UNIVERSITY OF TURKU

# ASSOCIATIONS BETWEEN MOTOR SKILLS, PHYSICAL ACTIVITY, AND SEDENTARY BEHAVIOR

## Early childhood in focus

Tanja Matarma

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SARJA - SER. D OSA - TOM. 1471 | MEDICA - ODONTOLOGICA | TURKU 2020

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ISBN 978-951-29-7986-8 (PRINT)
ISBN 978-951-29-7987-5 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)
Painosalama Oy, Turku, Finland 2020

UNIVERSITY OF TURKU
Faculty of Medicine
Department of Clinical Medicine
Paediatrics
TANJA MATARMA: Associations between motor skills, physical activity, and sedentary behavior – Early childhood in focus
Doctoral Dissertation, 175 pp.
Doctoral Programme in Clinical Research
March 2020

ABSTRACT

Physical inactivity is both a national and worldwide challenge as it increases risks for several health problems such as obesity, whereas physical activity decreases risks. Physical activity is often related to motor skills in children and adolescents. However, the strength of the association varies in different age groups and by the type of motor skill. Inconclusive results exist on differences in motor skills between girls and boys at preschool age. It is unclear which factors should be targeted in motor skills improvement and physical activity increase.

The main object of this study was to provide in-depth knowledge of the association between motor skills, physical activity, and sedentary behavior in 5–6-year-old children in the framework of Newell's constraints model of motor development. The individual and family-related associations with motor skills and physical activity in early childhood were studied. The data from the STEPS Study (Steps to the healthy development of children) with 1797 parents and their children were used.

No significant associations were found between motor skills and physical activity or sedentary time in preschool aged children. Body weight and body fat percentage among girls were associated with some motor skills. Healthy weight children had significantly better scores in nearly all motor skills than their overweight or obese peers. Parents' physical activity and sedentary behavior were associated with those of their children in early childhood. Attendance in day care and higher education level of parents were positively associated with physical activity and some motor skills. This study showed that the associations between physical activity and motor skills may be invisible in early childhood. Unhealthy body weight may serve as a constraint in motor skill development. A parental role model is of importance in early childhood in developing a physically active lifestyle and may prevent overweight or obesity.

KEYWORDS: physical activity, motor skills, children, preschool, family, motor development, constraints model

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
Kliininen laitos
Lastentautioppi
TANJA MATARMA: Associations between motor skills, physical activity, and sedentary behavior – Early childhood in focus
Väitöskirja, 175 s.
Turun kliininen tohtoriohjelma
Maaliskuu 2020

## TIIVISTELMÄ

Vähäinen fyysinen aktiivisuus on sekä kansallinen että maailmanlaajuinen haaste, sillä se lisää terveysriskejä kuten lihavuutta. Riittävä fyysinen aktiivisuus puolestaan vähentää riskejä. Fyysinen aktiivisuus yhdistetään usein motorisiin taitoihin lapsilla. Yhteyden vahvuus vaihtelee riippuen tutkittavien iästä ja motoristen taitojen osa-alueesta. Esikouluikäisten poikien ja tyttöjen välisissä motoristen taitojen eroissa on epäselvyyttä. Ei ole varmaa, mihin tekijöihin tulisi keskittyä motoristen taitojen kehittämisessä ja fyysisen aktiivisuuden lisäämisessä.

Tämän tutkimuksen päätavoitteena oli tuottaa tarkempaa tietoa motoristen taitojen ja fyysisen aktiivisuuden yhteydestä 5–6-vuotiailla lapsilla Newellin rajoiteteorian viitekehyksessä. Tutkittavana oli motorisiin taitoihin ja fyysiseen aktiivisuuteen vaikuttavia yksilöllisiä ja perheeseen liittyviä tekijöitä varhaislapsuudessa. Tutkimusaineisto koostui Hyvän Kasvun Avaimet-tutkimuksen 1797 vanhemmista ja heidän lapsistaan.

Motoristen taitojen ja fyysisen aktiivisuuden tai paikallaanolon ajan välillä ei ollut tilastollisesti merkitsevää yhteyttä alle kouluikäisillä lapsilla. Kehon paino ja rasvaprosentti tytöillä olivat yhteydessä joihinkin motoristen taitojen osa-alueisiin. Terveen painon omaavilla lapsilla oli ylipainoisia tai lihavia lapsia tilastollisesti merkitsevästi paremmat tulokset lähes kaikilla motoristen taitojen osa-alueilla. Vanhempien fyysinen aktiivisuus ja paikallaanolo olivat yhteydessä lapsen vastaaviin varhaislapsuudessa. Kodin ulkopuoliseen päivähoitoon osallistuminen ja vanhempien korkea koulutus olivat yhteydessä fyysiseen aktiivisuuteen ja joihinkin motoristen taitojen osa-alueisiin. Tämä tutkimus osoitti, ettei fyysisen aktiivisuuden ja motoristen taitojen yhteys välttämättä näy vielä alakouluiässä. Ylipaino saattaa olla rajoittava tekijä motoristen taitojen kehitykselle. Vanhempien roolimallina toimimisella on suuri merkitys lasten fyysisesti aktiivisen elämäntavan kehittymiselle, joka saattaa myös ehkäistä ylipainoa ja lihavuutta.

AVAINSANAT: fyysinen aktiivisuus, motoriset taidot, lapset, esikoulu, perhe, motorinen kehitys, rajoiteteoria

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# Abbreviations

| | |
|---|---|
| ANCOVA | Analysis of covariance |
| B | Balance |
| BF% | Body fat percentage |
| BIA | Body impedance analysis |
| BMI | Body mass index |
| BOTMP | Bruