activity will support the continued development of motor competence.

Overall, the literature indicates strong evidence for a positive relationship between motor competence and physical activity (see Holfelder & Schott, 2014; Logan, Webster, Getchell, Pfeiffer, & Robinson, 2015; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Robinson et al., 2015, for reviews). Some evidence further supports the notion of developmental changes in the relationship between these two factors over time (as hypothesized by Stodden et al., 2008). A recent systematic review by Logan et al. (2015) showed low to moderate correlations between FMS competence and physical activity at ages 3-5 years and low to high correlations at ages 6-12 years. Some longitudinal studies have also shown that childhood motor competence positively influences future physical activity (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lopes, Rodrigues, Maia, & Malina, 2011; Vandorpe et al., 2012).

1.1.3.2 Motor competence and perceived competence

Within the conceptual framework of Stodden et al. (2008), actual and perceived motor competence are weakly associated during early childhood due to cognitive maturation. According to Piaget's phase theory of cognitive development, children under the age of seven are not yet able to logically reason about events and to classify experiences (Gallahue et al., 2012). As they enter middle childhood and their cognitive capacity enhances, they begin to perceive themselves more accurately through comparison with other children and feedback from their environment. As a consequence the relationship between motor competence and perceived competence will become stronger. Stodden et al. (2008) also proposed that perceived competence mediates the relationship between motor competence and physical activity.

A number of studies have shown low to moderate correlations between actual and perceived motor competence in early and middle childhood (Barnett, Ridgers, & Salmon, 2015; LeGear et al., 2012; Liong, Ridgers, & Barnett, 2015; Robinson, 2011; Spessato, Gabbard, Robinson, & Valentini, 2013; Toftegaard-Stoeckel, Groenfeldt, & Andersen, 2010; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). In addition, research with specific subpopulations has demonstrated higher actual and perceived motor competence levels in healthy children when compared to children with overweight/obesity (Jones, Okely, Caputi, & Cliff, 2010; Southall, Okely, & Steele, 2004) and children with developmental coordination disorder (DCD; Yu et al., 2016). There is some evidence supporting the hypothesized mediating role of perceived competence in the relationship between motor competence (specifically, object control competence) and physical activity in adolescents (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Barnett, Morgan, van Beurden, & Beard, 2008), but not in young children (Crane, Naylor, Cook, & Temple, 2015).

1.1.3.3 Motor competence and physical fitness

The model of Stodden et al. (2008) postulated that motor competence will initially drive physical fitness during early childhood but indicates that these two factors will not be strongly correlated due to variability in the levels of physical activity and motor competence during the early years. As children transition to middle childhood, physical fitness will serve as a mediator between motor competence and physical activity because it supports the further development of motor skills and allows children to engage and maintain physical activity. The relationship between motor competence and physical fitness becomes more reciprocal during adolescence.

Recent systematic reviews showed moderate to strong positive associations between motor competence and physical fitness measures – e.g., cardiorespiratory fitness and muscular strength – in children and adolescents (Cattuzzo et al., 2015; Lubans et al., 2010; see also Robinson et al., 2015). However, the relationship between motor competence and flexibility remains unclear due to limited data. A cross-sectional study by Stodden et al. (2014) with children aged 4 to 13 years, showed an increase in the strength of association between motor competence and physical fitness across age, supporting the model of Stodden et al. (2008). In addition, a few longitudinal studies provide evidence that the motor competence level in early and middle childhood predicts adolescent physical fitness (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Hands, 2008; Vlahov, Baghurst, & Mwavita, 2014); two of these studies found locomotor skills to be not or less predictive of physical fitness during adolescence than object control skills (Barnett et al., 2008; Vlahov et al., 2014). Finally, a recent study with 8- to 9-year-old girls (Khodaverdi, Bahram, Stodden, & Kazemnejad, 2015) demonstrated preliminary evidence supporting Stodden et al. (2008)'s hypothesis of physical fitness as a mediator in the relationship between motor competence and physical activity.

1.1.3.4 Motor competence and weight status

Weight status is viewed as an important outcome within the model of Stodden et al. (2008) and is associated with motor competence, physical activity, perceived competence and physical fitness. Stodden et al. (2008) hypothesized that the relationship between weight status and motor competence is dynamic and influenced by other factors in the model across time (see Figure 4).

Studies have provided strong evidence of an inverse relationship between motor competence and weight status in children and adolescents. Overweight and obese children systematically displayed lower levels of motor competence than their normal-weight peers (see Cattuzzo et al., 2015; Lubans et al., 2010; Robinson et al., 2015, for reviews). The relationship between both factors already emerges at a very young age and seems to become stronger across primary school years (e.g., D'Hondt et al., 2011; D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009; Graf et al., 2004; Logan, Scrabis-Fletcher, Modlesky, & Getchell, 2011; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012). During adolescence, the strength of the relationship varies, ranging from weak to strong correlations (Lopes et al., 2011; O' Brien, Belton, & Issartel, 2015; Stodden, Langendorfer, & Roberton, 2009). There is some evidence supporting Stodden et al. (2008)'s proposed reciprocal relationship between motor competence and weight status across time. For instance, a longitudinal study by D'Hondt et al. (2014) in children aged 5 to 13 years showed that weight status negatively influences future motor competence and vice versa. Another longitudinal investigation in six-year-olds (Rodrigues, Stodden, & Lopes, 2016) demonstrated that children with a low or average developmental change in motor competence and physical fitness have a higher risk of becoming overweight or obese.

Recent research has shown that motor competence has many health benefits and indicates that the development of motor competence (particularly FMS competence) during early childhood may play an important role in developing an active lifestyle. However, the use of different motor assessments in motor development literature makes it difficult to compare findings across studies. Robinson et al. (2015) argued that highly standardized assessments need to be used consistently on a global scale in order to better understand motor competence across cultures and to examine its associations with physical activity and other health-related factors over time.

1.2 Motor assessment

Motor test batteries are important instruments that enable evaluation and monitoring of motor competence across childhood. In addition, examination of motor competence from early childhood onwards provides an opportunity to detect children who are at risk of motor delay and to deliver appropriate guidance for optimal motor competence development (Gallahue et al., 2012).

1.2.1 Purposes of assessment

Motor assessments are conducted in different settings, e.g., clinical practice, research, school. Regardless of the setting, there are different purposes for assessing motor competency in children. Burton and Miller (1998) outlined five main categories: (1) categorization or identification, (2) program or instruction design, (3) evaluation across time, (4) feedback, and (5) prediction.

The first category entails the categorization of motor competence levels to detect children who exhibit motor difficulties or impairment and are in need of additional support such as physical therapy, adapted physical education (PE), and/or motor skill intervention. The second category relates to assessment in view of planning movement programs and selecting appropriate teaching strategies; it also serves as a baseline measure to examine the progress of children. The third category is the evaluation of change in motor competence over time which involves general tracking of change in motor competence or evaluating progress in the context of therapeutic or intervention programs. A fourth category of assessment purposes is to give feedback to children and other stakeholders, e.g., parents, teachers, physicians, policy makers. The goal of feedback is not only to provide information on the motor status of children to parties involved, but also to communicate whether any particular therapy or intervention is needed and how children can be assisted in their motor development. The last category pertains to prediction: This may include predicting future health outcomes (e.g., weight status) or predicting required support in medical and/or educational setting.

1.2.2 Approaches to assessment

There are several methodological approaches to assess motor competence in children. We can generally classify these in four groups: norm-referenced, criterion-referenced, formal and informal methods (Burton & Miller, 1998; Gallahue et al., 2012).

Norm-referenced assessments compare children's performance of motor skills to a norm that is calculated from the test performance of a reference group. The reference or normative group consists of a sample that is representative of the target group regarding factors such as age, sex and socioeconomic status. Criterion-referenced assessments compare children's performance to a set of predetermined criteria that represent a proficient or expert performance. These two types are not mutually exclusive; criterion-referenced tests can also be norm-referenced when applying descriptive statistics (means and standard deviations, percentiles and standardized scores) to these scores. In addition, while norm-referenced tests are typically formal assessments, criterion-referenced tests can either be formal or informal (Burton & Miller, 1998).

Formal assessments follow a standardized protocol in terms of guidelines and conditions; this reduces measurement error between and within assessors and allows for comparison between children. Informal assessments are not administered in stringent conditions and generally do not have a standardized protocol in contrast to formal tests. While informal assessments, such as observing children's skill performance in naturalistic settings, have their own merit (for instance when designing a program and planning instructions), they have noticeable disadvantages such as validity and reliability issues. Validity relates to the objective of an assessment and specifies to what extent a motor test measures what it is supposed to measure. Reliability refers to the consistency of an assessment and indicates to what degree a motor test can replicate meaningful measurements (Portney & Watkins, 2009). Formal assessments are more suited when describing children's performance on a group level, identifying children who are in need of support or evaluating an intervention program. It should be noted that formal assessments also have flaws. For instance, the focus on a limited set of tasks under standard conditions may not provide a complete picture of children's motor competence as might be the case when observing children's motor skills in naturalistic conditions. Nevertheless, the adoption of a standardized protocol with specific guidelines in formal assessment allows for the development of tests with good psychometric properties (i.e., validity and reliability) that can be used on a large scale in both research and practice. We therefore focus on formal assessments within this thesis.

In motor development literature, we also encounter the terms 'product-oriented' and 'process-oriented' assessments (Gallahue et al., 2012; Goodway, Brian, Chang, & Park, 2015). Product-oriented tests examine the outcome or product of motor skills, e.g., the distance of a jump, and the number of times a child throws a ball and hits the target. Process-oriented tests assess the qualitative aspects of motor skills, e.g., backward arm swing before jumping, and the contralateral step when throwing a ball.

1.2.3 Assessment tools

Numerous instruments are available to assess and monitor motor competence in early childhood. These assessments have been designed with one or more goals and include one or more approaches as well. A review by Cools, De Martelaer, Samaey, and Andries (2009) lists seven assessments that are often adopted in international or European research: (1) Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2; Bruininks & Bruininks, 2005), (2) Body Coordination Test (Körperkoordinationstest für Kinder [KTK]; Kiphard & Schilling, 2007), (3) Maastricht Motor Test (Maastrichtse Motoriek Test [MMT]; Vles, Kroes, & Feron, 2004), (4) Motor Proficiency Test for 4- to 6-year-old Children (Motoriktest für Vier- bis Sechsjährige Kinder [MOT 4-6]; Zimmer & Volkamer, 1987), (5) Movement Assessment Battery for Children, Second Edition (M-ABC-2; Henderson, Sugden, & Barnett, 2007), (6) Peabody Development Scales, Second Edition (PDMS-2; Follio & Fewell, 2000), and (7) Test of Gross Motor Development, Second Edition (TGMD-2; Ulrich, 2000). We will briefly describe the test batteries that we have used in the research presented in this thesis: the KTK, MOT 4-6 and TGMD-2.

1.2.3.1 Body Coordination Test (KTK)

The KTK (Kiphard & Schilling, 1974) is a product-oriented and norm-referenced instrument that measures gross motor coordination in children aged 5 to 14 years. It is the abbreviated version of the Hamm-Manburger Body Coordination Test (Hamm-Manburger Körperkoordinationstest für Kinder; Kiphard & Schilling, 1974, 2007). Although the primary purpose of the KTK is to identify children with mild or severe motor difficulties, it can also be used for talent identification (Fransen et al., 2014). The test includes four dynamic-balance items: (1) walking backward along balance beams, (2) hopping for height, (3) jumping sideways over a slat, and (4) moving sideways on boards. The KTK manual provides normative data based on the scores of a German standardization sample ($N = 1{,}128$). Based on these normative data, each item raw score can be converted to a motor quotient adjusted for age (item 1-4) and sex (item 2 and 3); the sum of these individual motor quotients can be used to calculate a general motor quotient and percentile rank. The test can be administered in a small gymnasium and takes approximately 15-20 minutes to conduct.

The KTK is considered a highly standardized assessment tool (Cools, De Martelaer, Samaey, & Andries, 2009). Content validity was established through high explained variance of the total score by the item scores (80.9 – 97.7%) and construct validity was shown through factor analysis demonstrating all items loading on one factor (Kiphard & Schilling, 1974). The test manual also documents high levels of test-retest reliability ($r > .85$), inter-rater reliability ($r > .85$) and intra-rater reliability (ICC = .80 – .97; Kiphard & Schilling, 1974, 2007).

The strength of the KTK lies in its accuracy and robustness, which enables an efficient assessment of a child's motor competence due to its administrative properties, i.e., limited assessment training needed, minimum space required, simple instructions and brief set-up and testing time. Because of the wide age span, the test is highly suitable for longitudinal studies. The KTK is also used as a validation tool for other motor tests (Cools, De Martelaer, Samaey, & Andries, 2009). A weakness of the assessment is that it does not encompass FMS and only focuses on gross motor coordination.

1.2.3.2 Motor Proficiency Test for 4-6-year-old Children (MOT 4-6)

The MOT 4-6 (Zimmer & Volkamer, 1987) measures the gross and fine motor skills of children aged four to six years. The purpose of this product-oriented and norm-referenced assessment is to assess the motor competence level of young children and to identify those who are at risk of motor delay. The MOT 4-6 has roots in the KTK and the Lincoln-Oseretsky Motor Development Scale, but was specifically designed to suit the needs of children in their preschool years (Cools, De Martelaer, Samaey, & Andries, 2009; Zimmer & Volkamer, 1987). The test includes one practice item and 17 test items (14 gross motor skill items and 3 fine motor skill items; for details, see Table 1, p. 31). Items are scored on a three-point scale system (0-2). Using normative data, based on the performance of a German reference sample ($N = 548$), the raw scores can be summed to produce an age-based motor quotient and percentile rank. The MOT 4-6 can be administered in a medium-size gymnasium and takes approximately 15-20 minutes to complete.

The psychometric properties of the MOT 4-6 have been documented in the test manual (Zimmer & Volkamer, 1987). Content and construct validity have been described on the basis of movement skill literature. Furthermore, the original authors reported high levels of inter-rater reliability ($r = .88$), test-retest reliability ($r = .85$) and internal consistency reliability (Cronbach's $\alpha = .81$).

The major strength of the MOT 4-6 is its wide range of motor skill items to assess the motor competence of young children. In addition, the playful items make the test highly appropriate for young children. The assessment also has favorable administrative aspects, i.e., limited assessment training required, minimum space needed, simple instructions, and brief assessment time. A limitation of the MOT 4-6 is that it only covers the preschool age group which makes it not suited for longitudinal studies outside the indicated age range.

1.2.3.3 Test of Gross Motor Development-2 (TGMD-2)

The TGMD-2 (Ulrich, 2000) is a process-oriented, and criterion- and norm-referenced instrument that measures the FMS of children aged 3-10 years. The purposes of the test are (a) to assess the FMS competence of children, (b) to identify and screen children who are at risk for motor delay, (c) to provide information for the design of programs and instructions, (d) to evaluate progress over time in the context of maturation, experience and intervention programs, and (e) to serve as a research tool. The TGMD-2 is a revised version of the TGMD (Ulrich, 1985). The revised test includes 12 FMS items that are categorized into two subtests: (1) locomotor skills: run, gallop, hop, leap, horizontal jump, slide; and (2) object control skills: strike, dribble, catch, kick, overarm throw, underhand roll. The TGMD-2 manual provides normative data based on the performance of a US standardization sample ($N = 1{,}128$). Hence, each subtest's raw score can be converted into a standard score adjusted for age; the object control standard score is also adjusted for sex due to differences in performance between boys and girls (Ulrich, 2000). The locomotor and object control standard score, in turn, can be combined to produce the gross motor quotient and percentile rank. The test requires a large gymnasium and takes approximately 20 minutes to conduct.

The psychometric quality of the TGMD-2 has been well-established. Content validity was established through an expert panel and construct validity was shown through factor analysis (Evaggelinou, Tsigilis, & Papa, 2002; Simons et al., 2007; Ulrich, 2000; Valentini, 2012; Wong & Cheung, 2010). In addition, the test manual reports high levels of test-retest reliability ($r \geq .88$), inter-rater reliability ($r = .98$) and internal consistency reliability (Cronbach's α = .85, .88 and .91 for locomotor subtest, object control subtest and gross motor quotient).

The strength of the TGMD-2 is its process-oriented approach to assess FMS in children. In addition, the test covers the developmentally sensitive age period of early childhood up to 10 years. The test includes skills that are generally adopted in sports and games. The equipment is readily available and the test is easy to administer (simple instructions and brief test time); however, it should be noted that sufficient assessment training is required in order to correctly evaluate the motor skill patterns. Limitations of the TGMD-2 are its bias of some object control skills towards the American sports culture (i.e., strike and overarm throw) and the absence of balance skills.

Motor assessments are invaluable to describe and monitor motor competence across developmental time. In addition to the psychometric properties, the choice of an assessment tool depends on different factors: the purpose and content of the test, the age suitability, the user friendliness, the administration time, and the cultural appropriateness (Cools, De Martelaer, Samaey, & Andries, 2009). Nevertheless, there are methodological issues in motor development research related to the use of different motor competence measures. Robinson et al. (2015) suggested that there should be an agreement among researchers to adopt widely used assessments with adequate psychometric qualities in order to compare data across observational and experimental studies, and to further understand the role of motor competence in children's health. Taking these considerations into account, we selected the KTK, MOT 4-6 and TGMD-2 as these tests are considered reliable and valid, have favorable administrative qualities, and are frequently used in research and practice. The systematic use of such assessments should, however, be accompanied by methodological research that further investigates the psychometric properties of these assessments and provides support for measurement practices. This will allow researchers and practitioners to adequately examine children's motor competence status and progress, and to provide optimal assistance in designing and evaluating motor skill interventions.

1.3 Motor skill interventions

Gaining proficiency in FMS during early childhood is important for successful and continued participation in physical activity as these basic skills form the building blocks for later context-specific skills (Clark & Metcalfe, 2002; Gallahue et al., 2012; Seefeldt, 1980). The development of FMS is not merely maturational but, instead, it occurs through interaction between the individual and the environment. Environmental stimulation in the form of practice opportunities and guided instructions enable young children to develop and master FMS, and to attain motor competence. For this reason, different interventions have been designed and implemented in school or childcare settings (see Logan, Robinson, Wilson, & Lucas, 2012; Riethmuller, Jones, & Okely, 2009, for systematic reviews).

1.3.1 Instructional approaches

There are different instructional techniques that are used in the delivery of intervention programs. A distinction is generally made between teacher-centered and child-centered approaches.

The teacher-centered approach involves direct instruction from the teacher. The goals and activities are clearly defined by the teacher with little input from the children. Children have limited autonomy in selecting and/or performing an activity within this instructional climate and receive instructions on how to complete an activity successfully (Gallahue et al., 2012; Graham, Holt-Hale, & Parker, 2007). The child-centered approach involves creating a mastery motivational climate that supports children's motivation and autonomous learning. Children select and perform activities based on their preferences while the teacher acts as a facilitator and provides feedback and suggestions. The program content and instructions for this learning climate are developed using the TARGET structure: task, authority, recognition, group, evaluation and time (Ames, 1992). Both the teacher-centered and child-centered approaches have been shown to be successful in intervention studies (e.g., Goodway & Branta, 2003; Goodway, Crowe, & Ward, 2003; Robinson & Goodway, 2009; Valentini & Rudisill, 2004).

1.3.2 Impact of motor skill programs

There is strong evidence supporting the positive influence of motor skill interventions on FMS development in early childhood. Children greatly benefit from these motor skill programs that are generally delivered over a period of 8-12 weeks (Logan et al., 2012; Riethmuller et al., 2009). Bardid et al. (2013) demonstrated that a 10-week FMS program significantly influenced the FMS competence of three- to five-year-old children with motor problems. Moreover, the program helped nearly half of these children achieve a normal competence level. In contrast, the control group made no progress in FMS development. Goodway and Branta (2003) found similar findings in their 12-week intervention study with disadvantaged preschool children; the intervention group improved their FMS while the control group did not.

Many motor skill interventions have targeted children who are developmentally delayed or who are at risk of delay (Logan et al., 2012). Nonetheless, studies have shown that there is a general decline in motor competence levels in children from Western countries. Vandorpe et al. (2011), for example, investigated the motor competence levels of Belgian children aged 6-12 years using the KTK and found a higher portion of children with motor difficulties when compared to the German reference group from 1974; similar findings of downward trends have been found in other countries such as Australia (Okely & Booth, 2004), Canada (Darrah, Magill-Evans, Volden, Hodge, & Kembhavi, 2007) and Germany (Bös, 2003). In addition, the study of Raczek (2002) suggests that the secular decline in motor competence levels may already manifest itself in early childhood although other studies could not confirm this trend (e.g., Rethorst, 2003; Roth et al., 2010). In view of the reduced levels of motor competence in children and the importance of FMS development in early childhood, there is a need to provide motor skill programs to the general pediatric population.

The secular trends in motor competence and physical activity have led to increased efforts in research and policy to promote FMS in young children through the implementation of sustainable intervention programs. Although there is strong evidence on the effectiveness of small-scale intervention programs led by motor development experts, research on the impact of community-based programs led by local instructors is limited. One intervention study of van Beurden et al. (2003) in primary schools demonstrated that the modification of existing PE lessons through a collaborative approach (including teacher training) significantly increased the FMS competence of children. Community-based movement programs reach large numbers of children and are considered ecologically valid due to the program implementation within existing structures (WHO, 2012). However, there is a need for more research to examine the effectiveness of such programs and assess the feasibility of local instructors successfully delivering motor skill programs in naturalistic settings (Logan et al., 2012).

1.4 Research objectives

In Chapter 1, we reviewed the literature related to motor development and motor competence in young children. As mentioned, attaining motor competence in early childhood is considered an important factor for developing an active and healthy lifestyle (Gallahue et al., 2012; Robinson et al., 2015). It is, therefore, important to progress our understanding of motor competence and development, and provide recommendations for research and practice. The main goal of this thesis is to gain more knowledge on early childhood motor development by means of measuring, understanding and promoting motor competence in young children. Chapters 2 to 6 of this dissertation include original research consisting of four published studies and one study that has been submitted for publication.

Chapter 2 and 3 include validity studies that extend our knowledge of motor assessment in early childhood and provide support for measurement practices.

- In Chapter 2, we describe the similarities and differences between the KTK and MOT 4-6. These product-oriented assessments are considered reliable and valid, easy to administer and are both widely used. However, prior research has shown that the results of motor tests do not always agree which may impede the communication between researchers and/or practitioners. The extent to which the KTK and MOT 4-6 measures agree has not been thoroughly examined and would provide valuable information to the use of motor assessments and motor competence scores. Therefore, the aim of the study was to examine the convergent and divergent validity between both tests. Based on previous studies (Cools, De Martelaer, Vandaele, Samaey, & Andries, 2010; Fransen et al., 2014), we hypothesized that there would be a moderate positive correlation between total scores of the KTK and MOT 4-6. Additionally, there would be stronger associations between the KTK total score and MOT 4-6 total and gross motor composite scores than between the KTK total score and MOT 4-6 fine motor composite score.
- In Chapter 3, we delineate the investigation into the construct of motor competence in young children. The general use of composite scores in

motor assessment is based on the assumption that motor competence is a one-dimensional construct underlying various motor skills (i.e., the general motor ability [GMA] hypothesis; Brace, 1927). Interestingly, there is limited methodological research supporting that assumption. Adopting Rasch modeling, this study aimed to test the GMA hypothesis in early childhood by evaluating the dimensionality and homogeneity of the motor competence construct using the MOT 4-6 and to provide validation for the use of composite scores in motor assessment.

Chapter 4 and 5 include descriptive/comparative studies that provide motor competence data in young children and give a better understanding of motor competence and its cultural context.

- In Chapter 4, we report the comparison of motor competence levels in young Australian and Belgian children. There is limited research investigating the similarities and differences in motor competence across countries, partly due to the use of different measurements. A widespread adoption of a standardized non-sport specific test can provide valuable information on how motor competent children are on a global level and help identify relevant cultural factors that promote motor competence development. As such, the aim of the study was to evaluate the motor competence of children from Australia and Belgium using the KTK.
- In Chapter 5, we describe the motor competence levels of Belgian young children using the TGMD-2. Early childhood data on FMS in European countries is limited. The TGMD-2 is a process-oriented assessment that covers the developmentally sensitive age period for FMS development and can contribute to a better understanding of young children's motor competence. Nonetheless, the test is developed in the United States and has generally been used outside of Europe. As such, the aim of this study was to examine the FMS of Belgian children aged 3-8 years and to evaluate the suitability of using the TGMD-2 in a European context. Based on a previous study (Simons & Van Hombeeck, 2003), it was hypothesized that Belgian children would score similarly on locomotor skills but lower on object control skills when compared to the US reference sample.

Chapter 6 depicts an intervention study that examines the impact of a community-based FMS program for typically developing young children and gives insight into promoting motor competence.

- In Chapter 6, we describe the effects of the Multimove for Kids intervention in 3- to 8-year-old children. Participants followed a 30-week FMS program provided in a variety of community settings and implemented by local instructors who received teacher training. Although there is strong evidence supporting the value of expert-led motor skill programs on children's health and growth, little is known on the effectiveness of large-scale community-based programs led by local instructors. Therefore, the aim of the study was to evaluate the effectiveness of the Multimove program in young children and to examine possible sex differences. Based on prior intervention research (Logan et al., 2012; Morgan et al., 2013), we hypothesized that the FMS program would significantly improve children's motor competence.

Chapter 2

Comparison of two motor tests in early childhood

The aim of this study[1] was to investigate the convergent and divergent validity between the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]) and the Motor Proficiency Test for Four- to Six-year-old Children (Motoriktest für Vier- bis Sechsjährige Kinder [MOT 4-6]). A total of 638 children aged 5-6 years took part in the study. The results show a moderately positive association between the total scores of both tests (r_s = .63). Moreover, the KTK total score correlated higher with the MOT 4-6 gross motor score than with the MOT 4-6 fine motor score (r_s = .62 vs. .32). Levels of agreement were moderate when identifying children with moderate or severe motor problems, and low at best when detecting children with higher motor competence levels. This study provides evidence of convergent and divergent validity between the KTK and MOT 4-6. However, given the moderate to low levels of agreement, either measurement may lead to possible categorization errors. Children's motor competence should therefore not be judged based on the result of a single test.

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2.1 Introduction

Daily life activities challenge children to master different motor skills, i.e., goal-directed well-coordinated movement patterns of one or several muscle groups (Burton & Miller, 1998). The ability to perform a wide variety of gross and fine motor skills in a proficient manner has been defined by some authors as motor competence (e.g., Fransen et al., 2014; Haga, 2008). As early childhood is a sensitive period to learn and develop motor skills, acquiring a certain level of motor competence during preschool years increases the chance to become proficient in various sports and games in later life (Gallahue et al., 2012). Accordingly, adequate motor competence facilitates children's engagement and participation in physical activity (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lopes, Rodrigues, Maia, & Malina, 2011; Stodden et al., 2008).

In contrast, children with low levels of motor competence demonstrate lower levels of physical fitness and physical activity over time. For instance, the study of Green et al. (2011) showed that the low levels of motor competence in children with developmental coordination disorder (DCD) at the age of seven contributed to the low levels of moderate-to-vigorous physical activity at the age of twelve [see also Barnett et al. (2009) and Hands (2008)]. In their model, Stodden et al. (2008) refer to a negative spiral of disengagement in physical activity with low actual and perceived motor competence, low levels of physical activity, and low health-related fitness, leading to increased weight and obesity which in turn will stimulate further disengagement in physical activity.

Considering the importance of motor competence on health and well-being, there is a need to adequately identify and monitor the motor development in early childhood, especially in populations 'at risk' for motor delay or disorder, e.g., developmental disorders [DCD (Cairney et al., 2005), autism spectrum disorder (ASS; Gowen & Hamilton, 2013), or attention deficit hyperactivity disorder (ADHD; Piek & Dyck, 2004)]. Once motor problems are identified, adapted activity programs can be implemented to (partly) eliminate motor delays (e.g., Apache, 2005; Bardid et al., 2013; Goodway & Branta, 2003). Furthermore, good quality test batteries are also invaluable for monitoring progress after therapeutic practice.

To examine the level of motor competence in preschool children, several test batteries have been developed [for a review see Cools, De Martelaer, Samaey, & Andries, (2009)]. Most test batteries are aimed at identifying children with motor problems (Barnett & Peters, 2004; Yoon, Scott, & Hill, 2006). These assessment tools can be product- and/or process-oriented; product-oriented tools measure the outcome of motor tasks (e.g., number of sideway jumps in a limited time), while process-oriented instruments focus on the quality of motor skills based on selected criteria (e.g., arm-leg coordination during running). It has been shown that the results of different tests do not always agree, despite the fact that those tests claim to measure the same construct (i.e., motor competence). For example, the study of Smits-Engelsman, Henderson and Michels (1998) revealed a moderate association between the Movement Assessment Battery for Children (M-ABC; Henderson & Sugden, 1992) and the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]; Kiphard & Schilling, 1974, 2007) in children aged 5-13 years. Obviously, this may hamper communication between researchers and/or practitioners and has important implications with respect to diagnosing children with motor difficulties. By means of validity research, it is determined to what extent two measures assess the same construct (i.e., convergent validity) and to what extent they evaluate different characteristics, hence referring to different constructs (i.e., divergent validity; Portney & Watkins, 2009). This type of research can provide valuable information and is required for test batteries that are widely adopted.

Two motor tests that are widely used in West-European countries, are the KTK and Motor Proficiency Test for Four- to Six-year-old Children (Motoriktest für Vier- bis Sechsjährige Kinder [MOT 4-6]; Zimmer & Volkamer, 1987). Both tests have good psychometric properties, are user friendly and are used in clinical and educational settings (Cools, De Martelaer, Samaey, et al., 2009; Wiart & Darrah, 2001). The KTK was developed to identify children with motor problems but is also suitable for the determination of motor competence in typically developing children. The test measures gross motor coordination in children from 5 to 14 years old and consists of four dynamic balance tasks. The KTK has been used in different populations with disabilities, e.g., children with hearing problems (Gheysen, Loots, & Van Waelvelde, 2008), heart disease

(Stieh, Kramer, Harding, & Fischer, 1999), obesity (D'Hondt et al., 2011), and hypermobility (Hanewinkel-van Kleef, Helders, Takken, & Engelbert, 2009). The test is considered robust as the tasks are not easily mastered and therefore useful for follow-up (Kiphard & Schilling, 1974). The MOT 4-6 was designed to assess the gross and fine motor skills of preschool children (4 to 6 year old) and allows early identification of children with motor delay. The test features 18 test items, which are grouped in gross motor skills, including locomotor, object control and balance skills, and fine motor skills (Vandaele, Cools, de Decker, & de Martelaer, 2011; Zimmer & Volkamer, 1987; see also Table 1). The MOT 4-6 has also been used in different populations with disabilities, e.g., children with hypothyroidism (Arenz, Nennstiel-Ratzel, Wildner, Dörr, & von Kries, 2008). Due to its pedagogical approach (many items have a playful character), this test is considered very suitable for the preschool age group.

For both tests, the psychometric properties have been established and are discussed in the manual (Kiphard & Schilling, 1974; Zimmer & Volkamer, 1987). For the KTK, high explained variances of the total score by the item scores (ranging from 80.9% to 97.7%) indicated excellent content validity. Construct validity was shown through factor analysis and known groups method. Factor analysis demonstrated that all subtests load on one factor. With the known groups method, 91% of children with brain injury were differentiated from typically developing children. Furthermore, the test manual reports excellent test-retest and inter-rater reliability (all r-values > .85), and good intraclass correlations among test items (ICC = 0.80 - 0.96). For the MOT 4-6, construct and content validity have been described based on movement skill literature (Zimmer & Volkamer, 1987). In addition, the MOT 4-6 manual reports good internal consistency (Cronbach's alpha coefficient = 0.81) and a high test-retest and inter-rater reliability (r = .85 and .88 respectively). The KTK and the MOT 4-6 have shown moderate to strong correlations with motor tests, such as the M-ABC and Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2; Bruininks & Bruininks, 2005), that have been frequently used to identify children with DCD (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012; Cools et al., 2010; Fransen et al., 2014; Smits-Engelsman et al., 1998).

Table 1. Items in the Motor Proficiency Test for 4- to 6-year-old Children (MOT 4-6)

Subtests	**Items**	**Scale system**
Gross motor skills		
Locomotor	Jumping sideways over a rope	0 = ≤ 7 jumps in 10 s 1 = 8-11 jumps in 10 s 2 = ≥ 12 jumps in 10 s
	Moving balls from box to box	0 = ≥ 15 s (3 x 1 ball) 1 = 14-12 s (3 x 1 ball) 2 = ≤ 11 s (3 x 1 ball)
	Passing through a hoop	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
	Jumping jacks	0 = no elements included 1 = sustained for 10 s, rhythmic or coordinated 2 = sustained for 10 s, rhythmic and coordinated
	Jumping over a cord	0 = no successful jump 1 = 35 cm height jump 2 = 45 cm height jump
	Rolling sideways over the floor	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
	Twist jump in/out of a hoop	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
Object control	Catching a stick	0 = no catch or catch in zone 4 1 = catch in zone 2-3 2 = catch in zone 1
	Throwing a ball at a target disk	0 = 0 hits 1 = 1 hit 2 = 2-4 hits
	Catching a tennis ring	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
Stability	Balancing forward on a line	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
	Balancing backwards on a line	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
	Jumping on one leg into a hoop	0 = 0 succesful trials 1 = 1-2 succesful trial 2 = 3-4 succesful trials
	Standing and sitting while holding a ball on the head	0 = no successful trial 1 = succesful standing or sitting 2 = succesful standing and sitting
Fine motor skills	Placing dots on a sheet	0 = ≤ 26 dots in 10 s 1 = 27-37 dots in 10 s 2 = ≥ 38 dots in 10 s
	Grasping a tissue with toes	0 = 0 succesful trials 1 = 1 succesful trial 2 = 2 succesful trials
	Transferring matches	0 = ≥ 71 s (2 x 20 matches) 1 = 70-54 s (2 x 20 matches) 2 = ≤ 53 s (2 x 20 matches)

The KTK and the MOT 4-6 are both used to measure motor competence in young children aged 5 to 6 - an age group in which accurate and early identification of motor problems is very important. Up to now, only one analysis of convergent validity between KTK and MOT 4-6 has been reported in the MOT 4-6 manual (Zimmer & Volkamer, 1987). It is, however, limited both in sample size and in scope of the analyses. Further independent research is needed to examine the similarities and differences between the KTK and MOT 4-6, and to investigate the extent to which these tests detect the same atypically developing children. Therefore, the aim of the present study was to assess the convergent and divergent validity between the KTK and MOT 4-6 in a large sample of 5 to 6-year old children. Convergent validity was examined by evaluating the relationship between the standardized total scores or Motor Quotients (MQ) of both tests. Divergent validity was examined by evaluating the relationship between the KTK MQ and the different components of the MOT 4-6, as documented in the manual and by Vandaele et al. (2011) (see also Table 1). A second aim of the study was to assess the level of classification agreement between the two test batteries over the whole motor competence continuum. We hypothesized that the MQs of the KTK and MOT 4-6 would be positively correlated (with $r \geq 0.60$), based on earlier validity studies (Cools et al., 2010; Fransen et al., 2014; Smits-Engelsman et al., 1998; Van Waelvelde, Peersman, Lenoir, & Smits-Engelsman, 2007). In addition, the KTK MQ would exhibit stronger correlations with the MOT 4-6 MQ and its gross motor component than with the MOT 4-6 fine motor component.

2.2 Methods

2.2.1 Participants

A total of 638 young children (323 boys and 315 girls, aged between 5 and 6 years) took part in this cross-sectional study. Children were recruited from 49 settings (i.e., schools, sports clubs, local councils and day care centers) in Flanders, Belgium. To obtain a representative sample, these settings were selected from all Flemish provinces and the Brussels Capital Region. Written informed consent was provided for each participant by a parent or guardian. This study was approved by the ethics committee of Ghent University Hospital.

2.2.2 Procedure

All children were assessed with the two test batteries on the same day in the following order: MOT 4-6 and KTK. A break of 5-10 minutes was provided between the tests. Tests were performed barefooted in an indoor facility with sufficient rest given after each test item. The KTK and the MOT 4-6 were administered by trained assessors and in accordance with the manual guidelines. All assessors had a physical education (PE) background, received a detailed instruction manual and participated in a half-day assessment training. Tests were conducted between September 2012 and November 2012.

2.2.3 Instruments

2.2.3.1 Body Coordination Test (KTK)

The KTK includes 4 subtests: (1) walking backwards along balance beams of different widths, (2) hopping for height, (3) jumping sideways over a slat, and (4) moving sideways on boards (Kiphard & Schilling, 1974). Scores per subtest were converted into standardized Motor Quotients (MQ) based on normative data of 1128 German children. These standardized scores are adjusted for age (all subtests) and gender (hopping for height and jumping sideways over a slat). MQs of all four subtests were then summed and transformed into a total KTK MQ. Finally, this standardized total score was expressed as a percentile score to classify the motor performance into categories, based on the percentile cut-off points of the test manual: lower than or equal to percentile 2 ("impaired") and 16 ("poor"), between P16 and P84 ("normal"), and higher than P84 ("good") and P98 ("high").

2.2.3.2 Motor Proficiency Test for 4- to 6-year-old Children (MOT 4-6)

The MOT 4-6 consists of 1 practice item and 17 test items that are divided into 4 subtests (see Table 1; Cools, De Martelaer, Samaey, et al., 2009; Vandaele et al., 2011; Zimmer & Volkamer, 1987). Performance on each test item was converted into a score ranging from 0 to 2 where a higher score represents a better performance. The sum of all item scores was converted into a standardized MQ based on normative data of 548 German children. This age-adjusted standardized score was also transformed into a percentile score to classify the motor score, based on the percentile cut-off points of the test manuals: lower than or equal to percentile 2 ("impaired") and 16 ("poor"), between P16 and P84 ("normal"), and higher than P84 ("good") and P98 ("high"). In addition to the conversion of raw score to norm-referenced score specified in the manual, we calculated a separate gross and fine motor component of MOT 4-6 to investigate convergent and divergent validity with the KTK. The procedure for this was adopted from previous validity studies (Cools et al., 2010; Van Waelvelde et al., 2007). According to the muscle groups involved, two cluster scores were calculated: gross and fine motor score. For the gross motor component we also calculated the sum of the item scores for the locomotor, object control and stability subtest. The scores of the fine motor test items were summed to obtain the fine motor cluster score.

2.2.4 Data analysis

All data were analyzed using SPSS version 20 for Windows. Values of $p < 0.05$ were considered statistically significant. Descriptive statistics (i.e., means and standard deviations) were computed for the total KTK MQ, and the MOT 4-6 MQ, gross motor cluster score (locomotor, object control and stability) and fine motor cluster score. Distribution of all children classified in the five performance categories was also reported for both the KTK and MOT 4-6. Since some performance scores did not demonstrate normal distribution, Spearman's rank correlations were used to examine the convergent and divergent validity between the total KTK MQ, and the MOT 4-6 MQ, MOT 4-6 gross motor cluster score (locomotor, object control and stability) and MOT 4-6 fine motor cluster score. Cohen's kappa statistics were performed to determine the level of agreement in classification between both tests.

2.3 Results

The tests scores on the KTK (i.e., total MQ and item MQ) and MOT 4-6 (i.e., MQ and gross and fine motor cluster scores) for the total sample and the sample divided into age groups and gender groups are reported in Table 2 and Table 3. The distribution of all children across the 5 classes of motor competence for each test battery is presented in Table 4.

Table 2. Performance on the KTK (standardized total score and item scores)

Variable	5-year-old	6-year-old	Total
Total MQ			
Boys	97.1 ± 15.2	98.4 ± 12.4	97.7 ± 13.9
Girls	95.2 ± 13.9	92.3 ± 15.3	93.8 ± 14.6
Total	96.2 ± 14.6	95.4 ± 14.3	95.8 ± 14.4
Walking backwards MQ			
Boys	85.7 ± 11.3	86.9 ± 12.7	86.3 ± 12.0
Girls	88.8 ± 12.0	88.9 ± 13.3	88.9 ± 12.6
Total	87.2 ± 11.7	87.9 ± 13.0	87.6 ± 12.4
Hopping for height MQ			
Boys	100.4 ± 16.9	102.2 ± 12.5	101.2 ± 15.0
Girls	95.1 ± 15.0	88.3 ± 17.6	91.9 ± 16.6
Total	97.8 ± 16.2	95.3 ± 16.7	96.6 ± 16.5
Jumping sideways MQ			
Boys	109.4 ± 19.0	108.5 ± 12.8	109.0 ± 16.4
Girls	104.1 ± 14.3	101.7 ± 16.9	103.0 ± 15.6
Total	106.8 ± 17.0	105.1 ± 15.4	106.0 ± 16.3
Moving sideways MQ			
Boys	96.1 ± 12.3	98.0 ± 14.1	97.0 ± 13.2
Girls	97.7 ± 12.8	97.6 ± 14.2	97.6 ± 13.5
Total	96.9 ± 12.6	97.8 ± 14.1	97.3 ± 13.3

Table 5 shows the correlations between the total KTK MQ and the MOT 4-6 MQ, gross and fine motor cluster scores for the total sample and for each age group separately. For the total sample, moderately strong positive correlations were found between the total KTK MQ and MOT 4-6 MQ ($r_s = 0.63$) and between the total KTK MQ and MOT 4-6 gross motor cluster score ($r_s = 0.62$). Within the MOT 4-6 gross motor component, a moderately positive correlation was found between the total KTK MQ and MOT 4-6 locomotor score ($r_s = 0.56$) and low positive correlations were found between the total KTK MQ and MOT 4-6 stability score ($r_s = 0.43$) and object control score ($r_s = 0.37$). A significant but low positive correlation was found between the total KTK MQ and MOT 4-6 fine motor cluster score ($r_s = 0.32$).

Table 3. Performance on the MOT 4-6 (standardized total score and cluster scores)

Variable	5-year-old	6-year-old	Total
Total MQ			
Boys	94.3 ± 15.8	98.1 ± 12.8	96.1 ± 14.6
Girls	97.3 ± 14.8	97.6 ± 18.4	97.5 ± 14.1
Total	95.8 ± 15.4	97.8 ± 13.0	96.8 ± 14.3
Gross motor skills			
Boys	14.9 ± 4.5	18.5 ± 3.7	16.6 ± 4.5
Girls	15.8 ± 4.5	18.4 ± 4.0	17.0 ± 4.5
Total	15.3 ± 4.5	18.4 ± 3.8	16.8 ± 4.5
Locomotor skills			
Boys	8.4 ± 2.6	10.2 ± 2.4	9.3 ± 2.7
Girls	9.1 ± 2.7	10.6 ± 2.4	9.8 ± 2.7
Total	8.7 ± 2.7	10.4 ± 2.4	9.5 ± 2.7
Object control skills			
Boys	2.9 ± 1.3	3.9 ± 1.1	3.4 ± 1.3
Girls	2.4 ± 1.3	3.2 ± 1.2	2.8 ± 1.3
Total	2.6 ± 1.3	3.6 ± 1.2	3.1 ± 1.4
Stability skills			
Boys	3.6 ± 1.8	4.3 ± 1.6	4.0 ± 1.7
Girls	4.3 ± 1.8	4.6 ± 1.6	4.4 ± 1.7
Total	3.9 ± 1.8	4.4 ± 1.6	4.2 ± 1.7
Fine motor skills			
Boys	3.2 ± 1.6	4.6 ± 1.2	3.9 ± 1.5
Girls	3.5 ± 1.5	4.7 ± 1.2	4.0 ± 1.5
Total	3.4 ± 1.5	4.6 ± 1.2	4.0 ± 1.5

For each age group (5 and 6 years), strong or moderately strong positive correlations were found between the MQs of both tests (r_s = .61 - .67), and the total KTK MQ and MOT 4-6 gross motor score (r_s = .62 - .72). Within the MOT 4-6 gross motor component, moderately positive correlations were found between the total KTK MQ and MOT 4-6 locomotor score (r_s = .53 – .68) and low positive correlations between the total KTK MQ and MOT 4-6 stability score (r_s = .42 – .49) and object control score (r_s = .31 – .44) for each age group. Low correlations were found between the total KTK MQ and MOT 4-6 fine motor cluster score for each age cohort (r_s = .20 - .47).

Table 4. Proportions of children across classification categories based on the KTK and MOT 4-6 test manuals

		KTK MQ		MOT 4-6 MQ	
Classification		*N*	%	*N*	%
Impaired	≤ P2	27	4.2	30	4.7
Poor	≤ P16	122	19.1	110	17.2
Normal	P16 - P85	429	67.2	459	71.9
Good	> P84	58	9.1	37	5.8
High	> P98	2	0.3	2	0.3

The total number of children classified in each percentile category (P2, P16, P84 and P98) is shown in Table 6. The Cohen's kappa statistics showed moderate levels of agreement between the KTK and MOT 4-6 at P2 (κ = 0.50) and P16 (κ = 0.52), a fair level of agreement at P84 (κ = 0.23) and no agreement at P98 (κ = 0.00). For the P2 cut-off, 56% of the children classified in the ≤ P2 category by the KTK, falls within the same category when tested by the MOT 4-6. For the P16, P84, and P98 cut-off this proportion is 61%, 23% and 0% respectively.

2.4 Discussion

Early identification and appropriate monitoring of motor problems are key to a tailored approach in PE or therapeutic practice, where the activities are adapted to the needs of the individual. For this, practitioners are dependent on quality motor test batteries, with adequate psychometric properties and known relationships with other test batteries.

Table 5. Results of the Spearman correlations between the KTK motor quotient (MQ) and the MOT 4-6 MQ, gross and fine motor cluster scores

	KTK MQ					
	5-year-old		6-year-old		Total	
Variable	r_s	*p*	r_s	*p*	r_s	*p*
MOT 4-6 MQ						
Boys	.67	<.001	.61	<.001	.64	<.001
Girls	.66	<.001	.64	<.001	.65	<.001
Total	.65	<.001	.61	<.001	.63	<.001
MOT 4-6 Gross motor skills						
Boys	.71	<.001	.62	<.001	.62	<.001
Girls	.72	<.001	.70	<.001	.64	<.001
Total	.70	<.001	.64	<.001	.62	<.001
Locomotor skills						
Boys	.65	<.001	.53	<.001	.57	<.001
Girls	.67	<.001	.68	<.001	.61	<.001
Total	.64	<.001	.56	<.001	.56	<.001
Object control skills						
Boys	.44	<.001	.31	<.001	.37	<.001
Girls	.41	<.001	.32	<.001	.31	<.001
Total	.43	<.001	.36	<.001	.37	<.001
Stability skills						
Boys	.49	<.001	.42	<.001	.46	<.001
Girls	.47	<.001	.45	<.001	.45	<.001
Total	.46	<.001	.40	<.001	.43	<.001
MOT 4-6 Fine motor skills						
Boys	.47	<.001	.40	<.001	.42	<.001
Girls	.38	<.001	.20	<.001	.24	<.001
Total	.42	<.001	.28	<.001	.32	<.001

The purpose of this study was to investigate the convergent and divergent validity between the KTK and MOT 4-6 in children aged 5 to 6 years. Our second aim was to assess the level of agreement between these tests across the motor competence continuum. In agreement with our hypothesis, we found a moderately positive association between the total KTK MQ and MOT 4-6 MQ. Moreover, the total KTK MQ demonstrated stronger correlations with the MOT 4-6 MQ and its gross motor component than with the MOT 4-6 fine motor component. Finally, the level of agreement in classification was moderate at the low end of the continuum and absent at the high end.

Table 6. Results of the Cohen's kappa analysis between the KTK MQ and the MOT 4-6 MQ

		KTK MQ				
		> P2	**≤ P2**	**Total**	***κ***	***p***
MOT 4-6 MQ	> P2	596	12	608	.50	<.001
	≤ P2	15	15	30		
	Total	611	27	638		
		> P16	≤ P16	Total		
	> P16	440	58	498	.52	<.001
	≤ P16	49	91	140		
	Total	489	149	638		
		> P84	≤ P84	Total		
	> P84	14	25	39	.23	<.001
	≤ P84	46	553	599		
	Total	60	578	638		
		> P98	≤ P98	Total		
	> P98	0	2	2	.00	.937
	≤ P98	2	634	636		
	Total	2	636	638		

The moderate correlation coefficients identified between the total KTK MQ and MOT 4-6 MQ indicate that both test batteries measure a similar construct, which is in accordance with the results of the small study mentioned in the MOT 4-6 manual (r = .78; N = 181). Furthermore, the results are consistent with prior research by Smits-Engelsman et al. (1998) on the relationship between the KTK and M-ABC (r_s = .61), and Fransen et al. (2014) on the relationship between the KTK and BOT-2 (r_s = .62). Furthermore, Cools et al. (2010) found a correlation of 0.68 between the MOT 4-6 and M-ABC total scores. While these moderate associations are considered to be typical within the field of motor assessment, they do suggest that each test battery tends to measure a different aspect of a similar construct, i.e., motor competence. Clearly, the correlation coefficient is primarily dependent on the nature of the tasks. In this respect, it is reassuring that the present study provides evidence of divergent validity through stronger positive associations between the KTK and the MOT 4-6 gross motor cluster score than between the KTK total score and the MOT 4-6 fine motor cluster score. These findings are in accordance with previous studies where the gross motor scales of two test batteries correlate better than the gross motor scale of one battery and the fine motor scale of the other (Cools et al., 2010; Fransen et al., 2014; Van Waelvelde et al., 2007). In addition, within the MOT 4-6 gross motor component, stronger positive correlations were found between the KTK total score and MOT 4-6 locomotor and stability scores than between the KTK total score and MOT 4-6 object control score. Surprisingly, the MOT 4-6 locomotor score correlated higher with the KTK total score compared with the MOT 4-6 stability score. A possible explanation is that the locomotor items include agility and coordination, which are also present in the KTK test battery. Since both gross and fine motor skills play a key role in children's cognitive, physical and social development (Hill, 2010), motor assessment should take both components into account when measuring motor competence.

In keeping with Van Waelvelde et al. (2007), these findings indicate that test results should only be interpreted in relation to the specific tasks used in the test. Netelenbos (2001a, 2001b) commented that a test instrument with a large amount of motor tasks could provide a solution for mutually independent motor skills. However, such a test battery can by definition become time consuming and therefore be less suitable for children, particularly when they are young. The purpose of the assessment, the age appropriateness, the proportion of each item in relation to the overall test time and the user-friendliness should be considered when selecting an assessment tool for young children (Cools, De Martelaer, Samaey, et al., 2009). Although the time to administer the motor tasks is similar between MOT 4-6 and KTK (15 – 20 min), the MOT 4-6 consists of 18 tasks as opposed to the KTK, which only contains 4 tasks. Finally, an important factor that is often overlooked when measuring motor competence is physical fitness. As argued by Fransen et al. (2014), the degree to which a motor test depends on the level of physical fitness may partly explain why the correlation between the tests is only moderate. In the current study at least two items of the KTK (hopping for height and jumping sideways over a slat) require particular levels of strength and endurance that appear less important in the MOT 4-6.

Regarding the level of agreement on classification between the KTK and MOT 4-6, Cohen's kappa indicates moderate levels of agreement for P2 and P16, but low level of agreement for children scoring for P84. No agreement was reported for P98. Closer inspection of the data shows that 56% and 61% of the children classified in the < P2 and < P16 category by the KTK respectively, fall within the same category when tested by the MOT 4-6. In contrast, for P84 and P98 cut-off this proportion is 23% and 0% respectively. A possible explanation for the higher agreement at the lower end of the motor competence continuum, is that the KTK and MOT 4-6 tests were designed with the aim to detect children with motor delay (Kiphard & Schilling, 1974; Zimmer & Volkamer, 1987). Furthermore, it is worth noting that the rate of development may vary considerably amongst individuals of this age. Therefore, caution is warranted when categorizing them into subgroups indicating levels of motor competence, and regular follow-up is recommended to check whether development is deviant.

In addition, a decline in motor competence of the study sample is observed in comparison with the reference population (total KTK MQ: 95.8 versus 100; MOT MQ: 96.8 versus 100), which is accompanied with a general shift of the distribution of the sample towards the lower ends of the continuum (see Table 4). For both tests a rather high proportion of the children scored below the 16th percentile (23% and 22% for KTK and MOT 4-6, respectively), and only 9% and 6% (KTK and MOT 4-6, respectively) scored above P84. This decrease in childhood motor competence as compared to the norm samples tested in the 1970s (KTK) and 1980s (MOT 4-6) is consistent with previous studies (Bös, 2003; Darrah, Magill-Evans, Volden, Hodge, & Kembhavi, 2007; Sigmundsson & Rostoft, 2003; Eric van Beurden, Zask, Barnett, & Dieterich, 2002; Vandaele et al., 2011; Vandorpe et al., 2011). Since the levels of agreement between the KTK or MOT 4-6 are low to moderate, practitioners should be aware of possible categorization errors when using one of these tests. Therefore, as proposed by Fransen et al. (2014), it is advised that judgment of motor competence during childhood should not be based on performance of a single motor assessment battery.

The main strength of this study is its use of a large sample. Previous validity research (Cools et al., 2010; Smits-Engelsman et al., 1998; Van Waelvelde et al., 2007) included relatively small sample sizes, ranging from 31 to 208 children. One exception is the study of Fransen et al. (2014) in which 2485 participants performed the KTK and BOT-2 Short Form. There are some limitations to the present study that need to be addressed. First, the order of administering the two tests was not counterbalanced due to logistical constraints; the MOT 4-6 takes longer to set up compared to the KTK and was therefore administered first. Second, point scores were used for the gross and fine motor cluster scores for the MOT 4-6 as the manual does not provide separate standardized subscales. Still, we would argue that this division into two cluster scores has enhanced the comparison between the MOT 4-6 and KTK.

In conclusion, the present study showed some evidence of convergent validity between the total KTK MQ and MOT 4-6 MQ. Divergent validity between both tests was also established by means of stronger associations between the total KTK MQ and the MOT 4-6 gross motor score in comparison with lower associations between the total KTK MQ and the MOT 4-6 fine motor score. However, only moderate levels of agreement on classification of children with low motor competence and low to no agreement at the higher end of the motor competence spectrum were found. Considering the importance of providing optimal support to children with motor problems and preventing the development of health-related problems (Jongmans, 2005), it is advised to use at least two motor competence test batteries when evaluating motor competence in early childhood. Moreover, it is desirable to take both product (e.g., using KTK and MOT 4-6) and process [e.g., using the Test of Gross Motor Development – 2nd edition (TGMD-2; Ulrich, 2000)] into account when assessing young children's motor competence, especially given the large differences in rate of development at this stage. With regard to the latter, researchers and practitioners need to consider the purpose and suitability of a motor assessment when selecting a test battery for young children and use caution when categorizing young children into groups to indicate their level of motor competence. Regular follow-ups can provide additional valuable information to determine if a child's motor competence deviates from its normal developmental trajectory. Finally, a multitude of different tests are used in clinical and educational settings to assess motor competence or identify motor problems. Still, it remains unclear to what extent some tests actually measure the same construct. To ensure communication between researchers and practitioners, and to optimize the identification and support of children with motor difficulties, continuous efforts are needed to determine convergent and divergent validity between popular test batteries.

Chapter 3

Evaluation of the motor competence construct in early childhood

The present study[2] investigated the dimensionality and homogeneity of motor competence, which is defined as the ability that underlies the performance of a wide variety of motor skills, in early childhood using a large set of items. A total of 1467 children (aged 3-6 years) were measured with the Motor Proficiency Test for 4- to 6-year-old Children (Motoriktest für Vier- bis Sechsjährige Kinder [MOT 4-6]), which consists of 17 items. Analyses using the partial credit model and mixed Rasch model revealed a one-dimensional structure ($CR = 1.964$, $p_{CR} = .06$; $P\text{-}\chi^2 = -.227$, $p_{P\text{-}\chi^2} = .24$). Due to unordered threshold parameters, five items were excluded. These items have a scoring system that counts the amount of successful trials (0-2). The study shows item and person homogeneity within a validated motor score, using 12 items of MOT 4-6. Thus, it provides evidence of a single latent construct (i.e., motor competence), which underlies the performance of motor skills in early childhood. Furthermore, it shows that counting the number of successful trials may be less suitable as a scoring system in motor competence assessment. Present findings also support the use of validated composite scores in motor assessment.

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[2] This study has been published as: Utesch, T., Bardid, F., Huyben, F., Strauss, B., Tietjens, M., De Martelaer, K., Seghers, J., & Lenoir, M. (2016). Using Rasch modeling to investigate the construct of motor competence in early childhood. *Psychology of Sport and Exercise, 24*, 179-187. doi:10.1016/j.psychsport.2016.03.001

3.1 Introduction

3.1.1 Motor competence and related constructs

Motor development is considered an important factor in children's overall health (Hill, 2010; Lubans et al., 2010; Robinson et al., 2015; Stodden et al., 2008). In spite of its significance, a common understanding of the latent construct of motor behavior underlying assessment is lacking. Different hypotheses and concepts have been introduced to explain motor behavior. One popular hypothesis is the classic general motor ability (GMA) hypothesis which states that numerous motor abilities are highly related within a person and form a single general motor ability (Brace, 1927). In their well-known taxonomy, Burton and Miller (1998) defined movement skills, motor abilities and general motor ability in a hierarchical order with movement skills at the top and general motor ability at the bottom. This taxonomy was further elaborated upon by Burton and Rodgerson (2001). Movement skills are defined as a specific group of goal-directed movement patterns, which can be altered through instruction and practice (Burton & Miller, 1998; Burton & Rodgerson, 2001). Motor abilities are described as "general traits or capacities of an individual, that underlie the performance of a variety of movement skills" (Burton & Miller, 1998). This concept has been frequently investigated, e.g., the classification schemes of Fleishman (1964) and Bös (2001). The underlying component in Burton and Miller's (1998) taxonomy is the general motor ability that governs all movement skills. In the research field of motor development, different terminologies are applied to describe the same construct. For instance, movement skills and motor skills are used interchangeably (Gabbard, 2008). Another example is motor competence which refers to the ability to execute a wide variety of motor skills, including both gross (e.g., jumping) and fine motor skills (e.g., manual dexterity) (Haga, 2008). In the context of motor assessment, motor competence can be regarded as the general motor ability because – by definition – both are often implicitly measured in assessment tools through a composite score that is built out of a wide range of test items from different motor abilities or motor domains (Burton & Rodgerson, 2001).

3.1.2 Motor competence assessment and underlying theoretical assumptions

Various motor tests have been developed for children and used in both research and educational settings (see Cools et al., 2009). Motor assessment and monitoring are specifically important during early childhood as the preschool years form a sensitive age period for motor development (Gallahue & Cleland-Donnelly, 2007; Haywood & Getchell, 2009). Different aspects need to be considered when selecting an appropriate test, including the total test time (and the relative time amount for each item) and the suitability of the test for the target group (Cools, De Martelaer, Samaey, & Andries, 2009). Another important factor is the purpose of the assessment, which is related to the research or educational question (Mahar & Rowe, 2008). Test instruments are constructed using different theoretical assumptions (e.g., product- or process-oriented approach). These tests should therefore be thoroughly tested on validity and reliability. In general, test instruments can only be as valid as the theoretical construct that is proposed. In turn, the validity of the construct is closely related to the theoretical assumptions, which are specified by a theory of measurement.

The theory of measurement that has generally been used to develop motor test batteries is the classical test theory (CTT). As such, research on the underlying latent trait(s) was mostly conducted using CTT methods like factor analysis and inter-item correlation, which resulted in either hierarchical classification schemes such as muscular strength, endurance, balance and reaction (Bös, 2001; Fleishman, 1964; Rarick, Dobbins, & Broadhead, 1976), or single factor scales (Bruininks, 1978; Ulrich, 1985). In spite of limited support for the GMA hypothesis provided by CTT studies, the concept of a single latent trait (i.e., motor competence) was included in the taxonomy of Burton and Miller (1998) and underpins many widely used assessments (Burton & Rodgerson, 2001). Burton and Rodgerson (2001) argued that the lack of evidence might be due to an inappropriate analysis approach which has dismissed the construct of motor competence due to low correlations between motor composite scores within and between motor tests. For instance, Fransen et al. (2014) found a correlation of .62 between the total scores of the Bruininks-Oseretsky

Test of Motor Proficiency, Second Edition (BOT-2; Bruininks & Bruininks, 2005) and the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]; Kiphard & Schilling, 1974, 2007) in primary school children (6-12 years). In another example, Cools et al. (2010) reported a correlation of .68 between the Movement Assessment Battery for Children (M-ABC; Henderson & Sugden, 1992; Smits-Engelsman, 1998) and the Motor Proficiency Test for 4- to 6-year-old Children (Motoriktest für Vier- bis Sechsjährige Kinder [MOT 4-6]; Zimmer & Volkamer, 1987) in preschool children (4-6 years). Similar results are found in other convergent validity studies (Croce, Horvat, & McCarthy, 2001; Kaplan, Wilson, Dewey, & Crawford, 1998; Smits-Engelsman, Henderson, & Michels, 1998).

The argument against the construct of motor competence is mostly based on the general finding of correlations below .70. In a review on individual differences in motor performance, Marteniuk (1974) indicated that a general factor could only be supported if correlations account for ≥ 50% of the variance which has led to the arbitrary cut-off value of .70. However, Cohen (1992) stated that correlation coefficients of .50 are considered to be high in the field of behavioral sciences. In this regard, Burton and Rodgerson (2001) argued that the arbitrary criterion of .70 might not be appropriate to produce valid conclusions about the construct of motor competence. The use of these cut-off values is solely based on human judgment. This shows that using correlations as a criterion to answer those questions implies active choices made by researchers. From a content view one can debate whether a correlation above .4, .5 or .7 would be an indicator of a one-dimensional latent variable. Conducting factorial analysis to investigate the dimensionality of the latent variable comes along with (reasonable) choices such as setting the parameter estimation fixed, free or constrained or including correlated errors to improve model fit (Little, 2013). The CTT approach contains some additional limitations in the context of motor assessment such as sample and item dependence of results (Masters, 2005; Rost, 2004). Additionally, raw item scores are located on different scales. In the process of test construction, these item scores are transformed into an ordinal-scaled categorization system and often summed to a composite score. However, the CTT approach requires interval-scaled variables to conduct correlations. Because composite scores and categorizations are often not statistically verified for ordinal scaling and validity, the lack of a validated theoretical framework hampers the development of meaningful measures in motor assessment.

3.1.3 Rasch modeling in motor competence assessment

Alternative approaches that address the above mentioned limitations are models of item response theory (IRT; also known as probabilistic test theory). IRT models can be valuable when investigating the construct of motor competence, because they address the content related definition of motor competence and link it with test theoretical assumptions (see Strauss, Büsch, & Tenenbaum, 2007, 2012, for an overview in the field of sport psychology). IRT models use test and item scores and define the mathematical relationship between the measured latent variable (e.g., motor competence) and the item responses (Alagumalai, Curtis, & Hungi, 2005; Rost, 2004). The major advantage of IRT models is the invariance of parameters, which defines the equality of person and item parameters along different populations (Rost, 2004). This means that model conform data imply indicator and sample distribution free results along the continuum of the measured latent trait. Person ability as well as item raw scores from different measurement units can be measured onto the same scale (logit scale), which is interval-scaled. One of the basic IRT models is the one-parameter Rasch model for dichotomous data (Rasch, 1960), which is based on the concept of fundamental measurement, objectivity and order (Masters, 2005). Since its introduction in 1960, a variety of different Rasch measurement models have been developed.

The use of IRT models in the context of motor assessment has been recommended for decades (Linacre, 2000; Spray, 1987; Strauss et al., 2007; Strauss, 1999; Tenenbaum, Strauss, & Büsch, 2007; Wright & Mok, 2000; Zhu et al., 2011). Beside some work calibrating different test items in the context of motor assessment, IRT models can also be used to validate test batteries or to help evaluating, confirming or developing theory. For instance Linacre (2000) applied the Rasch model to the AAHPERD Youth Fitness Test (AAHPERD, 1976) and calibrated the seven items (*N* = 40). Zhu and Cole (1996) calibrated the Test of Gross Motor Development (Ulrich, 1985) for three to ten year-old children (*N* = 909) and Zhu et al. (2011) calibrated 30 items for children in kindergarten, 2nd and 5th grade.

Using the mixed Rasch model Büsch et al. (2009) analyzed two samples of primary school aged children (sample 1: 6-11 years, *M* = 8.4; sample 2: 9-11 years, *M* = 10.28) who completed the six items of the General Sport Motor Test for Children (Allgemeiner Sportmotorischer Test für Kinder [AST]; Bös, 2000). A two-dimensional structure in terms of skill difference between ball handling and locomotion was found in this age group. There are several studies which found one-dimensional scales within a wide range of various item sets. For example, Hands and Larkin (2001) found a separate scale each for five- to six-year-old boys and girls (*n* = 332) out of a wide range of 24 items. Yan and Bond (2011) used the "data fit the model" approach to create a motor scale with four out of nine items for six to twelve year-old children (*n* = 9439). Just recently, Utesch et al. (2015) validated six of the items of the Deutscher Motorik Test 6-18 [German Motor Test 6-18] (Bös et al., 2009) using the mixed Rasch model for nine- to ten-year old children as being one-dimensional.

3.1.4 Study objectives

Currently, the latent trait(s) underlying motor assessment in early childhood is/are not fully understood. The evidence provided by the CTT approach is inconclusive in validating or rejecting the GMA hypothesis. CTT neither offers a clear view of this concept nor does it support the current use of composite scores (or linear transformations thereof) in motor assessment. IRT models provide an alternative approach to gain new insights into the latent trait underlying motor assessment on item level. The aforementioned IRT studies support the GMA hypothesis indicating a one-dimensional structure in early childhood, but only within small item sets.

Using the IRT approach, the aim of this study was to examine the dimensional structure of motor competence in early childhood using a wide variety of motor skills within the large item bank of an existing motor assessment battery. Based on previous studies, it is expected that the construct of motor competence in this age group will have a one-dimensional structure. Furthermore, the present study demonstrates how the current use of composite scores in motor assessment can be validated.

3.2 Methods

3.2.1 Participants

This study is part of a large-scale evaluation of the motor competence of children in Flanders, Belgium. The total sample for this study consisted of 1467 children, aged 3 to 6 years old (see Table 7). Children were recruited from 54 settings (sports clubs, local councils, schools and day care centers) across the Flemish provinces and the Brussels-Capital Region.

Table 7. Age and sex distribution of the study sample

Age	**Gender**	***N***	**%**
3 years	Girls	137	46.8
	Boys	156	53.2
	Total	293	100
4 years	Girls	180	40.8
	Boys	261	59.2
	Total	441	100
5 years	Girls	191	47.9
	Boys	208	52.1
	Total	399	100
6 years	Girls	164	49.1
	Boys	170	50.9
	Total	334	100
Total	Girls	672	45.8
	Boys	795	54.2
	Total	1467	100

3.2.2 Materials

The MOT 4-6 (Zimmer & Volkamer, 1987) consists of one practice item and 17 test items. The test is easy to use and typically takes 15-20 minutes to administer. According to the authors, different motor domains are represented in the MOT 4-6 test to assess the motor competence of children. In the test manual the original authors describe in detail how to convert each item raw score into a point score ranging from zero (skill not mastered) to two (skill mastered). These point scores are used in practice to interpret test results of children and therefore have to be investigated in terms of empirical validity and order. In line with the test manual, all point scores were summed to attain a sum score.

The MOT 4-6 was constructed using the CTT approach. In the test manual (Zimmer & Volkamer, 1987), the original authors report high test-retest reliability and inter-rater reliability (r = .85 and r = .88 respectively) and a good internal consistency (Cronbach's alpha coefficient = .81). Content and construct validity have been determined through movement skill literature; neither a factor analysis nor cluster analysis demonstrated a valid factor structure (Cools, De Martelaer, Samaey, et al., 2009).

3.2.3 Procedure

This study was approved by the ethics committee of the Ghent University Hospital. For each participant, a written informed consent was obtained from a parent or guardian. Assessments were conducted by a group of trained assessors in an indoor facility during the period of September-November 2012. The MOT 4-6 was administered to assess the motor competence in young children (Zimmer & Volkamer, 1987). All children completed the tests barefoot in one session, in accordance with the manual guidelines.

3.2.4 Data analysis

Data were analyzed using SPSS 22 for Windows (SPSS Inc., Chicago, IL, USA) and Winmira 2001 (von Davier, 2001). Descriptive statistics were computed for all item scores. To examine the construct of motor competence in the MOT 4-6 data, IRT models were calculated. First, the partial credit model (PCM; Masters, 1982) was selected to analyze homogeneity and order within the assumed one-dimensional construct. The PCM is a generalization of the (dichotomous) Rasch model (Rasch, 1960), but for ordinal data (Rost, 2004). It is a test of dimensionality relying on the assumption of equal specificity and sensitivity of indicators (Rost, 2004). Probabilistic threshold parameters between each category as well as item locations are calculated (Strauss et al., 2007; Strauss, Büsch, & Tenenbaum, 2012). Model conform data implies invariance of parameters and provides sample distribution free and indicator distribution free results. Furthermore, person ability and item difficulty are measured on the same (logit) scale (Rost, 2004). Second, the mixed Rasch model (MRM) was used, which combines the PCM and Latent Class Analysis (LCA; Rost, 2004) and adds a qualitative aspect to the PCM. This means that possible item difficulty patterns between groups (e. g., boys and girls), are explored and person homogeneity is tested. The latter is shown in case the one-class solution fits best which indicates that all persons used the same ability to complete the assessment. In case more-class solutions only differentiate between overall skill level, a one-dimensional result indicates that a statistically verified composite score can be constructed with all fitting items.

Applying the PCM the bootstrapping procedure with the recommended 100 bootstrapping samples was executed (Rost, 2004; von Davier, 1997, 2001). The model fit was evaluated in three steps. At first, the global model fit is analyzed checking the statistical values Cressie-Read (CR) and Pearson-χ^2 (P- χ^2). Von Davier (1997) recommends checking both values and defines a good model fit at the significance level of 5 % ($p > .05$). Second, local model violations are analyzed. Unordered threshold parameters in form of overlapping item characteristic curves, show violations of the order within the ordinal scale. Items showing unordered threshold parameters within the continuum of the latent variable have to be excluded from further analysis. If no valid model was found, the third step would be to analyze local violations in form of item fit statistics. Winmira 2001 (von Davier, 2001) provides the Q-index of each item, which represents likelihood based estimations of the sensitivity. Overfitting items (closer to 0) show significantly better response patterns than the model expects while underfitting (closer to .5) items significantly deviate from it. Using the PCM, reliability is analyzed by Andrich's reliability coefficient (R_A; Andrich, 1988), which is a mean value of the reliability of each step of person test scores.

Conducting the MRM, the fit of two-class solutions is explored in terms of testing the global and local model fits congruently to the PCM. The two-class model is rejected if global or local model fits are violated. In case that both the one- and two-dimensional models fit the data, two types of information criteria are used to select the most appropriate model: Bayes Information Criterion (BIC; Schwarz, 1978) and Consistent Akaikes Information Criterion (CAIC; Bozdogan, 1987). As these criteria indicate the minimum of the global fit function, smaller BIC and CAIC demonstrate a relative better model fit.

3.3 Results

Table 8 shows the descriptive statistics of all 17 items; means range from 0.25 to 1.38. At first, the global model fit regarding the assumed one-dimensional structure was analyzed using PCM. First-step analysis showed a global model fit for all items of the MOT 4-6 (CR = .032, p_{CR} = .43; $P\text{-}\ \chi^2$ = -.356, $p_{P\text{-}\ \chi^2}$ = .55) and revealed four items with unordered threshold parameters: grasping a tissue with a toe, catching a tennis ring, rolling sideways over the floor and twist jump in/out of a hoop (see Table 9 and Figure 5).

These items were excluded from the model because they violated the order within the continuum of the latent variable. The follow-up modeling process using the PCM revealed a global model fit with ordered threshold parameters for the MOT 4-6 (CR = 1.964, p_{CR} = .06; $P\text{-}\ \chi^2$ = -.227, $p_{P\text{-}\ \chi^2}$ = .24, R_A = .79) and demonstrated good reliability, after the four items with unordered threshold parameters and an additional item (jumping on one leg into a hoop) were excluded. Item locations and threshold parameters of the fitting model with twelve items are presented in Table 10 and Figure 6. The item set for the remaining twelve items conform to the requirements of the PCM and fundamental measurement is attained. Thus, the accumulation of these items to one composite score represents one latent variable. The resulting distribution using the composite score for the remaining twelve items is shown in Figure 7.

Table 8. Descriptive statistics and score distributions for the MOT 4-6 items

					0		1		2	
	Test item	*M*	±	*SD*	**Count**	**%**	**Count**	**%**	**Count**	**%**
2	Balancing forward on a line	1.00	±	0.81	479	32.7	514	35	474	32.3
3	Placing dots on a sheet	0.92	±	0.82	558	38	467	31.8	442	30.1
4	Grasping a tissue with toes	1.25	±	0.84	380	25.9	338	23	749	51.1
5	Jumping sideways over a rope	0.91	±	0.80	545	37.2	516	35.2	406	27.7
6	Catching a stick	0.82	±	0.47	316	21.5	1100	75	51	3.5
7	Moving balls from box to box	0.75	±	0.71	598	40.8	634	43.2	235	16
8	Balancing backwards on a line	0.25	±	0.53	1169	79.7	231	15.7	67	4.6
9	Throwing a ball at a target disk	0.52	±	0.72	906	61.8	365	24.9	196	13.4
10	Transferring matches	0.68	±	0.79	766	52.2	406	27.7	295	20.1
11	Passing through a hoop	1.38	±	0.74	233	15.9	442	30.1	792	54
12	Jumping on one leg into a hoop	0.84	±	0.82	635	43.3	433	29.5	399	27.2
13	Catching a tennis ring	0.87	±	0.89	685	46.7	282	19.2	500	34.1
14	Jumping jacks	0.77	±	0.81	687	46.8	429	29.2	351	23.9
15	Jumping over a cord	0.94	±	0.82	548	37.4	465	31.7	454	30.9
16	Rolling sideways over the floor	1.40	±	0.78	273	18.6	332	22.6	862	58.8
17	Standing and sitting while holding a ball on the head	0.95	±	0.78	484	33	576	39.3	407	27.7
18	Twist jump in/out of a hoop	1.04	±	0.87	521	35.5	361	24.6	585	39.9

Item 1 (Jumping forward into a hoop) is a practice item and therefore not included

Table 9. Item location and threshold parameters for all MOT 4-6 items

			Threshold	
	Test item	**Location**	**1**	**2**
2	Balancing forward on a line	-0.27	-0.69	0.14
3	Placing dots on a sheet	-0.11	-0.38	0.16
4	Grasping a tissue with toes*	-0.80	-0.68	-0.92
5	Jumping sideways over a rope	-0.07	-0.50	0.36
6	Catching a stick	0.74	-1.80	3.27
7	Moving balls from box to box	0.35	-0.51	1.22
8	Balancing backwards on a line	1.65	1.55	1.75
9	Throwing a ball at a target disk	0.81	0.65	0.98
10	Transferring matches	0.42	0.26	0.58
11	Passing through a hoop	-1.17	-1.55	-0.79
12	Jumping on one leg into a hoop*	0.07	-0.11	0.24
13	Catching a tennis ring*	-0.03	0.38	-0.44
14	Jumping jacks	0.22	0.03	0.40
15	Jumping over a cord	-0.14	-0.40	0.12
16	Rolling sideways over the floor*	-1.15	-1.11	-1.18
17	Standing and sitting while holding a ball on the head	-0.16	-0.76	0.44
18	Twist jump in/out of a hoop*	-0.36	-0.27	-0.46

** unordered threshold parameters*

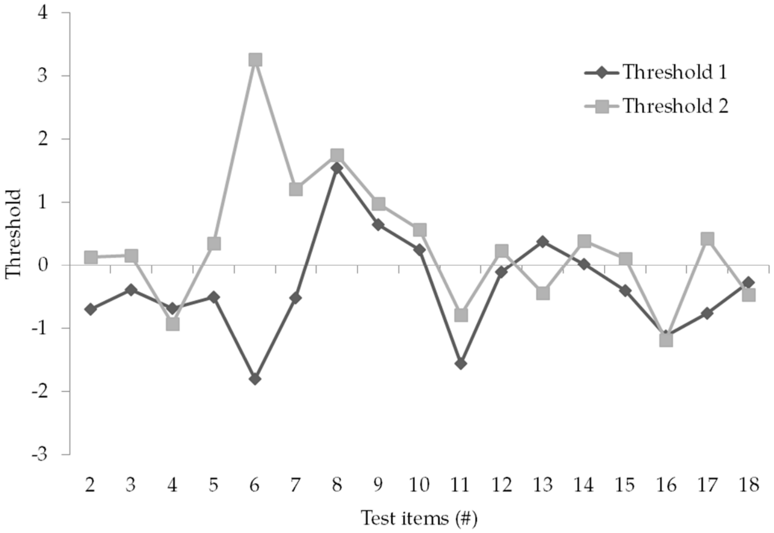

Figure 5. Threshold parameter profile of the partial credit model for all MOT 4-6 items

Table 10. Item location and threshold parameters for the 12 model conform MOT 4-6 items (one-class solution)

				Threshold	
	Test item	**Location**	**Q-Index**	**1**	**2**
2	Balancing forward on a line	-0.46	.20	-0.87	-0.04
3	Placing dots on a sheet	-0.29	.09	-0.56	-0.02
5	Jumping sideways over a rope	-0.25	.22	-0.67	-0.17
6	Catching a stick	0.54	.07	-2.00	3.07
7	Moving balls from box to box	0.16	.22	-0.69	1.02
8	Balancing backwards on a line	1.44	.11	1.36	1.52
9	Throwing a ball at a target disk	0.62	.18	0.47	0.78
10	Transferring matches	0.23	.19	0.08	0.38
11	Passing through a hoop	-1.36	.32	-1.75	-0.97
14	Jumping jacks	0.03	.16	-0.15	0.21
15	Jumping over a cord	-0.32	.09	-0.58	-0.07
17	Standing and sitting while holding a ball on the head	-0.34	.18	-0.94	0.26

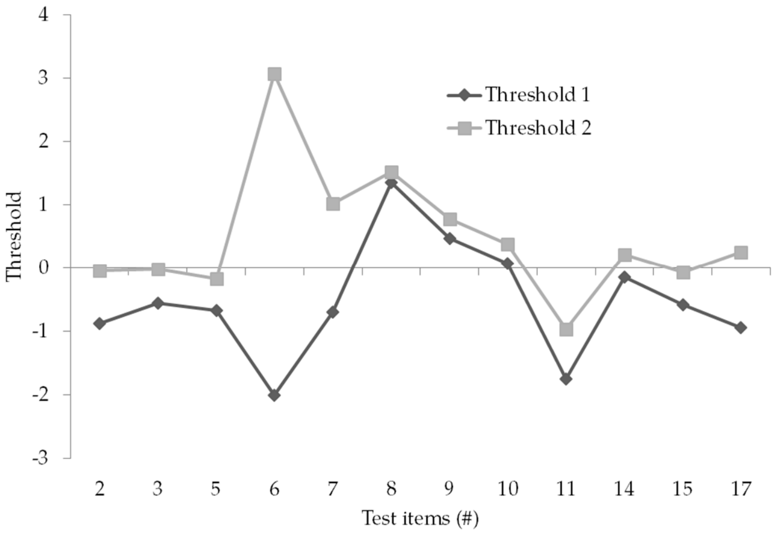

Figure 6. Threshold parameter profile of the partial credit model for the 12 model conform MOT 4-6 items

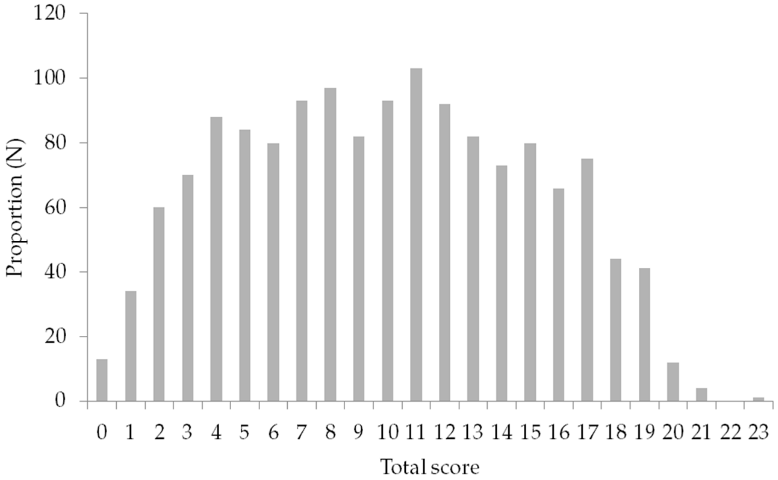

Figure 7. Distribution of the corrected MOT 4-6 total score in the study sample

To check for better fitting models, the 12 items were analyzed using the MRM. The two-class solution showed acceptable global model fit ($CR = 23$, $p_{CR} = .28$; $P\text{-}\chi^2 = -.53$, $p_{P\text{-}\chi^2} = .7$, $R_{A\_class\ 1} = .63$; $R_{A\_class\ 2} = .45$; see Table 11 and Figure 8). However, the MRM showed unordered threshold parameters between the classes (class 1: throwing a ball at a target disk, transferring matches; class 2: balancing forward on a line, jumping jacks) rejecting the model. Poor reliability values were reported for both classes. Person homogeneity was shown because the only global fit with ordered threshold parameters was shown in the one-class solution, which is identical to the PCM.

3.4 Discussion

Assessment tools are generally as valid as the proposed theoretical construct, which is closely connected to the theoretical assumptions. In the field of motor development, assessments often rely on the GMA hypothesis as motor competence is implicitly measured as a single latent trait when test scores of a wide range of motor skills are summed up to a composite score (Burton & Rodgerson, 2001). However, these composite scores are often not statistically verified. Prior research has not provided a clear understanding of the latent trait(s) underlying motor assessment, partially due to methodological limitations of the generally adopted CTT approach. Adopting the alternative IRT approach, this study investigated the dimensionality of the construct of motor competence in early childhood using the large item set of a popular motor assessment. This also provided the option to validate the composite score of this assessment tool.

Table 11. Item locations and threshold parameters for the 12 model conform MOT 4-6 items (two-class solution)

				Threshold	
	Test item	**Location**	**Q-Index**	**1**	**2**
	Class 1				
2	Balancing forward on a line	-0.61	.24	-1.08	-0.16
3	Placing dots on a sheet	0.99	.19	0.46	1.52
5	Jumping sideways over a rope	-1.03	.17	-1.21	-0.85
6	Catching a stick	0.98	.15	-0.65	2.6
7	Moving balls from box to box	0.06	.29	-2	2.13
8	Balancing backwards on a line	1.41	.19	-0.62	3.45
9	Throwing a ball at a target disk*	0.84	.15	1.21	0.47
10	Transferring matches*	0.18	.20	0.28	0.08
11	Passing through a hoop	-2.08	.21	-2.34	-1.83
14	Jumping jacks	-0.14	.18	-0.55	0.28
15	Jumping over a cord	0.03	.15	-0.55	0.61
17	Standing and sitting while holding a ball on the head	-0.63	.21	-1.24	-0.04
	Class 2				
2	Balancing forward on a line*	0.02	.27	0.14	-0.1
3	Placing dots on a sheet	-0.17	.28	-0.79	0.45
5	Jumping sideways over a rope	0.04	.27	-0.34	0.43
6	Catching a stick	-1.19	.23	-2.3	-0.09
7	Moving balls from box to box	0.4	.38	-2.73	3.54
8	Balancing backwards on a line	0.25	.30	-1.41	0.91
9	Throwing a ball at a target disk	1.62	.28	1.43	1.81
10	Transferring matches	0.79	.28	0.58	1.01
11	Passing through a hoop	-0.34	.29	-0.46	-0.21
14	Jumping jacks*	0.17	.27	0.22	0.12
15	Jumping over a cord	-0.96	.29	-1.77	-0.17
17	Standing and sitting while holding a ball on the head	-0.14	.26	-0.64	0.37

** unordered threshold parameters*

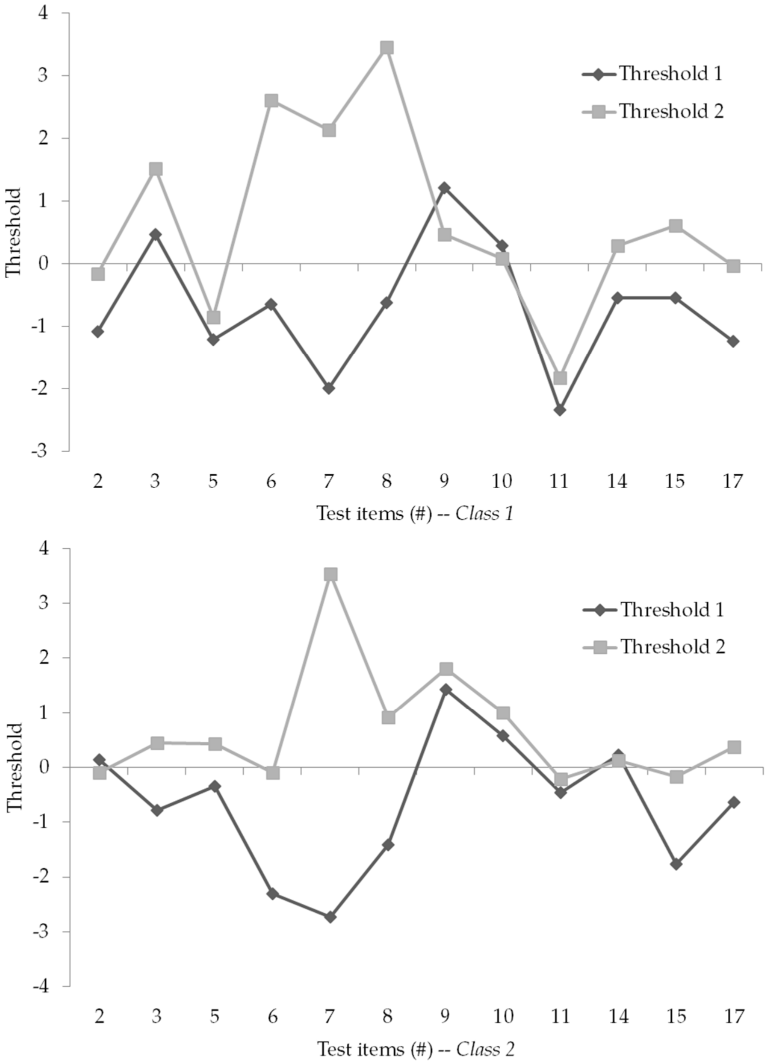

Figure 8. Threshold parameter profile of the mixed Rasch model for the 12 model conform MOT 4-6 items

The present study provided evidence of a one-dimensional construct of motor competence in early childhood using a large number of items. These findings are in agreement with a previous IRT study on preschool children (Hands & Larkin, 2001); the authors found a one-dimensional latent structure for five- and six-year-old children using a set of 24 items.

In contrast to the present findings, an IRT study of Büsch et al. (2009), that evaluated three locomotor and three object control skills in children aged 9 and 10, revealed qualitative different item difficulties for the AST (Bös, 2000). One group showed higher item difficulties in object control skills and the other in locomotor skills. However, in our study no differentiation between object control and locomotor skills was found for the preschool age group. One possible explanation is that the latent trait underlying motor assessment might divide in multiple motor domains due to an interaction of maturation and environmental experiences as found in other studies (e.g., Schulz, Henderson, Sugden, & Barnett, 2011).

Compared to the findings of Hands and Larkin (2001), who also found a one-dimensional construct of motor competence, the MRM did not reveal different item properties between groups. Hands and Larkin (2001) analyzed boys and girls separately and found descriptive differences between these groups. However, the MRM conducted in this study did not reveal differences between groups or classes, because only the one-dimensional model fitted the data. Instead, this study revealed a one-dimensional structure for all 17 items of the MOT 4-6 in early childhood. Furthermore, person homogeneity was shown for the 12-item model, which means that no qualitative different patterns of item difficulty were found between classes, such as boys and girls.

Zimmer & Volkamer (1987) constructed the MOT 4-6 and selected 17 items to cover multiple motor domains and a wide range of motor skills. In addition, the authors built a composite score with all items based on the implicit assumption that a single latent trait underlies the MOT 4-6 (Burton & Rodgerson, 2001). Our results support that implicit assumption of a single latent trait from a measurement-theoretical perspective; 12 items of the MOT 4-6 met the Rasch model requirements and therefore provided a valid measurement of motor competence through a composite score. Five items violated the assumption of order in the ordinal scale indicating that the categorization of one or two points is not related to the person's skill level but is random. Upon inspection of these items violating the model assumption, we found no similar content between these items; the items, grasping a tissue with a toe, catching a tennis ring, rolling sideways over the floor, twist jump in/out of a hoop and jumping on one leg into a hoop, represent different motor dimensions. However, the scoring system was equal for all these items: zero successful trials giving zero points, one successful trial giving one point and two or more successful trials giving two points. Thus, the results indicate that this scoring system seems inadequate under certain circumstances. With regard to this finding, categorization systems should be taken into account in the construction and analysis of motor assessments.

The IRT approach provides a solution for the limitations of generally used CTT methods and contributes to a better understanding of the latent trait(s) underlying motor assessment. In view of limited IRT studies in the field of motor assessment, present study examined the motor competence in early childhood using the IRT approach and provides evidence for the GMA hypothesis in that age group, which states that numerous motor abilities are highly related within a person and form a single general motor ability (i.e., motor competence). The main strength of our study is the use of a large set of 17 items, which covers a wide range of motor skills, and a large sample of 1467 children aged three to six years. In addition, this study investigated the items of an existing test battery (i.e., MOT 4-6) which provides information on the validation of the assessment. However, this study is not without limitations. One limitation to this study is the small amount of object control skills in the MOT 4-6. Since other test batteries include more object control items, this might restrict the generalizability of present findings. Future IRT research should evaluate motor assessments that include a wide item-set with a larger proportion of object control skills. Another limitation relates to the product-oriented approach of the MOT 4-6 where motor skills are scored based on the outcome of the performance (such as speed and frequency). However, qualitative factors such as arm-leg coordination are also important for motor performance. Future IRT studies should include item sets with process- and product-oriented approaches to better encompass motor competence. Finally, current IRT research – including the present study – has analyzed the construct of motor competence using a cross-sectional design. However, there is a need for longitudinal studies to investigate how the construct of motor competence might change across childhood.

In view of the importance of motor development in children's overall health, it is imperative to have valid measurements in order to make sound interpretations and decisions (Mahar & Rowe, 2008). This study gives insights into the latent trait(s) underlying motor assessment in early childhood. Rasch measurement provided support for the theoretical definition of motor competence (or general motor ability) and evidence for the GMA hypothesis, which could expand to older age groups. Whereas previous research investigating the taxonomy underlying motor assessment used the CTT approach and arbitrary cut-off values (correlations) based on random human judgment, the IRT approach provides models with goodness of fit statistics to address that limitation. Furthermore, this study shows the capacity of IRT models in the context of motor development research. It provides an alternative approach to test theories, to validate test instruments and detect non-fitting items. IRT models are specifically valuable to evaluate test instruments that use composite scores to describe motor behavior and should be included in the evaluation of the methodological standard for those test instruments.

The present study does not imply that only IRT models should be used in motor test and construct validation. Rather, a combination of appropriate psychometric approaches can further enrich scientific discourse and provide a deeper understanding of the underlying latent trait(s) of motor assessment.

Chapter 4

Cross-cultural comparison of motor competence in early childhood

Motor competence in childhood is an important determinant of physical activity and physical fitness in later life. However, childhood competence levels in many countries are lower than desired. Due to the many different motor skill instruments in use, children's motor competence across countries is rarely compared. The purpose of this study[3] was to evaluate the motor competence of children from Australia and Belgium using the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]). The sample consisted of 244 (43.4% boys) Belgian children and 252 (50.0% boys) Australian children, aged six to eight years. A MANCOVA for the motor scores showed a significant country effect. Belgian children scored higher on jumping sideways, moving sideways and hopping for height but not for balancing backwards. Moreover, a chi-square test revealed significant differences between the Belgian and Australian score distribution with 21.3% Belgian and 39.3% Australian children scoring 'below average'. The very low levels reported by Australian children may be the result of cultural differences in physical activity contexts such as physical education and active transport. When compared to normed scores, both samples scored significantly worse than children 40 years ago. The decline in children's motor competence is a global issue, largely influenced by increasing sedentary behavior and a decline in physical activity.

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[3] This study has been published as: Bardid, F., Rudd, J. R., Lenoir, M., Polman, R., & Barnett, L. M. (2015). Cross-cultural comparison of motor competence in children from Australia and Belgium. *Frontiers in Psychology*, 6, 1-8. doi:10.3389/fpsyg.2015.00964

4.1 Introduction

The ability to perform various motor skills in a proficient manner, is often defined as motor competence (Gabbard, 2008; Gallahue et al., 2012; Haga, Pedersen, & Sigmundsson, 2008). Motor competence relies on motor coordination which refers to the cooperation between muscles or muscle groups to produce a purposeful action or movement (Magill, 2011), and physical fitness which refers to the capacity to perform physical activity (Ortega et al., 2008).

Over the past few decades, decreased levels of motor competence in primary school children have been reported in Western countries (Bös 2003; Okely & Booth, 2004; Vandorpe et al., 2011; Tester et al., 2014; Hardy et al., 2013). These findings are of major concern as children with high motor competence have been linked with positive outcomes in both physical activity and weight status (Lubans et al., 2010). Furthermore, motor competence predicts levels of physical activity and physical fitness in later life (Jaakkola et al., 2015; Lopes et al., 2011; Barnett et al., 2008). In view of this, it is important to examine and monitor motor behavior during childhood in order to provide appropriate strategies to support children's motor development.

A variety of test instruments are used to measure motor competence during childhood (see Cools et al., 2009; Wiart & Darrah, 2001, for reviews on this matter). The choice of assessment batteries depends on a number of criteria such as the purpose of measurement, age specificity, and the suitability of the test for the target group (Cools, De Martelaer, Samaey, et al., 2009). The popularity and implementation of test instruments also vary depending on the geographical region. For example, in Australia, assessment batteries such as the Test of Gross Motor Development, Second Edition (TGMD-2; Ulrich, 2000) are generally used to measure motor competence of children through a set of fundamental motor skills (e.g., running, throwing, jumping, catching), whilst Belgium and other European countries have preferred to use the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]; Kiphard & Schilling, 1974, 2007), a non-sport specific assessment of a child's gross motor coordination.

Although motor tests measure the same broad construct (i.e., motor competence), research on test comparisons generally reveals only moderate correlations. For instance, a study of Fransen et al. (2014) compared the KTK and Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2; Bruininks & Bruininks, 2005) in primary school children and found a moderate association between the two tests performances. These findings are similar to other convergent validity studies (Logan, Robinson, & Getchell, 2011; Smits-Engelsman et al., 1998; Van Waelvelde et al., 2007) which suggests that assessment batteries should not be used interchangeably to evaluate motor competence. Alternatively, the wide adoption of a highly standardized test battery, would enable comparison of motor competence within and between countries.

There is a dearth of research comparing children's motor competence between countries. One study by Chow et al. (2001) compared the motor competence between children from China (Hong Kong) and the United States, and revealed differences between the groups: Chinese children performed significantly better on manual dexterity and balance tasks whilst American children outperformed Chinese children on throwing and catching tasks. These differences give insight into different cultural practices (such as encouragement in some types of sport e.g., baseball in America) that help or hinder development in certain types of skills. Clearly, cross-cultural research can provide valuable insights into how different motor skills are developed in different cultural contexts and how tests which measure specific motor skills are sensitive to cultural differences.

In summary, it would be unwise to undertake comparisons using different assessment tools because the small, but significant differences in measurement might not provide meaningful findings and valid conclusions. As highlighted in the study of Chow et al. (2001), we should also be cautious about using an assessment tool which relates more closely to the sports played in some countries more than others, as whilst this gives information on particular skills it may not present an overall picture of the populations' motor competence. A better approach would be to adopt a standardized non-sport specific test of motor competence across all countries. The KTK assesses motor coordination without a sport context and may therefore be a suitable test. It is a standardized and popular test battery that makes it an appropriate tool to measure motor competence internationally and provide cross-cultural comparisons (Iivonen, Sääkslahti, & Laukkanen, 2014).

There is evidence of streamlining of assessment and international collaborations in other areas of health and physical activity behavior. An example is the development of the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). In 1998 an International Consensus Group met in Geneva with the purpose of developing a self-reported measure of physical activity, which could be used to assess physical activity across countries. It was recognized at that time that physical inactivity was a global health concern, but that there were no standardized approaches to measurement, which made international comparisons and global surveillance challenging. Similarly, the wide adoption of a single test to measure motor competence, has the potential to build a strong picture of how children are performing on an international level rather than just on a national level. This will have many benefits in terms of understanding how motor competent children are on a global level and then proceeding to understand what cultural factors help to better facilitate motor competence.

The aim of this study was to evaluate the motor competence of 6 to 8 year-old children from Australia and Belgium using the KTK. A secondary aim of this study was to compare the distribution of both samples across the KTK performance categories and against the reference population from 1974. Based on the declining levels of motor competence found in Western countries (Bös 2003; Okely & Booth, 2004; Vandorpe et al., 2011; Tester et al., 2014; Hardy et al., 2013), it was hypothesized that the distribution of both Australian and Belgian children would be shifted towards the lower end of the motor competence continuum when compared to the KTK reference population of 1974.

4.2 Methods

4.2.1 Participants

Data were collected in Melbourne (Australia) between October 2012 and June 2013, and Flanders (Belgium) between September 2012 and November 2012. A total of 496 children (252 Australian and 244 Belgian children) between the ages of 6 and 8 years participated. In Melbourne, four schools were selected in four local council municipalities. In Flanders, children were recruited from five schools in different provinces. For each participant written informed consent was obtained from the parents or guardian. The study was approved by the University Ethics Committee and the Department of Education and Early Childhood Development in both countries.

4.2.2 Measurements

All assessments were conducted by trained assessors. All assessors had a physical education (PE) background and followed a training on KTK assessment. For the tests, children were barefooted and wore light sport clothes. First, anthropometric measurements (height and weight) were taken. Secondly, children's motor competence was assessed with the KTK.

4.2.3 Anthropometry

In both countries, height and weight were measured with an accuracy of 0.1 cm and 0.1 kg respectively. In Australia, height was assessed with a Mentone PE087 portable stadiometer (Mentone Educational Centre, Melbourne, Australia) and weight was assessed using a SECA 761 balance scale (SECA GmbH & Co. KG., Birmingham, UK). In Belgium, height was measured by means of a SECA 123 portable stadiometer (SECA GmbH & Co. KG., Hamburg, Germany) and weight was measured using a SECA Robusta 813 digital balance scale (SECA GmbH & Co. KG, Hamburg, Germany). Height and weight values were used to calculate body mass index (BMI) [BMI = weight (kg) / height^2 (m^2)]. Weight status was determined by the sex- and age-specific BMI cut-off values for children of the International Obesity Task Force (Cole & Lobstein, 2012).

4.2.4 Gross motor coordination

The KTK measures gross motor coordination in typically and atypically developing children, aged 5 to 14 years (Kiphard & Schilling, 1974, 2007). The psychometric quality of the KTK is good. Content and construct validity have been established for the general pediatric population (Kiphard & Schilling, 1974, 2007). The test manual also describes good-to-excellent test-retest and inter-rater reliability (all r-values > .85) as well as good intraclass correlations for all test items (r = .80 – .96).

In both countries the KTK was administered according to the manual guidelines (Kiphard & Schilling, 1974, 2007). The KTK consists of 4 outcome-based subtests. Walking backwards (WB) requires participants to walk backwards along three different balance beams, with increasing levels of difficulty due to the width of the beams decreasing from 6cm to 4.5cm to 3cm respectively. Three trials are given for each balance beam with a maximum score of 72 steps (i.e., maximum 8 steps per trial). Hopping for height (HH) requires participants to hop on one leg over an increasing number of 5cm foam blocks to a maximum of 12 blocks. Participants have to begin hopping 1.5m away from the foam blocks, hop up to and over the foam block and complete a further two hops for the trial to be deemed successful. Three trials are given for each height with 3, 2 or 1 point(s) given for a successful performance during 1st, 2nd or 3rd trial, respectively. Jumping sideways (JS) requires participants to complete as many sideway jumps as they can, with feet together, over a wooden slat in 15 seconds. Moving sideways (MS) requires participants to move across the floor during 20s using two wooden platforms. Participants step from one platform to the next, move the first platform, step on to it, and repeat the same process as much as possible in 20s. Two trials are given for both jumping sideways and moving sideways. The KTK requires little time to set-up and takes approximately 15-20 minutes to administer.

Using the normative data of the German 1974 sample, raw item scores were converted into standardized scores adjusting for age (all items) and sex (hopping for height and jumping sideways over a slat). In turn, standardized score items were summed and transformed into a total MQ. The total MQ allows classification of a child’s performance into five categories : “impaired” 2%, “poor” 14%, “normal” 68%, “good” 14% and “high” 2% (Kiphard & Schilling 1974, 2007).

4.2.5 Data analysis

Data were analyzed using SPSS Statistics 20 for Windows. Values of $p \leq 0.05$ were considered statistically significant for all analyses. Descriptive statistics were calculated for anthropometric measures (height, weight and BMI) and KTK scores (raw and standardized scores). Using a chi-square test, we first investigated possible differences in distribution across BMI categories (based on the International Obesity Task Force cut-off values) between the Australian and Belgian sample. Further, the effect of country (Australia and Belgium) and age (6, 7 and 8 years) on KTK raw scores were examined using a 2 x 3 MANCOVA. Since weight status is associated with motor competence (D’Hondt et al., 2011; Lubans et al., 2010), the body mass index (BMI) was included as a covariate in the analysis. Significant interaction and main effects were further investigated with Bonferroni post hoc tests or pairwise comparisons. In addition, the effect of country on the age and sex specific MQs were inspected using one-way ANCOVAs with BMI as a covariate. Separate models were used for the item MQs and total MQ, i.e., MANCOVA and ANCOVA, respectively. Finally, a chi-square test was used to compare the distributions of Australian and Belgian children across the KTK performance categories (impaired, poor, normal, good, high). Additionally, chi-square analysis was used to compare the observed distribution of both samples with the expected distribution based on the German reference sample.

4.3 Results

4.3.1 Sample characteristics

Descriptive statistics of anthropometric measurements (i.e. height, weight and BMI), stratified by age and sex, are shown in Table 12 for both the Australian and Belgian sample. Chi-square analysis demonstrated that the distributions across BMI categories are similar between both samples ($\chi 2 = 6.011$, $p = .111$; see also Figure 9).

Table 12. Descriptive statistics (*M* ± *SD*) of anthropometric measurements, stratified by age and sex

		Australia		**Belgium**	
Age group	**Variables**	**Boys**	**Girls**	**Boys**	**Girls**
6 years	N	22	23	47	54
	Height (cm)	122.9 ± 5.1	121.9 ± 7.6	120.2 ± 5.8	119.5 ± 6.7
	Weight (kg)	25.2 ± 5.6	24.7 ± 4.5	23.1 ± 4.0	22.9 ± 4.5
	BMI (kg/m^2)	16.57 ± 2.93	16.55 ± 1.82	15.90 ± 2.00	15.87 ± 1.74
7 years	N	54	55	33	40
	Height (cm)	127.2 ± 5.6	125.9 ± 7.3	129.0 ± 5.8	124.2 ± 5.0
	Weight (kg)	27.4 ± 6.0	26.7 ± 6.5	27.0 ± 5.2	25.3 ± 4.3
	BMI (kg/m^2)	16.83 ± 2.80	16.64 ± 2.60	16.09 ± 1.89	16.34 ± 2.16
8 years	N	50	47	26	44
	Height (cm)	131.1 ± 6.0	131.6 ± 7.2	133.7 ± 5.7	130.5 ± 6.6
	Weight (kg)	29.5 ± 5.1	30.1 ± 9.0	28.7 ± 3.8	29.0 ± 6.7
	BMI (kg/m^2)	17.04 ± 2.14	17.15 ± 3.63	16.00 ± 1.43	16.81 ± 2.54
Total	N	126	125	106	138
	Height (cm)	128.0 ± 6.4	127.3 ± 8.1	126.2 ± 8.1	124.4 ± 7.7
	Weight (kg)	27.8 ± 5.7	27.6 ± 7.5	25.7 ± 5.0	25.5 ± 5.8
	BMI (kg/m^2)	16.87 ± 2.57	16.82 ± 2.91	15.98 ± 1.83	16.31 ± 2.16

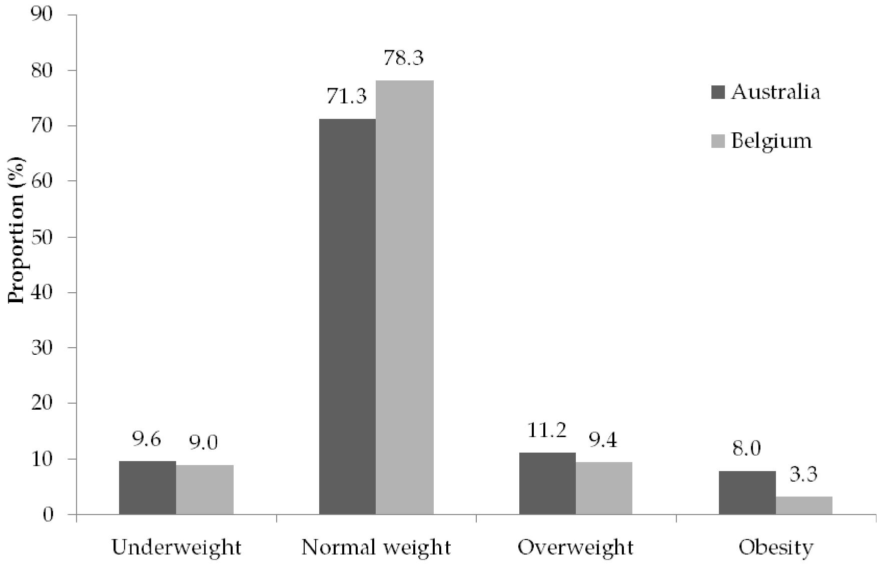

Figure 9. Distribution of Australian and Belgian children across the BMI categories

4.3.2 Differences in raw scores between Australian and Belgian children

Mean scores and standard deviations for each country are reported in Table 13. The results of the MANCOVA are presented in Table 14. BMI was shown to be a significant covariate.

Table 13. Performance on the KTK (raw and standardized scores)

	Australia (*N = 252)*		Belgium (*N = 244)*	
Variable	**M**	**SD**	**M**	**SD**
Raw scores				
Walking backwards	31.1	14.1	27.6	13.1
Hopping for height	34.6	15.0	35.7	15.5
Jumping sideways	44.5	13.8	45.0	12.0
Moving sideways	31.1	7.6	34.5	6.2
Motor Quotients				
Walking backwards	88.7	15.3	85.8	13.9
Hopping for height	96.5	17.1	99.5	16.6
Jumping sideways	100.5	17.5	106.6	15.2
Moving sideways	86.0	16.7	97.5	13.9
Total	90.6	16.5	96.4	13.6

The MANCOVA for the 4 subtests showed a significant country x age effect (Wilks' $\lambda = 0.96$; $F = 2.78$; $p = .005$; partial $\eta 2 = .022$). However, follow-up ANCOVAs could not confirm the interaction effect for any subtest (see Table 14). Results also showed significant main effects for country (Wilks' $\lambda = 0.89$; $F = 14.613$; $p < .001$; partial $\eta 2 = .108$) and age (Wilks' $\lambda = 0.71$; $F = 22.84$; $p < .001$; partial $\eta 2 = .159$). For country effect, significant differences at the univariate level were found for hopping for height, jumping sideways and moving sideways in favor of Belgian children (p-values ≤ 0.01). No significant country differences were found for walking backwards on a balance beam ($p = .105$). For age effect, significant differences at the univariate level were found for each subtest with older children performing higher than their one-year younger counterparts (all p-values ≤ 0.005).

Table 14. Results of the two-way MANCOVA for the KTK performance

Variables	$F_{\text{COUNTRY x AGE}}$	η^2_p	F_{COUNTRY}	η^2_p	F_{AGE}	η^2_p	F_{BMI} *covariate*	η^2_p
Raw scores								
Walking backwards	1.42	.006	2.64	.005	32.45 ***	.117	12.39 ***	.025
Hopping for height	2.97	.012	8.28 **	.017	79.70 ***	.246	14.88 **	.030
Jumping sideways	0.76	.003	6.61 *	.013	71.08 ***	.226	5.10 *	.010
Moving sideways	0.44	.002	40.52 ***	.077	26.55 ***	.098	5.31 *	.011

***$p < .001$, **$p < .01$, *$p \leq .05$

4.3.3 Comparing Motor Quotients of Australian and Belgian children

Results show that BMI is a significant covariate in the analyses for the total MQ and all item MQs (F-values ≥ 6.11; p-values $\leq .05$; η^2_p-values $\leq .024$) except for jumping sideways ($F = 2.76$; $p = .097$; partial $\eta^2 = .026$). The ANCOVA for the total KTK Motor Quotient showed a significant country effect ($F = 13.87$, $p < .001$, partial $\eta^2 = .027$). The performance of Belgian children was higher in comparison with Australian children (see Table 13). The MANCOVA for the Motor Quotients of the subtests showed a significant country effect (Wilks' $\lambda = 0.83$; $F = 25.46$; $p < .001$; partial $\eta^2 = .172$). Motor Quotient scores of Belgian children were significantly higher for jumping sideways ($F = 14.69$; $p < .001$; partial $\eta^2 = .029$) and moving sideways ($F = 63.043$; $p < .001$; partial $\eta^2 = .114$) in comparison with Australian children. However, the latter group did score significantly higher on walking backwards ($F = 6.98$, $p = .009$; partial $\eta^2 = .014$). No significant differences in Motor Quotients were found for hopping for height ($F = 2.295$; $p = .130$; partial $\eta^2 = .005$).

4.3.4 KTK classification of motor competence in the Australian and Belgian sample

The distribution of Australian and Belgian children across the KTK performance categories are shown in Figure 10. A chi-square analysis demonstrated a significant difference in distribution between both samples ($\chi^2 = 23.06$, $p < .001$; $\phi_c = 0.216$). The proportion of children scoring in the normal range of motor competence differed between Australia and Belgium (53.6% vs. 71.7%, respectively). Moreover, the percentage of Australian children performing below average was higher compared with Belgian children. The proportion of children scoring above average was similar for the Australian and Belgian sample. Additional chi-square tests also revealed that the observed percentages of both Australian and Belgian children across the performance levels differed significantly from the expected percentages of KTK classification based on the German reference sample (Australia: $\chi^2 = 90.24$, $p < .001$; $\phi_c = 0.247$; Belgium: $\chi^2 = 15.68$, $p = .003$; $\phi_c = 0.103$). The percentages of Australian and Belgian children scoring below average are 39% and 21% respectively as opposed to 16% in the German standardization sample. In contrast, the percentages of Australian and Belgian children performing above average are lower compared to the children of the German sample (7.1% vs 16% and 7% vs 16% respectively).

4.4 Discussion

The main aim of this study was to compare the motor competence of 6 to 8 year old children from Australia and Belgium using the KTK. A secondary aim was to compare the Australian and Belgian samples across the different performance categories of the KTK. In view of downward trends of motor competence (Bös 2003; Okely & Booth, 2004; Vandorpe et al., 2011; Tester et al., 2014; Hardy et al., 2013) we also investigated whether the Australian and Belgian distributions across the KTK categories had shifted towards the lower end of the motor competence spectrum when compared to the KTK reference sample.

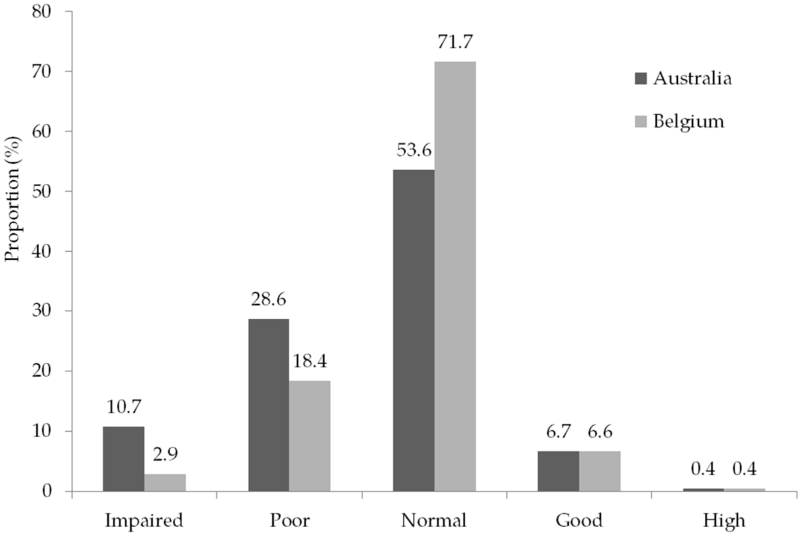

Figure 10. Distribution of Australian and Belgian children across the KTK performance categories

Overall, children from Belgium demonstrated a higher level of motor competence. Looking at the raw scores, Belgian children scored significantly better than the Australian children on three of the four individual tasks: moving sideways, jumping sideways and hopping for height. These tasks required a combination of lateral, upper and lower body coordination. Because this analysis was done using raw scores, the differences between countries at first appeared trivial (see Table 14). However, when the scores were standardized by age and sex, and we looked at the differences between countries using the Motor Quotients, the differences became more meaningful with Belgian children performing 17% higher than Australian children. Looking at the item motor quotients, children from Belgium scored significantly better on two of the four tests, though only one of these can be considered truly meaningful: Belgian children, on average, scored 11% better on moving sideways than Australian children. Australian children performed significantly higher on walking backwards although the effect size can be regarded as trivial ($\eta^2_p = .014$). No significant difference was found for hopping for height.

It has been suggested that measuring motor competence (especially when using a product-based assessment) also evaluates some elements of a child's physical fitness such as strength, speed, endurance and flexibility. Compared to the Australian children, the Belgian children scored higher on three tasks that involve both coordination and aspects of physical fitness, but not on the walking backwards task that is less sensitive to physical fitness. This indicates that physical fitness may play a potential role in the cross-cultural differences in motor competence. Results also showed that differences in motor performance between both countries were independent of age. As expected, age was found to influence motor competence within the groups, attesting to the quality of the KTK as a test battery. We also found BMI had a significant negative association in each model reinforcing previous literature on the inverse relationship between weight status and motor competence (D'Hondt et al., 2009; Lopes et al., 2012; Lubans et al., 2010). This points to the importance of adequate motor competence for children's healthy weight status as indicated in the model of Stodden et al. (2008).

In an effort to explain why Australian children generally scored lower than their Belgian counterparts, and why both countries scored significantly lower when compared to German norms, we adopted the three constraints based model as a framework which shapes motor development (Newell, 1986). Descriptive data showed that both samples had similar sex distributions and anthropometric characteristics, although the Belgian children were on average 3 months younger (which is why the difference in raw scores do not appear meaningful as they have not accounted for age). The KTK is a test of gross motor coordination, as such the tasks were novel for all children taking part. It is therefore likely that the physical activity contexts such as PE in preschool and primary school played a role in the differences observed in the KTK performance.

Early childhood is described as the optimal time to develop motor skills and establish motor competence (Hardy et al., 2010) and preschool has been lauded as the ideal institution for physical activity promotion in young children (Hinkley, Salmon, Okely, Hesketh, & Crawford, 2012; Ward, 2010). In Belgium, 98% of children aged 3 to 6 attend a free preschool program for 30 hours a week (Flemish Ministry of Education and Formation, 2011). In Australia, 70% of children aged 3 to 5 years attend a pre-school program of which only 23% attend for ≥ 15 hours per week, and often there is a cost attached to these services (Australian Bureau of Statistics, 2008). Overall, Australia is performing poorly in its ability to meet a set of minimum standards for children in their formative years when compared to other countries from the Organization for Economic Cooperation and Development. Australia currently only meets two of the 10 standards whilst Belgium complies with six standards (UNICEF Innocenti Research Centre, 2008). Therefore, the lower levels of motor performance observed in Australian children at the age of six years may be due to pre-school experiences, or the lack of them prior to beginning primary school.

In both countries, PE may be the main vehicle for developing children’s motor competence in primary schools. Differences in policies and common practices in PE may explain the higher motor scores found in Belgian children. The PE curriculum in Flanders is protected by the decree “Education II” (Flemish Ministry, 1990) which legitimizes PE as part of the basic school curriculum and dictates that two 50 minute lessons a week are compulsory for all children from 6-18 years (Arnouts & Spilthoorn, 1999). Though there is little evidence available for the quality of PE, approximately 81% of Flemish primary schools deploy a specialist teacher to teach PE (European Commission/EACEA/Eurydice, 2013). The Australian government recognizes that PE and sporting programs in schools have the potential to make people active for the rest of their lives and one of its primary objectives is to boost the number of children participating in sport through education (Commonwealth of Australia, 2010). However, despite this, PE has been marginalized to the periphery of the school curriculum leading to diminished time on school timetables (Moneghetti, 1993; Morgan & Hansen, 2008; Hardy et al., 2010). PE in Australian primary schools is generally provided by classroom teachers (Hardy et al., 2010). However, the total curriculum of the pre-service teacher education – provided by Australian universities – includes only two PE courses (Morgan & Bourke, 2005) which raises questions about the quality of PE in Australian primary schools.

Interestingly, whilst Belgian children displayed better scores overall than Australian children, both groups scored significantly lower than the German standardization sample from 1974. Although this finding could be attributed to cultural differences between these countries, a more likely reason can be found in the international decline in physical activity over the past decades (Dollman et al., 2005). Australia has seen a 42% decline in active transport between 1971 and 2013 and children's top ten preferred play spaces have seen a marked transition from outdoors to indoors between 1950 to 2000 (Active Healthy Kids Australia, 2014).

The latter explanation is in line with a large-scale Australian study in primary school children where a general decline was found in motor competence and physical fitness. This decline was especially apparent in six-year-old children who performed worse than their counterparts in the 1980s in tasks such as underarm throws, catching and bouncing balls (Tester et al., 2014). Lifestyles across Europe and Australia have changed over the past 40 years with advances in technology and increased standards of living, and this has changed how children spend their leisure time with an increase in sedentary activity and a decrease in physical activity levels (Dollman et al., 2005). In view of Stodden et al. (2008)'s model on the dynamic relationship between the motor competence and PA, the downward trends of physical activity levels may affect the levels of motor competence and should therefore be addressed by policymakers.

A limitation to this study is the sole focus on gross motor coordination as the measurement of motor competence. However, fundamental motor skills (specifically object control skills) also play a role in children's motor competence and their engagement in physical activity and sports (Barnett et al., 2009), and fitness (Vlahov et al., 2014). Therefore, future research should investigate cross-cultural differences in these fundamental motor skills in order to gain a better understanding of children's motor competence on a global level. Nonetheless, a strength of this study is the use of a standardized and robust assessment tool that is easy to use in both clinical and educational settings (Cools, De Martelaer, Samaey, et al., 2009). Importantly, this study has enabled the cross-cultural comparison of motor competence in a large sample of young children.

In conclusion, this study provides valuable information on cross-cultural comparison of motor competence levels in children using the KTK. Present findings show that overall Belgian children scored generally higher on motor competence than Australian children. Also, distributions across performance categories revealed that a greater percentage of Australian children (nearly twice the Belgian percentage) scored below average. These results can be explained by possible physical activity contexts such as PE and organized sports. However, future research is needed to investigate the role of physical activity and fitness on cross-cultural differences in motor competence.

Chapter 5

Assessment of FMS in early childhood

This study[4] aimed to understand the fundamental motor skills (FMS) of Belgian children using the process-oriented Test of Gross Motor Development, Second Edition (TGMD-2) and to investigate the suitability of the United States (US) test norms in Belgium. Sex, age, and motor performance were examined in 1,614 Belgian children aged three to eight years (52.1% boys) and compared with the US reference sample. More proficient FMS performance was found with increasing age from three to six years for locomotor skills and three to seven years for object control skills. Sex differences were observed in object control skills with boys performing better than girls. In general, Belgian children had lower levels of motor competence than the reference sample, specifically for object control skills. The score distribution of the Belgian sample was skewed, with 37.4% scoring below average and only 6.9% scoring above average. This study supported the usefulness of the TGMD-2 as a process-oriented instrument to measure gross motor development in early childhood in Belgium. However, it also demonstrated that caution is warranted when using the US reference norms.

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[4] This study has been published as: Bardid, F., Huyben, F., Lenoir, M., Seghers, J., De Martelaer, K., Goodway, J. D., & Deconinck, F. J. A. (2016). Assessing fundamental motor skills in Belgian children aged 3-8 years highlights differences to US reference sample. *Acta Paediatrica.* doi:10.1111/apa.13380

5.1 Introduction

Motor competence is defined as the ability to perform a wide range of motor skills in a proficient manner (Haga, 2008). During the early years (ages 3-8), children's level of motor competence is reflected by their proficiency in fundamental motor skills (FMS), such as locomotor skills and object control skills executed in a bipedal position (Burton & Miller, 1998; D.F. Stodden et al., 2008). Locomotor skills involve movement through space and include skills such as running and jumping. Object control skills involve manipulation of objects and relate to skills such as catching and kicking. The FMS phase during early childhood is often described in motor development models and is considered important for the long-term development of motor competence and engagement in physical activity across the lifespan (Gallahue et al., 2012; Stodden et al., 2008). Within this framework, FMS provide the foundation for more complex or specialized motor skills. That is why mastering these skills in the preschool and early elementary school years is crucial to participation and competency in sports, games and other forms of physical activity (Gallahue et al., 2012; Stodden et al., 2008).

It is a common misconception that children naturally develop FMS competence through maturation processes (Clark, 2005), whereas in reality they also need practice and instruction to learn and develop FMS. Studies have demonstrated that children progress through developmental sequences while learning these important skills, starting with skills that are inefficient and have little functional utility and progressing to more mechanically efficient skills that can be successfully applied in sports and games (Gallahue et al., 2012). Unfortunately, some children do not effectively progress through these sequences and demonstrate delays in FMS development (Goodway, Robinson, & Crowe, 2010).

In their conceptual model, Stodden et al. (2008) described the dynamic and synergistic relationship between motor competence and physical activity. They considered motor competence to be one of the key underlying mechanisms driving physical activity behaviors throughout childhood and adolescence. This view has been supported by other studies that have demonstrated that motor competence was positively associated with levels of physical activity in children. Moreover, longitudinal research has suggested that motor competence in childhood predicts physical activity levels in later life (Robinson et al., 2015). Considering that childhood motor competence contributes to the development of an active lifestyle and concurrent health-related benefits (Gallahue et al., 2012; Stodden et al., 2008), it is imperative to assess and monitor motor competence, particularly in early and middle childhood.

Different measurement instruments have been developed to evaluate motor competence (Cools, De Martelaer, Samaey, et al., 2009) and a distinction can be made between product-oriented and process-oriented measurement methods (Burton & Miller, 1998). Product-oriented tests focus on the distance, the time or the number of successful trials of motor tasks such as the number of successful throws at a target disk. Rather than evaluating the outcome of motor skills, process-oriented tests focus on how motor skills are performed by examining the movement patterns, such as the contralateral step with overhand throw. While both methods contribute to a better understanding of children's motor competence, process-oriented motor assessment looks at motor competence from a developmental perspective. These tests can reveal aspects of a motor skill that have been poorly developed and they can assist in designing instructional interventions. One example of a process-oriented test is the Test of Gross Motor Development, Second Edition (TGMD-2; Ulrich, 2000).

The TGMD-2 evaluates the gross motor competence of children with and without disabilities from 3 to 10 years of age (Ulrich, 2000). The test consists of 12 FMS that are further divided into six locomotor skills (run, gallop, hop, leap, horizontal jump and slide) and six object control skills (strike, dribble, catch, kick, overhand throw and underhand roll). The test takes about 15 to 20 minutes and only requires equipment that is commonly used in physical activity programs. The TGMD-2 is both a criterion-referenced and norm-referenced test, as it evaluates a child's performance against a selected set of process criteria for each motor skill and it compares the individual score to the performance of a normative sample (Burton & Miller, 1998). The normative sample for the TGMD-2 consists of 1,208 children from the United States (US) and was stratified by age relative to sex, race, region and residence (Ulrich, 2000). The psychometric properties of the TGMD-2 have been well documented. The test manual reports good test-retest reliability and good inter-rater reliability with *r* values greater than .85. Furthermore, a good to excellent internal consistency has been described in the TGMD-2 manual with Cronbach's alpha coefficients of at least 0.85. The content, construct and concurrent validity have been established for diverse American and Asian populations and subgroups (Kim, Han, & Park, 2014; Ulrich, 2000; Valentini, 2012).

In Europe, product-oriented measurement instruments, such as the Body Coordination Test (Körperkoordinationstest für Kinder [KTK]; Kiphard & Schilling, 2007), have typically been used to evaluate motor competence in elementary school children (Cools, De Martelaer, Vandaele, Samaey, & Andries, 2009; Lopes et al., 2011; Vandorpe et al., 2011). For example, Vandorpe et al. (2011) used the KTK to examine motor competence in 6- to 12-year-old children in Flanders, Belgium. However, empirical evidence on the FMS of younger children in Belgium and other European countries is limited. In light of the scarcity of motor competence data on young children in Europe, the TGMD-2 would be an appropriate instrument for data collection as it covers the critical age period for FMS development. It also adopts a process-oriented approach to assess motor competence in early and middle childhood, which has value in the development of future instructional interventions.

When researchers and practitioners adopt a measurement instrument to evaluate motor performance, it is important that they consider the cultural background of the normative sample (Miyahara et al., 1998). For example, Vanvuchelen et al. (2003) administered the Peabody Developmental Motor Scales 2nd Edition (PDMS-2) (Folio & Fewell, 2000) in five year-old Belgian children and found comparable scores between the Belgian and US cohort, with the exception of visual-motor skills, where the Belgian group performed better. The authors stated that the differences in motor performance could have been explained by differences in the educational system. In contrast to the US, nearly every child in Belgium attends preschool, starting from the age of three. In addition, the Organization for Economic Cooperation and Development (OECD) has reported that publicly-funded preschool education is more developed in European countries than in non-European countries such as the US (OECD, 2013). The majority of these European countries, including

Belgium, provide at least two years of free publicly-funded preschool education to all children, which provide them the opportunities to develop and master motor skills.

The TGMD-2 might be of great use to assess the gross motor competence of typically developing children in European settings, as it uses a process-oriented approach on FMS and provides both criterion-referenced and norm-referenced data, with the noted limitation of the reference sample not being European. Most importantly, these data have translational value in the development of future FMS instructional interventions. Research on the suitability of the TGMD-2 norms for European populations is limited. Simons and Van Hombeeck (2003) compared the scores of a Belgian sample of 30 six-year-old children to the US normative sample. Their findings revealed similar locomotor scores, but different scores on the object control subtest with a better performance in the US reference sample. Given the limitations of that study, in particular the small sample and a single age group, further investigations are needed in a European context, with a large sample and broad age range.

In order to better understand motor competence and promote FMS development in a European context, the present study examined the FMS of Belgian children aged three to eight years, from a process-oriented perspective and during a developmentally sensitive age period. The primary aim was to report on the FMS of children from Belgium and investigate possible sex- and age-related differences. The secondary aim was to compare the TGMD-2 performance and categorization of the Belgian sample with the US reference population. Based on the study of Simons and Van Hombeeck (2003), we hypothesized that the locomotor scores would be similar, but that the object control score of Belgian children would be lower than the US normative sample.

5.2 Methods

5.2.1 Participants

A large-scale, government-funded project called Multimove for Kids (multimove.be) was set up to examine the motor competence of young children in Flanders, Belgium. To obtain a representative sample for this region, 51 settings (i.e., sports clubs, local councils, schools and day care centers) were selected from all five Flemish provinces and the Brussels Capital Region. The study sample consisted of 1,614 children aged three to eight years, with 841 boys and 773 girls. Written informed consent was obtained from a parent or a guardian of each child. The ethics committee of Ghent University Hospital granted permission for this study.

5.2.2 Procedure

Anthropometric data (height and weight) were collected prior to the motor assessment. Height was measured to an accuracy of 0.1 cm using a SECA 123 portable stadiometer and weight was assessed with an accuracy of 0.1 kg using a SECA Robusta 813 balance scale (SECA GmbH & Co. KG., Hamburg, Germany). The body mass index (BMI) was calculated from height and weight values using the following formula: weight / height^2 (kg/m^2) (see Table 15). Children's motor competence was assessed with the TGMD-2 by trained examiners in accordance with the test manual (Ulrich, 2000). All examiners had a physical education background, received a detailed instruction manual and were trained on the TGMD-2 in a half-day workshop. The assessments were coordinated and supervised by researchers, experienced in test assessment. The tests took approximately 20 minutes per child and were performed in an indoor facility. The assessments were conducted and coded live between September 2012 and November 2012.

Table 15. Descriptive statistics of anthropometric measurements, stratified by age and sex

		Boys			Girls		
Age group	**Variables**	***M***	**±**	***SD***	***M***	**±**	***SD***
3 years	Height (cm)	100.8	±	4.5	99.0	±	4.5
	Weight (kg)	16.6	±	2.0	15.9	±	2.1
	BMI (kg/m^2)	16.27	±	1.17	16.21	±	1.34
4 years	Height (cm)	106.9	±	4.6	106.4	±	4.5
	Weight (kg)	18.5	±	2.4	18.3	±	2.5
	BMI (kg/m^2)	16.08	±	1.27	16.09	±	1.48
5 years	Height (cm)	113.7	±	4.9	113.0	±	5.1
	Weight (kg)	20.6	±	2.8	20.1	±	3.0
	BMI (kg/m^2)	15.89	±	1.42	15.69	±	1.55
6 years	Height (cm)	120.5	±	5.4	119.9	±	5.8
	Weight (kg)	23.1	±	3.5	23.4	±	4.2
	BMI (kg/m^2)	15.83	±	1.69	16.17	±	1.90
7 years	Height (cm)	126.8	±	6.3	125.7	±	5.7
	Weight (kg)	26.5	±	5.3	26.6	±	5.1
	BMI (kg/m^2)	16.38	±	2.05	16.79	±	2.50
8 years	Height (cm)	132.6	±	6.0	131.4	±	6.3
	Weight (kg)	28.7	±	5.2	29.7	±	6.4
	BMI (kg/m^2)	16.23	±	2.10	17.09	±	2.60

5.2.3 Measurement

The TGMD-2 covers 12 fundamental motor skills that are divided into two subcategories. The locomotor subtest consists of six skills: running, galloping, hopping, leaping, horizontal jump and slide. The object control subtest also includes six skills: striking a stationary ball, stationary dribble, catching, kicking, overhand throwing and underhand rolling (Ulrich, 2000). Following a visual demonstration, each child was instructed to perform each of the 12 skills twice. Each skill has three to five critical elements, which were scored by the trained raters on a dichotomous scale:

the rater gave a score of one if a critical element was present and a zero if it was not. We calculated the total scores for each skill and for each subtest, ranging from 0 to 48. Using normative data, based on the performance of the US reference sample, raw scores for each subtest were transformed into standard scores, ranging from 0 to 20. Then, the locomotor and object control standard scores were added together and converted into a gross motor quotient (GMQ; $M = 100$, $SD = 15$, range = 46-160). Finally, the GMQ was used to categorize the motor performance of each child, from very poor to very superior (Ulrich, 2000).

5.2.4 Data analysis

All analyses were performed using SPSS 20 for Windows (SPSS Inc., Chicago, Illinois, USA) and the significance level was set at $p \leq 0.05$. Descriptive statistics were used to present the TGMD-2 scores. A two-factor ANOVA of the subtest raw scores was performed in order to investigate age (3, 4, 5, 6, 7 and 8 years) and gender (boys and girls) differences in the TGMD-2 scores of Belgian children. Significant interaction and main effects were further examined with Bonferroni post hoc tests or pairwise comparisons. One-sample *t*-tests were used to compare the raw and standard scores for the locomotor and object control subtest as well as the GMQ between the Belgian sample and the US reference population, with the US average as the reference value (Ulrich, 2000). Finally, chi-square tests were used to evaluate performance categories based on the cut-off points found in the test manual.

5.3 Results

5.3.1 Influence of age and sex on fundamental motor skills

Table 16 presents the TGMD-2 subtest scores for Belgian boys and girls of each age group. In accordance with the first aim of the study, we will discuss gender and age differences in the TGMD-2 raw scores of the Belgian sample. A significant age effect for both locomotor and object control skills indicated different TGMD-2 performance, depending on age (locomotor: $F = 294.998$, $p < .001$, partial $\eta^2 = 0.479$; object control: $F = 374.131$, $p < .001$, partial $\eta^2 = 0.539$). For the locomotor subcategory, post-hoc analysis revealed that four, five, and six-year-old children scored significantly higher than children who were one year younger than them (all p-values < 0.001) but seven and eight-year-old children did not (p = .106 and 1 respectively). For the object control subcategory, post-hoc tests demonstrated that each age group performed significantly higher than their 1-year younger counterparts (all p-values < 0.001, except for 7 versus 8 year-old group: $p = .038$). A significant gender effect for the object control skills indicated that boys scored significantly higher than girls in all age groups ($F = 275.845$, $p < .001$, partial $\eta^2 = 0.147$). A significant interaction between age and sex ($F = 3.983$, $p = .001$, partial $\eta^2 = .012$) and the separate follow-up analyses for boys and girls, revealed that only girls in the eight-year-old group scored significantly better on object control skills than the girls who were one year younger than them ($p = .022$). Analysis of the locomotor skills showed no significant sex differences ($F = 2.231$, $p = .135$) and no significant interaction between age and sex ($F = 1.083$, $p = .368$).

5.3.2 Comparison of the Belgian sample with the US reference population

Figure 11 shows the raw subtest scores of the Belgian sample in comparison with the US reference population. Differences varied with age and sex when it came to locomotor skills. No significant differences were found between the Belgian boys and their US counterparts on the locomotor subtest in the age groups of three ($t = 0.961$, $p = .338$), four ($t = 1.735$, $p = .084$) and five ($t = 1.300$, $p = .195$). Similar findings were recorded for three-year-old girls ($t = -0.828$, $p = .410$) and four-year-old girls ($t = 1.233$, $p = .220$), but five-year-old Belgian girls scored significantly higher on locomotor skills than five-year-old girls from the US ($t = 4.813$, $p < .001$, Cohen's $d = 0.4$). However, results show lower locomotor skill performances for Belgian boys and girls aged six (boys: $t = -5{,}632$, $p < .001$, Cohen's $d = 0.446$; girls: $t = -2.193$, $p = .030$, Cohen's $d = 0.161$), seven (boys: $t = -4.036$, $p < .001$, Cohen's $d = 0.396$; girls: $t = -3.106$, $p = .002$, Cohen's $d = 0.306$) and eight (boys: $t = -3.577$, $p = .001$, Cohen's $d = 0.453$; girls: $t = -9.717$, $p < .001$, Cohen's $d = 1.095$) when compared to their US counterparts. Regardless of sex, Belgian children of all age groups performed significantly worse on object control skills than the US reference population (all p-values < 0.001, Cohen's $d = 0.303 – 1.269$).

Table 16. Performance on the TGMD-2 (subtest raw scores) for Belgian children

			Locomotor skills						**Object control skills**					
	N		**Girls**		**Boys**		**Total**		**Girls**		**Boys**		**Total**	
Age group	**Girls**	**Boys**	***M***	**± *SD***	***M***	**± *SD***	***M***	**± *SD***	***M***	**± *SD***	***M***	**± *SD***	***M***	**± *SD***
3	113	121	20.4	± 8.0	19.7	± 7.7	20.0	± 7.8	14.1	± 5.3	17.5	± 6.3	15.9	± 6.0
4	159	215	29.7	± 6.9	28.0	± 8.1	28.7	± 7.6	18.1	± 5.3	22.3	± 6.0	20.5	± 6.1
5	149	181	34.4	± 6.0	33.6	± 6.3	34.0	± 6.2	23.3	± 5.6	27.4	± 6.4	25.6	± 6.4
6	164	159	37.1	± 5.6	36.5	± 5.6	36.8	± 5.6	26.5	± 5.8	33.1	± 6.4	29.8	± 7.0
7	107	103	38.5	± 4.9	38.1	± 4.8	38.3	± 4.9	29.7	± 6.1	36.4	± 5.6	33.0	± 6.7
8	81	62	38.4	± 4.2	39.6	± 5.3	38.9	± 4.7	32.4	± 5.2	38.1	± 4.6	34.9	± 5.7

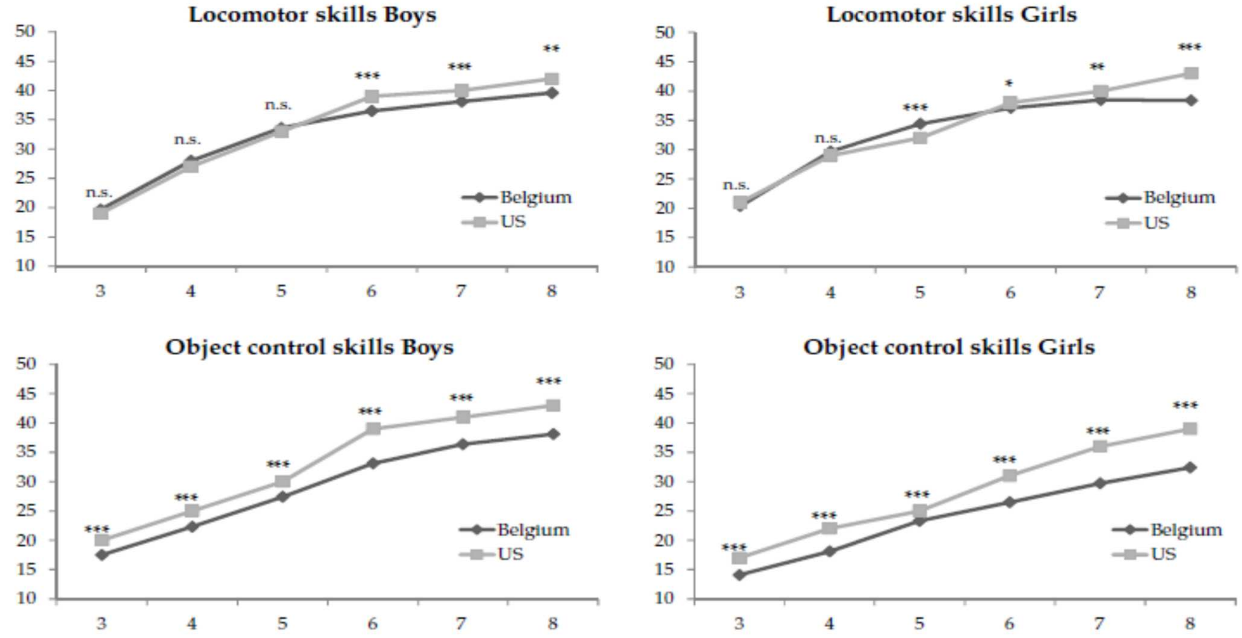

Figure 11. Comparison of locomotor and object control raw scores between the Belgian sample and the US reference sample

In addition to raw scores, analyses were conducted using standard scores based on the US reference population. Table 17 presents the locomotor and object control standard scores and the GMQ for boys and girls in each age group.

Table 17. Performance on the TGMD-2 (standard scores) for Belgian children

		3-year-old (*N* = 234)	4-year-old (*N* = 374)	5-year-old (*N* = 330)
		M* ± *SD	***M* ± *SD***	***M* ± *SD***
Subtests				
Locomotor	*Girls*	9.6 ± 2.4	10.6 ± 2.4	10.3 ± 2.4
	Boys	9.2 ± 2.3	10.0 ± 2.7	10.0 ± 2.3
	Total	9.4 ± 2.4	10.2 ± 2.6	10.2 ± 2.4
Object Control	*Girls*	8.9 ± 1.8	8.2 ± 1.8	8.2 ± 2.2
	Boys	8.9 ± 2.0	8.7 ± 2.0	8.4 ± 2.0
	Total	8.9 ± 1.9	8.5 ± 1.9	8.3 ± 2.1
GMQ	*Girls*	95.4 ± 10.4	96.3 ± 10.3	95.5 ± 10.8
	Boys	94.4 ± 10.5	96.1 ± 11.6	95.4 ± 10.6
	Total	94.9 ± 10.5	96.2 ± 11.1	95.5 ± 10.7
		6-year-old (*N* = 323)	**7-year-old (*N* = 210)**	**8-year-old (*N* = 143)**
		M* ± *SD	***M* ± *SD***	***M* ± *SD***
Subtests				
Locomotor	*Girls*	9.5 ± 2.5	9.0 ± 2.3	7.8 ± 2.2
	Boys	9.4 ± 2.4	8.7 ± 2.3	8.5 ± 2.7
	Total	9.5 ± 2.4	8.8 ± 2.3	8.1 ± 2.5
Object Control	*Girls*	7.8 ± 2.3	7.4 ± 2.5	7.0 ± 2.4
	Boys	8.3 ± 2.2	7.7 ± 2.3	7.1 ± 2.1
	Total	8.0 ± 2.3	7.5 ± 2.4	7.1 ± 2.3
GMQ	*Girls*	91.9 ± 11.8	89.1 ± 11.6	84.3 ± 9.8
	Boys	93.0 ± 10.9	89.0 ± 10.2	86.8 ± 11.7
	Total	92.5 ± 11.4	89.1 ± 10.9	85.4 ± 10.7

The mean scores of the locomotor standard score, object control standard score and the GMQ of the US sample were 10 ± 3, 10 ± 3 and 100

± 15, respectively. When we compared the subtest standard scores with the US norms (see Table 18), Belgian children scored significantly lower on the locomotor and object control subtests (all *p*-values < .001, Cohen's *d* = 0.16 – 0.909). Likewise, the GMQ of the Belgian sample was significantly lower than the US sample (*p* < .001, Cohen's *d* = 0.477 – 0.617).

Table 18. Results of the one-sample t-test comparing the TGMD-2 standard scores of Belgian children to the US norms

		M* ± *SD	***t***	***p***
Subtests				
Locomotor	*Girls (N = 773)*	9.6 ± 2.5	-4.07	<.001
	Boys(N = 841)	9.5 ± 2.5	-5.73	<.001
	Total (N = 1614)	9.6 ± 2.5	-6.95	<.001
Object Control	*Girls (N = 773)*	8.0 ± 2.2	-24.94	<.001
	Boys(N = 841)	8.4 ± 2.1	-22.51	<.001
	Total (N = 1614)	8.2 ± 2.2	-33.46	<.001
GMQ	*Girls (N = 773)*	92.9 ± 11.5	-17.28	<.001
	Boys(N = 841)	93.6 ± 11.3	-13.90	<.001
	Total (N = 1614)	93.2 ± 11.4	-23.85	<.001

5.3.3 TGMD-2 classification of GMQ scores in the Belgian sample

Figure 12 shows the distribution of the Belgian children across the TGMD-2 performance categories in comparison to the US reference population. The classification of GMQ according to the TGMD-2 manual (Ulrich, 2000) consists of seven performance levels. Children with a GMQ below 70 are rated as having very poor motor competence, 70 – 79 is poor, 80 – 89 is below average, 90 – 110 is average, 111 – 120 is above average, 121 – 130 is superior, and above 130 indicates very superior motor competence.

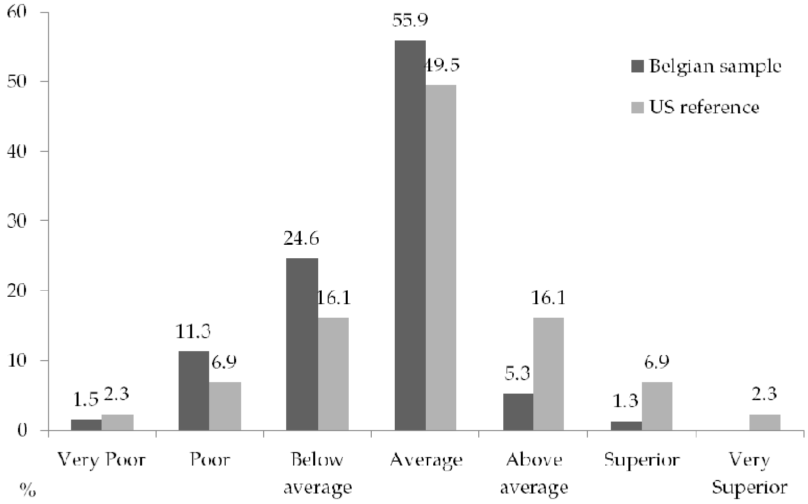

Figure 12. Distribution of Belgian children across the TGMD-2 performance categories for Gross Motor Quotient (GMQ)

Chi-square analyses showed significant differences when we compared the distribution of the Belgian children across the GMQ categories with the distribution according to the TGMD-2 manual (χ^2 = 219.548, p < .001, Cramer's V = 0.279). Figure 12 shows that the Belgian sample shifted towards the lower end of the motor continuum. The percentages of Belgian children in the average, below average and poor categories were higher than the percentages specified by the TGMD-2 US norms (55.9% versus 49.5%, 24.6% versus 16.1% and 11.3% versus 6.9%, respectively). This shift was not present in the very poor category (1.5% versus 2.3%). Only 1.3% of the Belgian children were identified as having a superior or very superior motor competence in contrast to the 9.2% of the US reference sample. Furthermore, 16.1% of the US sample were above average, compare to only 5.3% of the Belgian sample.

Inspection of the distribution across categories for the two subtests, also showed a shift of Belgian children's performance towards the lower end for both the locomotor (χ^2 = 147.872, *p < .001*, Cramer's V = 0.229) and object control subtest (χ^2 = 357.94, *p < .001*, Cramer's V = 0.356; see Figure 13 and Figure 14).

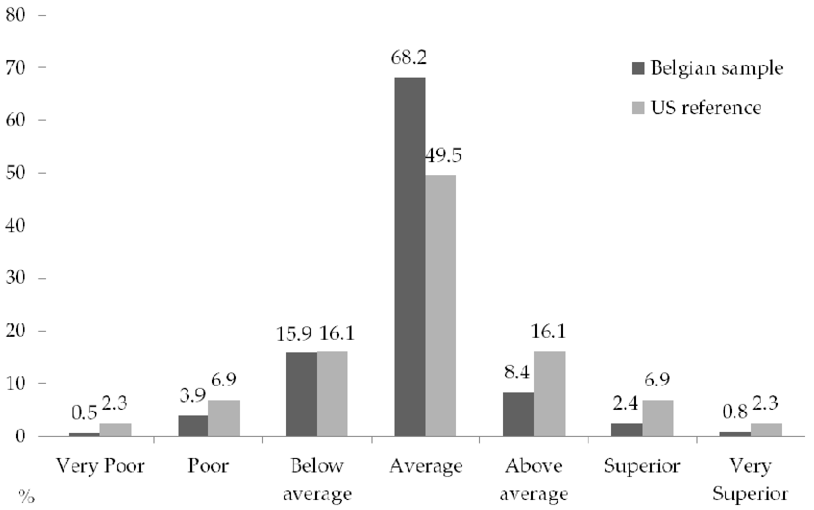

Figure 13. Distribution of Belgian children across the TGMD-2 performance categories for the locomotor subtest

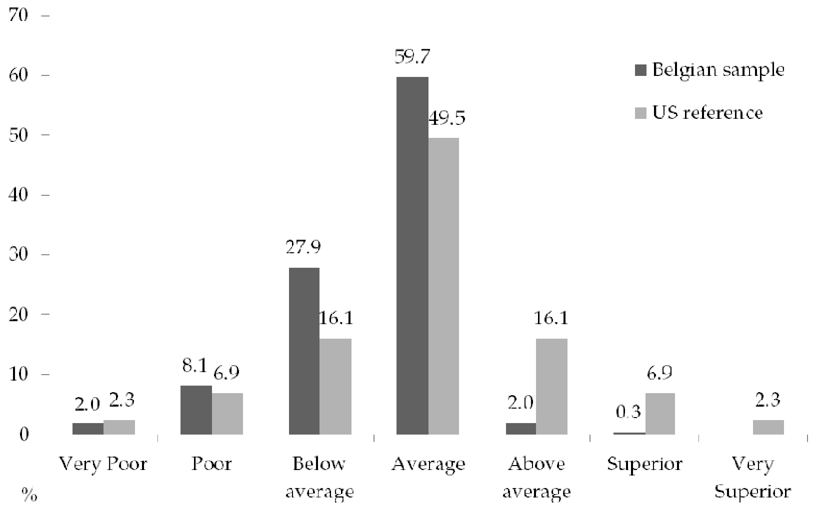

Figure 14. Distribution of Belgian children across the TGMD-2 performance categories for the object control subtest

For the locomotor subtest, the percentages of Belgian children in the very superior, superior and above average categories were lower than the percentages of the US sample (0.8% versus 2.3%, 2.4% versus 6.9% and 8.4% versus 16.1% respectively). However, this leftward shift was not present in the remaining categories of below average, poor and very poor. The percentage of Belgian children described as having a normal locomotor score was higher than compared to the US sample (68.2% versus 49.5%).

For the object control subtest, the Belgian distribution was more consistent with the distribution across the GMQ categories. The percentages of Belgian children in the very superior, superior and above average categories were lower than the US reference values (0% versus 2.3%, 0.3% versus 6.9% and 2% versus 16.1% respectively) and higher for the average, below average and poor categories (59.7% versus 49.5%, 27.9% versus 16.1% and 8.1% versus 6.9% respectively). This shift was not present in the very poor category.

5.4 Discussion

In view of the importance of motor skill development in early and middle childhood, this study evaluated the motor competence of young children in a European context, using the process-oriented TGMD-2. We described the FMS of 1,614 Belgian children aged three to eight years and analyzed possible age and sex differences. In addition, we compared the test performance and categorization of the Belgian sample and the US reference sample.

There were age differences in FMS in the Belgian sample, with children aged three to six years showing an age-related increase in motor performance in both the locomotor and object control subtests. These results are in agreement with previous studies (Cools, De Martelaer, Vandaele, et al., 2009; Van Waelvelde, Peersman, Lenoir, Smits-Engelsman, & Henderson, 2008). In contrast, the similar locomotor performances between children aged six, seven and eight in our cohort disagreed with the findings of Ahnert, Schneider and Bös (2009), and Vandorpe et al. (2011), who reported improvements across all ages in elementary school children. It should be noted, however, that both studies used the KTK where the focus of assessment is product-oriented and lies on coordination and balance rather than locomotor and object control skills. Indeed, similar skill plateaus for both locomotor and object control scores can be found in the reference population of the TGMD-2 (Ulrich, 2000). A possible explanation for these findings is that locomotor skills emerge earlier in children's motor development, which may cause a ceiling effect in the locomotor subtest of the TGMD-2. As mentioned earlier, most children in Belgium attend preschool at the age of three and preschool activities may enable children to develop locomotor skills earlier. However, these skills might stabilize over time as children enter elementary school and their focus on motor instruction shifts to object control related activities. This assumption is partly supported by the results of object control scores where a gradual improvement across all age groups was found, except for eight-year-old boys who showed no difference to the seven-year-old boys. Another possible explanation might be that the sensitivity of the test to detect changes in FMS is limited to a certain age range due to the criteria included in the assessment.

In agreement with prior research (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Goodway et al., 2010), findings on sex differences indicated similar locomotor scores for Belgian boys and girls, while object control scores were higher for boys. Although sex differences in motor performance have been classified as an individual constraint due to the biological factors related to them (Gallahue et al., 2012), physical characteristics such as body type, body composition, strength and limb lengths are quite similar between prepubertal boys and girls (Malina, Bouchard, & Bar-Or, 2004). Therefore, researchers argue that sex differences before puberty are more likely to be associated with socio-cultural factors such as a child's perception of their appropriate gender role with regard to sports and games (Wrotniak et al., 2006). Children learn a gender role from their family, peers, and teachers or coaches through socialization and imitation, and consequently participate in activities that fit these gender norms (Thomas & French, 1985). Thus, a possible explanation for the sex differences in favor of boys is that boys engage in more object control related activities, such as ball games, than girls and therefore have more opportunities to practice and develop these skills. The sex-related results observed in the Belgian sample are in line with the findings in the normative sample of the TGMD-2, which supports the use of separate object control norms for boys and girls (Ulrich, 2000).

To examine the suitability of the TGMD-2 in a European context, we compared the raw and standardized scores of the Belgian sample with the US reference population. The findings were not straightforward as the results varied by age and subtests. In the three to five year age group, the scores for the locomotor skills of Belgian children were similar to those of US children, but the US children were significantly better when it came to object control skills. These findings are consistent with the study by Simons and Van Hombeeck (2003). The authors suggested that differences in object control skills might be attributed to Belgian children's lack of experience with some object control skills of the TGMD-2, mainly striking with bat and overarm throwing, that are prominent in the American sports culture (e.g., baseball and softball) but not in the Belgian sports culture. In the older age group of six to eight years in the present study, the results show that Belgian children scored lower on both locomotor and object control skills than the US reference group.

The lower TGMD-2 scores of Belgian children compared to the US reference sample indicate that cultural factors may play an important role in understanding differences between children from distinct regions. For instance, when we compared our Belgian sample with the Brazilian sample from the 2012 study by Valentini (2012), the raw locomotor scores for the Belgian sample were 11-32% higher, depending on age, when compared to the Brazilian sample. For object control, Belgian children scored 2-31% higher than Brazilian children. Although Belgian and Brazilian sports cultures are more similar to each other – with soccer being the most popular sport – than to the US, the observed differences in motor scores can be related to differences in the early childhood education systems. Structured and unstructured activities in a school environment enable children to learn and develop motor skills. According to the 2013 OECD report (2013), 98-99% of Belgian children aged three to five years were enrolled in early childhood education while the enrolment rates in Brazil were 37%, 57% and 80% for age three, four and five, respectively. Nonetheless, Belgian children did score lower on the TGMD-2 than children from the US, even though the enrolment rates of three, four and five-year-olds in early childhood education were lower in the US (50%, 78% and 83% respectively; OECD, 2013). However, young children can also practice and develop motor skills through structured and unstructured physical activity outside the school setting.

The lower TGMD performance in the Belgian sample might have also been due to a decline in motor competence, as observed in Western countries (Bardid, Rudd, Lenoir, Polman, & Barnett, 2015; Hardy et al., 2013; Vandorpe et al., 2011). Because there was a time gap of approximately 15 years between the data collection of the US reference sample (1997-1998) and the Belgian sample (2012), it could be argued that the lower TGMD-2 performance of Belgian children might be due to a secular decrease in motor competence. In turn, this trend might be related to the decrease of physical activity in contexts such as active transport, PE and organized sports in many countries (Dollman et al., 2005). Physical activity provides opportunities to practice FMS and gain motor competency, but the observed secular trend might hamper the development of these skills to a mastery level. In addition, Stodden et al. (2008) stated that the relationship between motor competence and physical activity strengthens over time, which might explain the discrepancy between the younger and older age groups – three to five years versus six to eight years – when comparing the locomotor scores between children from Belgium and the US. Future research is needed to examine the relative impact of cultural trends, such as sports culture, organized sports, education system, and secular trends in FMS competence. As such, it would be valuable to compare the FMS of the Belgian sample with a current sample of US children.

Our investigation of the suitability of the TGMD-2 cut-off points demonstrated differences in the distribution of the performance categories of the Belgian and US sample. The results show a shift in the Belgian distribution towards the lower end of the motor competence spectrum, indicating that a larger portion of Belgian children scored below average compared to the US reference sample. In addition, a lower percentage of the Belgian sample scored above average. This shift was also observed in the object control subtest and, to a smaller degree, in the locomotor subtest. Interestingly, no Belgian child was categorized as having very superior GMQ or object control skills. It is also remarkable that the distribution shift towards the lower end of the continuum was not apparent in the very poor category. Our findings indicate that these TGMD-2 categories at the lowest and highest end of the motor competence spectrum (i.e., very poor and very superior) are perhaps not sufficiently discriminative in a Belgian sample. Nevertheless, the shift towards lower levels of motor performance might be related to a cultural bias of the TGMD-2 towards the US sports context and does not necessarily imply that we should just adjust the norms for Belgian children. The criterion elements of the TGMD-2 outline proficient performance of FMS. Thus, if we were to lower the norms for the Belgian sample we would not be advocating for the most proficient patterns of performance for these skills. As noted by Vandorpe et al. (2011), instead of lowering the norms, we should focus on developing motor skills in order to help as many children as possible to achieve a sufficient level of gross motor competence. Such a view is supported by the literature (Stodden et al., 2008) which suggests that the development of motor competence in the early years is critical to engagement in physical activity and perceived motor competence. In this respect, the TGMD-2 can be a useful measurement instrument to assess FMS in a developmental manner and provide the possibility of evaluating if a child’s gross motor competence fits within a normal range by means of its reference values.

The findings of our study provide valuable information on the use of a process-oriented evaluation of gross motor competence in Belgium and potential cultural differences between the Belgian sample and the US reference sample. Given that cultural influences on motor development, such as the range of sport activities, are similar in Belgium and the rest of Europe, our findings related to weaker object control skills may potentially be extrapolated to other European regions. Although the use of a standardized worldwide assessment can allow direct comparison between countries, it is also important to understand to what degree a test battery is biased towards a specific cultural context. For instance, the cross-cultural study by Bardid et al. (2015) using the German KTK test, demonstrated that Belgian children performed better than Australian on motor coordination, which may support the notion that the Belgian elementary PE curriculum enhances motor coordination but not object control skills. Moreover, Rudd et al. (2016) recently put forward a holistic model of motor competence that supports the need to measure both motor coordination and FMS to have a more comprehensive understanding of motor competence. Future research efforts are required to study the impact of cultural differences on measuring motor competence in a broader international context. A limitation of this study was that children's TGMD-2 performance was not video-recorded for later assessment, and thus it was not possible to report inter-rater reliability in this study.

In conclusion, this study provides information on early childhood motor development in a European context using a process-oriented perspective. Representative values on the TGMD-2 test were provided for Belgian children, with a performance improvement from three to six years in the locomotor subtest and three to seven years in the object control subtest for boys and to eight years for girls. Sex differences in object control skills support the use of separate TGMD-2 norms for boys and girls with these skills. In general, Belgian children scored lower on motor competence than the US reference sample, especially for the object control subtest, which may be explained by cultural differences or a downward trend in motor competence. These findings were further highlighted in a shift of Belgian children's performance toward the lower end of the motor competence continuum. The present study supported the usefulness of the TGMD-2 as a process-oriented instrument to measure gross motor development in early childhood in Belgium. However, it also demonstrated that caution is warranted when using the US reference norms. Although we could consider the development of separate norms for Belgian children, it is more valuable to focus on providing instructional programs that develop FMS and motor competency in early and middle childhood, in order to prepare children for future sports and games.

Chapter 6

The effectiveness of Multimove for Kids in early childhood

This study[5] aimed to examine the effectiveness of a 30-week fundamental motor skill (FMS) program in typically developing young children and to investigate possible sex differences. A multicenter quasi-experimental design was set up for this study, which involved 992 children aged 3 to 8 years. All participants received their typical physical education curriculum and habitual movement activities. The intervention group ($N = 523$; 53.5% boys) received a weekly 60-min motor skill session provided by trained local instructors in existing child settings; the control group ($N = 469$; 49.7% boys) received no additional practice. FMS were assessed using the Test of Gross Motor Development, 2nd Edition (TGMD-2) before and after the intervention. To assess the effect of the intervention and possible sex differences, hierarchical linear regression analyses were conducted for locomotor and object control gain scores. The intervention group demonstrated a higher gain in both locomotor ($\beta = 3.78$, $SE = 1.08$, $p < 0.001$) and object control ($\beta = 4.46$, $SE = 1.06$, $p < 0.001$) skills than the control group. Girls demonstrated a lower gain in object control skills ($\beta = -3.50$, $SE = 0.49$, $p < .001$) and higher gain in locomotor skills ($\beta = 1.01$, $SE = 0.44$, $p = .022$) than boys, regardless of group. The present study demonstrated the effectiveness of a wide-scale community-based intervention in typically developing children. The sex differences reported may indicate the need to use different pedagogical and instructional strategies to enable boys and girls to master a wide range of motor skills.

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[5] This study will be published as: Bardid, F., Lenoir, M., Huyben, F., De Martelaer, K., Seghers, J., Goodway, J. D., & Deconinck, F. J. A. (in press). The effectiveness of a community-based fundamental motor skill intervention in children aged 3-8 years: Results of the "Multimove for Kids" project. *Journal of Science and Medicine in Sport.*

6.1 Introduction

The ability to perform a variety of basic motor skills is crucial for participation and engagement in physical activity. These skills, also known as fundamental motor skills (FMS), are considered to be the building blocks for more complex skills needed in sports, games and other activities across childhood and adulthood (Lubans et al., 2010). FMS are generally categorized into locomotor skills (e.g., running and hopping) and object control skills (e.g., kicking and throwing; Haywood & Getchell, 2009). Mastery of FMS during early childhood is important as around the age of seven, children begin to apply their FMS in sports and other physical activities that involve more specific and complex movement patterns (Goodway & Robinson, 2015). Developing FMS competence early is also important as over the past decades, research has shown that FMS competence is related to different health benefits in terms of physical activity, physical fitness, perceived motor competence and weight status (Robinson et al., 2015). In addition, longitudinal studies have shown that proficiency levels of FMS in childhood is a significant predictor of physical activity in adolescence (Barnett et al., 2009; Lopes et al., 2011). Thus, FMS are a critical set of skills to develop if children are to be physically active across their childhood and adolescent years. However, although maturation influences the emergence of FMS, young children need to practice FMS if they are to develop motor competence (Goodway & Robinson, 2015; Robinson et al., 2015).

Early childhood motor skill interventions can provide opportunities for children to practice and master FMS through structured and unstructured activities. To this end different motor skill programs that promote FMS proficiency in children have been developed and implemented (see Logan, Robinson, Wilson, & Lucas, 2012, for a review on this matter). The majority of these interventions have targeted specific populations, especially children with motor difficulties (e.g., Bardid et al., 2013) and disadvantaged children (e.g., Goodway & Branta, 2003). However, some studies have demonstrated decreased levels of motor competence in general pediatric populations in Western countries (Darrah et al., 2007; Okely & Booth, 2004; Vandorpe, Vandendriessche, Lefevre, et al., 2011), which might be related to a decline in children's physical activity levels (Dollman et al., 2005).

Given the value of FMS in children's overall development, intervention programs should target all children, not only children who are at risk. Although FMS interventions have been shown to be effective in improving children's motor competence, few programs have been implemented on a large scale using a collaborative approach with community-based organizations and local instructors (van Beurden et al., 2003). In Belgium, the Flemish government has highlighted the importance of getting children active early through policy initiatives (Flemish Government, 2009) and implemented the Multimove for Kids program in existing child settings across Flanders (see section 6.5 Appendix). Such population-based initiatives reach large numbers of children and have strong ecological validity that randomized controlled trials with smaller samples generally lack (WHO, 2012). However, such public policy initiatives in community settings are often not evaluated using robust measures and therefore there is little knowledge on the effectiveness and translational value of these FMS programs. Overall, there is a gap in the literature on the effectiveness of community-based motor skill interventions for typically developing children.

To fill this gap, the present study examined the effectiveness of the Multimove intervention on the FMS of children aged 3-8 years old in Flanders, Belgium. A second objective was to investigate possible sex differences in FMS. Based on previous intervention literature (Logan et al., 2012), it was hypothesized that the intervention would significantly improve children's FMS.

6.2 Methods

Thirty-seven child settings with a total of 50 sites were purposively selected for the Multimove for Kids project based on the type of setting (sports club, local council, school and day care center) and geographical distribution (5 provinces). A total of 1123 children, aged 3 to 8 years, initially took part in the Multimove intervention. Of this group, the children with an attendance rate of ≥70% (i.e., 21 lessons) were assessed on FMS before and after the intervention (N = 523; M age = 5.6 ± 1.4 years; from 39 out of 50 sites). This intervention group consisted of 280 boys and 243 girls. A control group of 491 children was recruited from five schools in different provinces through convenience sampling. Of this group, 469 children (M age = 5.9 ± 1.6 years; 233 boys and 236 girls) were assessed twice on FMS proficiency. This study was approved by the ethical committee of Ghent University Hospital and written informed consent was provided from the parents or legal guardians for all participants.

Children in the intervention group received a 30-week theoretically underpinned FMS program consisting of one session (approximately 60-min) per week, offered in existing community settings and provided by trained local instructors (e.g., sport and recreation leaders, school teachers or caregivers). The Multimove program offered a wide range of playful activities using 12 basic motor skill themes: running, climbing, swinging, gliding, rotating, jumping, catching and throwing, pushing and pulling, lifting and carrying, hitting, kicking, dribbling. During each session children experienced 2-3 FMS themes, each of which were practiced for 15-30 min. All instructors received a one-day training workshop and support during the program (see section 6.5 Appendix).

Children's FMS were measured using the Test of Gross Motor Development, 2nd edition (TGMD-2; Ulrich, 2000), before and after the 30-week intervention. The test was administered in an indoor facility and took approximately 20 minutes per child to complete. The TGMD-2 is a criterion-referenced test examining the quality of performance in 6 locomotor skills (run, gallop, hop, leap, horizontal jump and slide) and 6 object control skills (strike a stationary ball, stationary dribble, catch, kick, overhand throw and underhand roll). Each child was evaluated twice on each skill using three to five components, which were marked as either present (=1) or absent (=0). Raw scores of locomotor skills and object control skills were summed to compute a raw subtest score. Subsequently, gain scores were calculated by subtracting the baseline score from the post-intervention score. The psychometric quality of the TGMD-2 is well-established with excellent test-retest reliability and inter-rater reliability (all r-values > 0.85) as well as a good internal consistency (Cronbach's α is 0.85 and 0.88 for locomotor and object control subtests respectively). Construct, content and concurrent validity have been established for children aged 3-10 years (Ulrich, 2000). Data collection was conducted by a group of trained examiners in accordance with the test manual (Ulrich, 2000). All examiners had a background in physical education, received a detailed TGMD-2 manual and completed a half-day assessment training.

Descriptive statistics were computed for the TGMD-2 subtest scores using SPSS 21 for Windows (IBM Corp., Armonk, NY, USA). Using a nested design (i.e., children within sites), hierarchical linear regression analyses with fixed and random effects were conducted in HLM 7 Student for Windows (SSI Inc., Skokie, IL, USA) to examine: (1) the effect of the Multimove intervention on the gain in locomotor and object control scores, and (2) sex differences. Potential effects of confounding factors such as sex, age, baseline score, and age x sex interaction were controlled for at level 1 (child level), and mean age and mean baseline score were controlled for at level 2 (site level). Full maximum-likelihood estimation was used for the 2-level model and the significance level was set at $p \leq .05$. Where relevant, effect sizes (ES) were calculated as the ratio of the absolute value of the estimate to the standard deviation of the gain score distribution (Raudenbusch & Bryk, 2002).

Separate hierarchical linear models were run for the gain in locomotor score (model 1) and object control score (model 2). First, two-level null models (child – site) including only the outcome, were estimated for gain in locomotor score (null model 1) and gain in object control score (null model 2). Next, level 1 variables (sex, age, baseline score and age x sex interaction) were added to the model for locomotor gain score (model 1a) and object control gain score (model 2a) to examine child characteristics. Sex was entered as a dichotomous variable (0 = boy; 1 = girl); age and baseline score were entered as continuous variables. Age x sex interaction was calculated as following*: [age - (mean age per site)] x sex*. Only significant effects were kept in further analysis.

Finally, to investigate the effect of the intervention and possible sex differences, level 2 variables (treatment, mean age and mean baseline score) and a cross-level interaction (sex x treatment) were inserted in the model for locomotor gain score (model 1b) and object control gain score (model 2b). Treatment was added as a dichotomous variable (0 = control; 1 = intervention); mean age and mean baseline score per site were included as continuous variables. Age was group mean centered at level 1 due to age range differences between sites. All other variables with no meaningful zero value were grand mean centered in all analyses.

6.3 Results

Table 19 shows the means and standard deviations for the baseline and post-intervention scores on the TGMD-2 outcomes. ANOVAs showed no significant differences in baseline scores between intervention and control group for locomotor skills ($F = 0.47$; $p = .492$) and object control skills ($F = 1.75$; $p = .187$). There were no significant differences in locomotor baseline scores between boys ($M = 32.02$, $SD = 8.90$) and girls ($M = 33.06$, $SD = 8.50$) ($F = 3.551$; $p = .06$). However, boys demonstrated higher baseline scores for object control skills than girls ($M = 27.83$ vs. 23.44, $SD = 9.035$ vs. 8.047; $F = 64.89$, $p < .001$; Cohen's $d = 0.51$). The results of the hierarchical linear regression analyses are presented for each outcome: locomotor gain score (model 1; see Table 20) and object control gain score (model 2; see Table 21).

Table 19. Performance on the TGMD-2 for the Multimove and control group

	Control			**Intervention**		
Variable	***M***	**±**	***SD***	***M***	**±**	***SD***
Locomotor score						
Baseline	32.3	±	8.9	32.7	±	8.5
Post-intervention	33.5	±	7.8	36.6	±	7.4
Gain	1.1	±	6.1	3.9	±	6.6
Object control score						
Baseline	25.3	±	8.8	26.1	±	8.9
Post-intervention	26.7	±	8.8	30.4	±	9.0
Gain	1.4	±	5.8	4.3	±	6.4

Table 20. Results of the hierarchical linear regression analyses for locomotor skill gain

	Null model 1				**Model 1a**				**Model 1b**			
Fixed effect	***β***	***SE***	***t***		***β***	***SE***	***t***		***β***	***SE***	***t***	
Intercept	3.87	0.49	7.95	*	3.61	0.52	6.91	***	0.32	0.98	0.33	*n.s.*
Treatment									3.74	1.08	3.48	***
Mean Age ‡									2.07	0.58	3.57	***
Mean Baseline score ‡									-0.13	0.12	-1.03	*n.s.*
Sex					0.85	0.37	2.28	*	1.01	0.44	2.29	*
Sex x Treatment									-0.39	0.62	-0.62	*n.s.*
Age †					1.34	0.27	4.90	***	1.17	0.23	5.05	***
Baseline score ‡					-0.55	0.03	-18.76	***	-0.53	0.02	-21.35	***
Age x Sex					-0.43	0.28	-1.57	*n.s.*				
Random effect	σ^2	***SD***	χ^2		σ^2	***SD***	χ^2		σ^2	***SD***	χ^2	
Intercept	7.37	2.71	262.46	***	8.90	2.98	238.99	***	4.28	2.07	200.26	***
level-1 residual	35.91	5.99			21.78	4.67			22.43	4.74		
Sex					1.01	1.00	32.45	*n.s.*				
Age					0.66	0.81	53.70	*	0.49	0.70	74.12	**
Baseline score					0.01	0.08	36.61	*n.s.*				
Age x Sex					0.24	0.49	47.73	*n.s.*				

*Note: † group mean centered, ‡ grand mean centered; *** $p < .001$, ** $p < .01$, * $p \leq 0,05$, n.s. = not significant*

Table 21. Results of the hierarchical linear regression analyses for object control gain

	Null model 2				**Model 2a**				**Model 2b**			
Fixed effect	***β***	***SE***	***t***		***β***	***SE***	***t***		***β***	***SE***	***t***	
Intercept	3.79	0.52	7.32	***	5.34	0.59	9.02	***	1.35	0.97	1.40	*n.s.*
Treatment									4.46	1.06	4.21	***
Mean Age ‡									3.77	0.64	5.84	***
Mean Baseline score ‡									-0.37	0.13	-2.82	**
Sex					-2.75	0.38	-7.18	***	-3.50	0.49	-7.11	***
Sex x Treatment									0.99	0.66	1.52	*n.s.*
Age †					1.62	0.24	6.74	***	1.68	0.18	9.09	***
Baseline score ‡					-0.46	0.03	-14.24	***	-0.47	0.03	-14.83	***
Age x Sex					0.03	0.28	0.12	*n.s.*				
Random effect	σ^2	***SD***	χ^2		σ^2	***SD***	χ^2		σ^2	***SD***	χ^2	
Intercept	8.95	2.99	295.26	***	11.68	3.42	202.11	***	4.11	2.03	123.29	***
level-1 residual	32.21	5.68			24.13	4.91			24.59	4.96		
Sex					0.55	0.74	37.57	*n.s.*				
Age					0.20	0.45	41.46	*n.s.*				
Baseline score					0.01	0.09	56.51	***	0.00	0.06	53.65	*n.s.*
Age x Sex					0.12	0.35	36.19	*n.s.*				

*Note: † group mean centered, ‡ grand mean centered; *** p < .001, ** p < .01, * p ≤ 0,05, n.s. = not significant*

The null model for gain in locomotor skills (null model 1) demonstrated a significant variance at level 2 [$\chi^2(43) = 262.5$; $p < .001$]. The ICC showed that 17% of the variance in locomotor gain was situated at site level and 83% at child level. Of the included level 1 variables (model 1a), sex, age and baseline score were significantly related to children's locomotor gain. Girls made significantly more gain in locomotor skills than boys [β = 0.85; *SE* = 0.37; *t*(43) = 2.28; *p* = 0.028; ES = 0.13]. As age increased, the locomotor gain score increased [β = 1.34; *SE* = 0.27; *t*(43) = 4.90; *p* < .001; ES = 0.20]. As the baseline score increased, the gain score decreased [β = -0.55; *SE* = 0.03; *t*(43) = -18.76; *p* < .001; ES = 0.08]. A random effect was found for age [$\chi^2(37) = 53.70$; $p = .037$] which indicates that the relationship between age and locomotor gain differs between sites. Results from the model that included treatment, mean age and mean baseline score per site (model 1b) indicated that – after controlling for different characteristics – children in the Multimove intervention sites had higher locomotor gain than children in control sites [β = 3.74; *SE* = 1.08; *t*(40) = 3.48; *p* = .001; ES = 0.57]. No significant cross-level interaction between sex and treatment was found; sex differences were similar in both intervention and control sites.

The null model for gain in object control skills (null model 2) showed a significant variance at level 2 [$\chi^2(43) = 295.26$; $p < .001$]. The ICC revealed that 22% of the variance in object control gain was situated at the site level and 78% at the child level. With regard to the included level 1 characteristics in the random coefficient model (model 2a), sex, age and baseline score were significantly related to children's object control gain. Girls made significantly less gain in object control skills than boys [β = -2.75; *SE* = 0.38; *t*(43) = -7.18; *p* = 0.028; ES = 0.43]. As age increased, the object control gain increased [β = 1.62; *SE* = 0.24; *t*(43) = 6.74; *p* < .001; ES = 0.25]. As baseline score increased, the gain score decreased [β=-0.46; *SE* = 0.03; *t*(43) = -14.24; *p* < .001; ES = 0.07]. A random effect was found for baseline score [$\chi^2(35) = 56.51$; $p = .012$], which indicates that the relationship between baseline and gain score differed between sites. The model that included treatment, mean age and mean baseline score per site (model 2b) revealed that – after controlling for different characteristics – children in the intervention sites had higher object control gain scores than children in control sites [β = 4.46; *SE* = 1.06; *t*(40) = 4.21; *p* < .001; ES = 0.70].

There was no significant cross-level interaction between sex and treatment.

6.4 Discussion

The purpose of this study was to examine the effectiveness of a government-supported, community-based motor skill intervention on the FMS competence of 3- to 8-year-old children. The results show that the Multimove intervention brought positive changes in children's FMS. Children who participated in the Multimove intervention made more progress in both locomotor and object control skills compared to children in the control group. The effect size values indicated a medium intervention effect (i.e., 0.57 and 0.69 for locomotor and object control skills respectively). These findings are consistent with previous research on motor skill interventions, which showed medium to large effect sizes for locomotor skills and medium effect sizes for object control skills (Logan et al., 2012; Morgan et al., 2013). The present study provides evidence that a community-based FMS program containing developmentally appropriate activities, can be effective for typically developing children. It also highlights that such programs led by trained local instructors can be as effective as programs led by motor development experts.

Results also revealed that children with lower baseline scores demonstrated higher gains in locomotor and object control skills than children with higher baseline scores. Such a finding may be related to the notion that children with lower levels of FMS have a greater potential to improve their motor proficiency (Logan et al., 2012). However, regardless of the baseline score, children who received the Multimove intervention benefited from the program in comparison to the control group. This finding demonstrates the importance of the motor skill intervention in all children's development, regardless of their initial status.

A secondary objective of this study was to investigate possible sex differences in FMS. Similar to previous studies, no sex differences were found for locomotor skills before the intervention, but boys exhibited higher baseline scores for object control skills than girls regardless of group (Bardid et al., 2013; Goodway et al., 2003; Thomas & French, 1985). In addition, a significant difference in object control gain scores favoring boys, was found. It seemed that the Multimove intervention did not allow girls to catch up with their male counterparts in object control skills, which is in agreement with some prior intervention research (Morgan et al., 2013). For example, the study of McKenzie, Alcaraz, Sallis, and Faucette (1998) demonstrated that boys made more gain in object control skills than girls. Perhaps, the observed sex differences in object control skills may be attributed to how the instructor interacts with boys and girls (e.g., instructor feedback), and differences in practice across the intervention. In this respect, a review by Davis (2003) highlights that boys tend to receive more corrective feedback than girls, which – if formulated in a positive manner – is important to promote the development of object control skills. Interestingly, this study showed that girls made more gain in locomotor skills than boys although the effect size is small. It should be noted that other studies did not demonstrate sex differences in skill gain (Morgan et al., 2013). For instance, van Beurden et al. (2003) found similar improvements in FMS for boys and girls across the intervention. Nonetheless, literature does show differences in FMS performance between boys and girls, specifically for object control skills (Barnett et al., 2016). These sex differences related to the type of motor skills may be linked to gender roles in sports and games where boys participate more in object control related activities (e.g., ball games) while girls engage more in activities that rely on locomotor skills (e.g., dance) during free play (Garcia, 1994; Hardy, Reinten-Reynolds, Espinel, Zask, & Okely, 2012). Children's preference for certain types of activities due to gender norms may have enabled boys and girls to practice and develop certain skills more easily. In addition, a study of Garcia (1994) showed gender-specific patterns in children's interactions when learning FMS, with boys interacting in a competitive and individualized manner and girls in a cooperative and caring manner. In view of the observed sex differences in the present study, future research should aim to examine the instructional and social aspects of motor skill programs and develop pedagogical approaches that would reduce differences in FMS performance between boys and girls and support an optimal development of their FMS.

A major strength of this study is the translational value of the study as it involved a wide-scale implementation of a FMS intervention – resulting from public policy – by local instructors within existing community settings. It is particularly noteworthy that this curriculum could be implemented successfully in a wide variety of community settings (e.g., sport clubs, schools, child cares) across a large geographic area using existing resources. A limitation of the study was the lack of a true experimental design with the Multimove intervention being delivered to children by sport organizations, local councils, school and day care centers, whereas control children were recruited from schools. Despite this limitation, it could be argued that the control group was representative as the schools were selected across Flanders and baseline scores between the intervention and control group were similar. An additional limitation of the study was the lack of fidelity measures on the Multimove curriculum implementation. It was not possible to examine how the Multimove curriculum was implemented by the different instructors. However, instructors were trained in the Multimove program and received the Multimove teaching manual with a wide range of activities for each skill, but they were free to select the content for each session. In spite of these limitations it appears the Multimove curriculum is very robust as it had a positive impact on the FMS development of children across Flanders which establishes the ecological validity of this program.

In conclusion, the present study showed that a 30-week FMS intervention program was effective in improving the FMS of typically developing young children. The collaborative approach with existing community-based organizations and instructors highlights the ecological value of the Multimove program and supports its further use in community settings. Sex differences showed that boys made more progress in object control skills and girls made more gain in locomotor skills. Further research is needed to determine long-term effects of community-based interventions and to explore appropriate teaching strategies that would address differences in FMS between boys and girls. In addition, policy makers need to utilize existing resources and invest in instructor preparation and training in FMS programs such as Multimove for Kids in order to support an effective implementation of such programs in various community settings.

6.5 Appendix

The Multimove for Kids project is a policy-based initiative funded by the Flemish Government. The main objective of this project was to promote FMS development of young children aged three to eight years. Experts of several institutions and organizations took part in the development and implementation of the project: Ghent University, Vrije Universiteit Brussel, KU Leuven, Flemish Sports Federation (Vlaamse Sportfederatie), Flemish Institute of Sports Management and Recreational Policy (Vlaams Instituut voor Sportbeheer en Recreatiebeleid), and the Flemish Government's Department of Culture, Youth, Sports and Media.

A FMS intervention was set up to achieve the aforementioned objective. The project team developed a teaching manual that adopted 12 FMS themes: running and walking, climbing, swinging, gliding, rotating, jumping, throwing and catching, pushing and pulling, lifting and carrying, hitting, kicking, and dribbling. The development and selection of the program content (i.e., developmentally appropriate activities for each skill theme) was based on motor development literature (see Gallahue et al., 2012, for an overview of developmental stages in FMS). The age-related developmental stages in FMS were provided in the teaching manual to enable instructors to select appropriate activities for their group. Using Newell's constraints model (Newell, 1986), each FMS theme included a list of practice variations based on environmental, task and individual constraints. For instance, hitting can be performed in different ways (e.g. underhand, overhand), alone or in 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). Moreover, each FMS theme contained 15-39 activity sheets, which included the description of the activity, required material, points of interest, variations in task and environment, and examples of differentiation for each activity based on the aforementioned factors. The emphasis of the program was on providing sufficient and various movement opportunities for each skill to promote children's FMS. Each session focused on 2-3 FMS themes for which appropriate activities were selected. The lesson content and structure depended on several aspects: children's developmental stage (based on age and performance), organizational elements (i.e., play themes, material, space and group size) and movement concepts (i.e., body awareness, space awareness, speed and rhythm). As such, the teaching manual provided information on the general development of children aged 3-8 years and guidelines with regard to organizational, didactical and pedagogical aspects when implementing and instructing the program.

The Multimove intervention was designed to be offered on a large scale in a sustainable manner through instructor-led programs in community settings. For this purpose, a public invitation was sent to Flemish organizations involved in sports or physical activity such as sports clubs and local councils. Thirty-seven organizations with a total of 50 sites were purposively selected for the project based on the type of settings (sports club, local council, school and day care center) and the geographical distribution (five provinces). Prior to the start of the program, instructors from these settings received a one-day training workshop that addressed the teaching manual consisting of activities and didactical guidelines for appropriate delivery of the Multimove program. During the workshop, instructors received a morning lecture on FMS development during early childhood and information on teaching strategies and pedagogical principles. This lecture also contained group assignments that linked theory to practice, e.g., identifying developmental stages of motor skills for children of a certain age, selecting appropriate activities based on the age and developmental stages of children. In the afternoon, microteaching was implemented where groups of three instructors prepared and gave a 30 min session to young children while other instructors observed the motor skill session. These practice sessions were followed by classroom discussion and feedback.

During the program, instructors received a bimonthly newsletter with didactical tips and good practices. Instructors reported the skill themes for each session every six weeks which were checked by a supervisor for intervention fidelity. In addition, instructor observations were conducted each semester followed by feedback from a member of the project team.

For more information on the Multimove program, visit the website (www.multimove.be) or contact the author (farid.bardid@ugent.be).

Chapter 7

General discussion

The main goal of this thesis was to develop a better understanding of motor competence and motor development in early childhood. In this respect, the studies reported in Chapters 2 to 6 provide information on the psychometric properties of motor competence assessments, the cultural context of motor competence and the effectiveness of a community-based motor skill program in young children. In this chapter, we summarize the conclusions of previous chapters and describe the practical implications. Following, we discuss the limitations of the research presented in the thesis and provide suggestions for future research.

7.1 Conclusions

The development of motor competence in early childhood plays an important role in children's general development and can be considered an important cornerstone in developing an active and healthy lifestyle (Barnett et al., 2008; Barnett et al., 2009; Smits-Engelsman et al., 1998). As such, early monitoring of motor competence is crucial to help advance our understanding of children's motor competence and its role in physical activity and health, and to inform programs or practices targeting motor skills.

7.1.1 Measuring motor competence

A number of assessment tools for young children have been established and used in research, educational and clinical settings (see Cools, De Martelaer, Samaey, & Andries, 2009, for a review on this matter). These assessments generally rely on the general motor ability (GMA) hypothesis as they measure motor competence as a one-dimensional construct through the use of composite scores. However, prior research has not provided a clear view of the motor competence construct, partly due to methodological limitations of the generally adopted classical test theory approach. In Chapter 3, we tested the GMA hypothesis adopting the item response theory approach, and we examined the motor competence construct in early childhood using the Motor Proficiency Test for 4- to 6-year-old Children (MOT 4-6; Zimmer & Volkamer, 1987). The MOT 4-6 is specifically designed to assess motor competence during preschool years and contains a large item set that covers a wide range of motor skills. In accordance with Hands and Larkin (2001), this study revealed a one-dimensional structure in the motor competence construct for children aged three to six. These findings provide evidence for the GMA hypothesis in early childhood and support the general use of composite scores in motor assessments.

Validity research is also important to compare assessment tools. Motor tests claim to measure the same construct (i.e. motor competence) although the scores of different tests do not always agree. In Chapter 2, we investigated the convergent and divergent validity between the Body Coordination Test (KTK; Kiphard & Schilling, 1974, 2007) and MOT 4-6, two standardized tests that are widely adopted in Western European countries (Cools, De Martelaer, Samaey, et al., 2009). The study provided evidence of convergent validity through moderate positive correlations between the KTK and MOT 4-6, which is in line with prior research investigating the relationship between these assessment tools and others (Cools, De Martelaer, Samaey, & Andries, 2011; Fransen et al., 2014; Smits-Engelsman et al., 1998). It also demonstrated divergent validity through a higher correlation between the KTK and MOT 4-6 gross motor component than between the KTK and MOT 4-6 fine motor component which is also consistent with previous validity studies (e.g. Cools et al., 2010; Fransen et al., 2014). These findings do indicate that each test seems to assess a different aspect of a similar construct. As such, the interpretation of test scores needs to be considered in the context of the item content of that test (Fransen et al., 2014; Smits-Engelsman et al., 1998; Van Waelvelde et al., 2007). Additionally, in light of the moderate to low levels of agreement between the KTK and MOT 4-6, both researchers and practitioners need to be aware of possible categorization errors when classifying children on the basis of either test score. Nonetheless, both the KTK and MOT 4-6 have favorable features for use in practice. Both tests require limited assessment training and can be easily administered in a time-proficient manner. In addition, while most assessment tools focus on identifying children with motor difficulties, both the KTK and MOT 4-6 are suited to assess performance across the motor competence spectrum. Therefore, the KTK and MOT 4-6 can be of value in research and practice when measuring the motor competence of young children. It is recommended, however, to adopt more than one motor assessment, specifically in contexts such as detection of motor delay and talent identification (Fransen et al., 2014). Moreover, it is suggested to use both product-oriented measures (e.g., KTK and MOT 4-6) and process-oriented measures (e.g., Test of Gross Motor Development, Second Edition [TGMD-2]; Ulrich, 2000) to provide a comprehensive view of motor competence in early childhood.

7.1.2 Understanding motor competence

Research on convergent validity (see Chapter 2) indicates that assessment tools should not be used interchangeably. In contrast, the widespread implementation of a highly standardized test can provide the opportunity to compare performances within and between countries and to better understand motor competence and its cultural context. In Chapter 4, we examined differences between young Australian and Belgian children using the KTK. The KTK is a highly standardized, non-sport specific assessment tool that has been used for various subgroups, e.g. children with obesity, patients with heart disease and elite athletes (D'Hondt et al., 2011; Stieh et al., 1999; Vandendriessche et al., 2012; Vandorpe et al., 2011). The test covers a wide age range of 5 to 14 years and uses the same items for all ages, which makes it appropriate for longitudinal research and follow-up. The study showed that Belgian children performed higher on the KTK than Australian children. These results might be attributed to cultural differences in physical activity contexts such as physical education (PE). Contrary to Australia, nearly all children in Belgium attend preschool (OECD, 2013), which offers opportunities to practice and develop motor skills. Additionally, while PE is provided by specialist teachers in the majority of Belgian primary schools, Australian primary schools generally deploy classroom teachers to teach PE (Hardy, King, Espinel, et al., 2010). As such, differences in preschool experiences and common practices in PE may explain the cross-cultural differences in motor competence. Interestingly, although Belgian children scored higher on most items of the KTK, they did not score higher on walking backwards along balance beams, which is less related to physical fitness than the remaining KTK items. These findings may therefore indicate that physical fitness plays a potential role in the differences between Belgian and Australian children, but it also suggests that we should consider the role of physical fitness as a confounding factor when we measure motor competence. Both Belgian and Australian groups scored lower than the German reference sample from 1974. This may be attributed to the international decline of physical activity over time (Dollman et al., 2005) and the increased prevalence of overweight and obesity (de Onis, Blössner, & Borghi, 2010; Olds & Maher, 2010).

As mentioned in previous chapters, the choice of a test instrument depends on multiple factors including the purpose of assessment, the psychometric properties and the administrative aspects of the test. Another important factor to consider, is the approach of the assessment. While product-oriented tests assess the outcome of motor skills, process-oriented tests evaluate the movement patterns of motor skills. Product-oriented assessments, such as the KTK and MOT 4-6, are generally used in Europe. However, there is limited data on motor competence from a process-oriented perspective which can give valuable insights into the development of FMS in young children. In Chapter 5, we investigated the motor competence of Belgian children aged three to eight years using the TGMD-2. The TGMD-2 is a process-oriented test with good psychometric qualities and is frequently used in the United States and Australia. This study demonstrated a significant increase in FMS competence with age: from three to six years for locomotor skills and from three to seven years for object control skills in boys and up to eight years in girls. The content in PE might be a possible explanation for this discrepancy. While locomotor skills are developed and stimulated through preschool activities, these skills might stabilize when children enter elementary school where the focus of motor instructions shift towards object control related activities. The findings also revealed that boys scored higher on object control skills than girls; these sex differences are in line with previous literature and support the use of separate norms for boys and girls. It should be noted that, due to the cross-sectional design of the present study, longitudinal investigations are needed to better understand the development of motor skills across (early) childhood and the role of sex and physical activity engagement therein. Due to cultural differences, we also compared the performance of Belgian children with the US reference group. Our investigation into the suitability of TGMD-2 norms in a European context revealed differences between the Belgian group and the US reference sample from 2000. Belgian children aged three to five years had similar scores on locomotor skills than the US children – except for five-year old Belgian girls who performed better than their US peers – but scored lower on object control skills. The findings on object control differences may be related to a cultural bias in the TGMD-2; Belgian children are less acquainted with some object control skills, including two-handed striking and overarm throw, that are more prominent in US sports culture (e.g. baseball and softball; Simons & Van Hombeeck, 2003). Interestingly, Belgian children aged six to eight years scored lower on both locomotor and object control skills than the US reference group, which – similar to the findings in Chapter 4 – may be related to the international decline in motor competence and physical activity levels. This study supports the use of the TGMD-2 as a process-oriented test to assess motor competence in early childhood within a European context but indicates that caution is warranted when using US reference norms. This highlights the need to further validate well-known assessment tools in various countries.

7.1.3 Promoting motor competence

Developing FMS during early childhood is imperative in order to be successful in games, sports and other types of physical activity that require more specialized skills (Gallahue et al., 2012). Many intervention programs have generally focused on young children with motor delay or children who are at risk of delay as early remediation can prevent children from entering a negative spiral of disengagement in physical activity (Robinson et al., 2015; Stodden et al., 2008). However, the observed decline of motor competence levels among children in Western countries (e.g. Bös, 2003; Cools, De Martelaer, Vandaele, et al., 2009; Hardy et al., 2013; Kambas et al., 2012; Tester et al., 2014; see also Chapter 5), indicates that FMS interventions may benefit typically developing children as well as children who are at risk. The downward trend of motor competence has prompted researchers and policy makers to promote FMS development through the implementation of sustainable interventions. Contrary to small-scale motor skill programs led by motor development experts, there is little knowledge on the efficacy of policy-based initiatives involving community-based programs led by local instructors (Logan et al., 2012). In Chapter 6, we evaluated the effectiveness of the Multimove for Kids program, a government-supported, community-based motor skill program for young children aged three to eight years. The study showed that the Multimove program had a significant effect on the FMS of children in the intervention group. These findings are consistent with previous literature (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015; Morgan et al., 2013) and support the use of well-designed programs instructed by local instructors in existing settings. These types of programs reach large groups of children and have ecological validity as opposed to small-scale programs provided by movement experts. This study also revealed sex differences with boys making more gain than girls on object control skills but not on locomotor skills. These results may be attributed to gender roles in sports and games where boys engage more in object control related activities and girls in locomotor related activities. In addition, Garcia (1994) demonstrated that boys and girls show distinct behavioral patterns in their interaction with others when learning FMS; on average, boys are more competitive and individualistic while girls are more caring and cooperative. This suggests that a gender conscious approach may be needed to support optimal FMS development of both boys and girls. These findings highlight the value of sustainable, community-based FMS programs and indicate that policy makers should continue to invest in training and support for local instructors.

7.2 Limitations

In the previous chapters, we discussed the limitations of the studies presented in this thesis. We will briefly describe the most important limitations in the context of measuring, understanding and promoting motor competence.

- A limitation of the construct validity study (Chapter 3) is the small amount of object control skills included in the item set of the MOT 4-6. In addition, the MOT 4-6 is a product-oriented assessment which focuses on the outcome of performance (e.g. target hit during throw). However, qualitative components (e.g. contralateral step during throw) are also related to motor competence. Therefore, generalization of the study findings should be made with caution.
- It should be acknowledged that only the KTK was used for the cross-cultural comparison of motor competence (Chapter 4). The KTK focuses on the gross motor coordination but does not measure FMS, specifically object control skills.
- Physical activity and physical fitness have not been assessed in the research presented in this thesis (Chapters 2-5). These factors could (partially) explain the cross-cultural differences in motor competence (Chapters 4-5) and play a role in the effects of the intervention program (Chapter 6). In addition, the socio-economic status was not included which could also affect the motor competence development of children.

- An important limitation of the intervention study is the lack of fidelity measures in the intervention study (Chapter 6). Due to the large scale of the intervention, it was not possible to investigate how the curriculum was implemented by the different instructors (e.g., lesson content and practice time). Furthermore, there is a potential selection bias in our sample due to a purposeful cluster sampling procedure and the lack of randomization. As such, generalization of the study findings should be made with caution.

7.3 Future directions

The aim of the thesis was to gain more insights into early childhood motor development. We can conclude that the research presented in this thesis has contributed new knowledge to measuring, understanding and promoting motor competence in young children. However, there are still many interesting challenges and opportunities lying ahead that can help move forward our understanding of children's development and inform policy and practices pertaining to sports and physical activity.

7.3.1 Measurement practices

Our research showed evidence of motor competence as a single construct underlying assessment, supporting the GMA hypothesis and the use of composite scores in early childhood. However, the findings and limitations of our research have also brought forth new research questions that should be addressed in future work. For instance, little is known on the development of the motor competence construct over time. Does the GMA hypothesis still hold true as children grow older? A study by Schulz et al. (2011) on the construct of motor competence in three age cohorts (3-6 years, 7-10 years and 11-16 years), suggests that there is a change in the motor competence structure across age where the latent trait might differentiate into distinct abilities such as object control and balance due to biological maturation and environmental experiences. As current research mainly provides cross-sectional data on the construct of motor competence, longitudinal studies are needed to evaluate if and how the motor competence structurally changes over time. In view of the role of physical fitness in motor assessment, it is also advised to examine the link between physical fitness and motor competence and changes that may occur across age.

Due to the use of different test batteries in research and practice, continued efforts should be made to evaluate the reliability of and the validity within and between these assessments in different populations. An important topic that has not been adequately addressed in the literature is the convergent and divergent validity between assessment tools across age groups. For instance, the study of Fransen et al. (2014) showed similar correlations (*r* values = .60-.64) between the KTK and Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) for age groups 6-7, 8-9 and 10-11 years. However, Logan, Barnett, Goodway and Stodden (2016) found different levels of correlation between locomotor skills of the TGMD-2 and Get Skilled: Get Active (GSGA; New South Wales Department of Education and Training, 2000) for age groups 4-5, 7-8 and 10-11 years (*r* values = .17-.70). The authors noted that these findings may be related to a potential ceiling effect on the TGMD-2 locomotor skills (also discussed in Chapter 5). Due to differences in sensitivity between tests and across age groups, it is recommended to investigate how motor assessments correlate over time. Furthermore, it would be advised to examine the predictive validity of motor tests for health-related factors such as physical activity and BMI. This information can be of added value for researchers and practitioners when choosing an assessment.

In 2015, the first International Consortium of Motor Development Research was held in France with experts across the globe. During this assembly, important topics have been discussed related to the field of motor development: e.g. theoretical frameworks, research methods, intervention work, cross-disciplinary research, future directions. Such a consortium can provide a venue to discuss how we should assess motor competence and set measurement standards to facilitate comparisons of findings across studies and populations and to enable global surveillance. A first step, as noted by Robinson et al. (2015), is to reach a consensus among researchers to adopt widely used standardized assessments. A second step is to develop an online platform that provides procedures and training for the administration of these selected assessments. This will assist in streamlining the measurement methodology in motor development research and practice. In addition, the platform can be used to coordinate data collection across countries.

7.3.2 Motor competence and health

Literature reviews (e.g. Lubans et al., 2010; Robinson et al., 2015) have shown evidence for the relationships of motor competence with physical activity, perceived competence, physical fitness and weight status, as proposed by Stodden et al. (2008) in their conceptual model (see Figure 4). However, some hypotheses in the model still need to be (further) explored, such as the mediating role of physical fitness and perceived competence in the relationship between motor competence and physical activity. Additionally, future longitudinal research should evaluate the dynamic interactions between these health-related factors over time in order to test Stodden et al. (2008)'s proposed spiral of (dis)engagement in physical activity. In relation to this, it would also be valuable to test the proficiency barrier hypothesis (Seefeldt, 1980), which states that a certain level of competence is needed to allow children to apply their FMS to sports, games and other types of physical activity, and develop context-specific skills. This can help us have a better understanding of children's trajectories of physical activity.

Further investigations are also needed into the cultural context of motor competence to better understand motor competence on a global scale. Our research on cross-cultural comparison of motor competence, did not include measures of physical fitness, physical activity and perceived competence. Studies investigating these factors across countries, can help identify relevant cultural factors that influence motor competence, which in turn will inform the design of new motor skill programs or the tailoring of existing interventions. Moreover, in view of Bronfenbrenner's bioecological theory (Bronfenbrenner, 2005), it is important to investigate the role of environmental contexts (family, peers, neighborhood, school) in children's motor competence and physical activity engagement. As mentioned earlier, reaching a consensus on how we operationalize and measure motor competence, physical activity and other health-related factors, is essential to advance our field of research and to further develop effective strategies for physical activity and health promotion.

7.3.3 Movement programs and sports policy

Collaborations with existing organizations are key to sustainable programs and health promotion. Our research demonstrates that a motor skill intervention can be successfully implemented on a large scale by local instructors in various community settings such as sports clubs, schools and day care centers. However, a limitation of the study is the lack of fidelity measures (e.g., lesson content and activity time). Future community-based intervention studies need to evaluate the extent to which fidelity of implementation affects motor competence development. It is also important to evaluate how instructor training and online/offline support (e.g., feedback, instructional materials) impact the fidelity of implementation and the outcomes. Such investigations can help identify effective practices and formulate guidelines on the required training and support for instructors in community-based programs.

To further develop and tailor motor skill programs, more research is required on intervention characteristics including instructional approach and program duration. FMS programs are generally delivered using the teacher-centered approach and focus on improving actual motor competence. Nonetheless, literature has shown that perceived competence is also an important outcome to consider as it is associated with motor competence and physical activity engagement. Both teacher-centered and child-centered approaches have been shown to be effective in motor skill programs (e.g., Goodway & Branta, 2003; Goodway, Crowe, & Ward, 2003; Robinson & Goodway, 2009; Valentini & Rudisill, 2004). However, while it has been shown that a teacher-centered climate can have a positive effect on children's perceived competence (e.g. Goodway & Rudisill, 1996), other studies on instructional approaches found that only a child-centered climate positively influences perceived competence (Robinson, Rudisill, & Goodway, 2009; Valentini & Rudisill, 2004). It should be noted that different aspects such as instructional time, practice time and number of practice trials, still need to be explored in order to determine the most appropriate instructional climate in a given context. In addition, as the motor skill programs in the aforementioned studies were provided to children with motor difficulties and delivered by motor development experts, future intervention research should examine how these types of instructional approach can be successfully implemented in community-based programs and how they impact the actual and perceived motor competence of typically developing children.

Previous literature has shown that the duration of effective intervention programs varied, ranging from 6 to 30 weeks (Logan et al., 2012; Riethmuller et al., 2009; see also Chapter 6). However, the dose-response relationship for motor skill programs including the Multimove intervention is unknown. Similar to examining the role of training and support for instructors, it is important to determine the optimal program duration in order to provide guidelines for an efficient design and effective implementation of motor skill programs in various community settings.

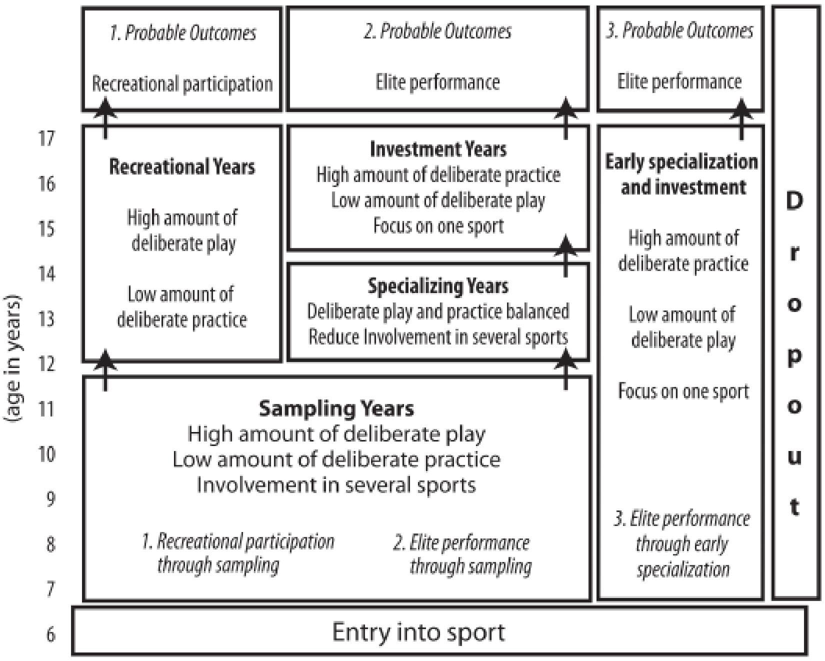

Figure 15. The Developmental Model of Sport Participation (DMSP; reprinted from Côté et al., 2007)

Developing competence in FMS in early childhood is key to successful and continued participation in sports and other types of physical activity as these basic skills form the foundation for sport-specific skills (Clark &

Metcalfe, 2002; Gallahue et al., 2012; Seefeldt, 1980). The importance of FMS development and the decreasing levels of motor competence and physical activity has prompted policy makers to invest in interventions such as the Multimove program. This program has had a large impact in practice due to the support of the Flemish government and partner organizations, and the collaborative approach with local organizations. It has introduced early diversification or sampling as a pathway in youth sport participation rather than early specialization. A framework that discusses these developmental pathways in youth sport participation is the Developmental Model of Sport Participation (DMSP; Côté & Fraser-Thomas, 2007; Côté & Hay, 2002; Côté, Horton, MacDonald, & Wilkes, 2007; see Figure 15). The pathway of early sampling during the elementary school years can be translated as adopting FMS in different sports before specializing in one sport.

Early sampling as described in the DMSP may be preferred as a pathway in youth sports participation as it provides a trajectory for both recreational participation and elite performance. Rather than promptly switching from a FMS program to sport specialization, it is advised to provide an intermediary program that includes sampling of different sports. Within the context of an integrated Flemish sports policy, we therefore recommend the adoption of a multisport program during elementary school years which can be seen as an extension of the Multimove program. This may serve as a gradual transition into sport specialization and/or contribute to the development of an active and healthy lifestyle.

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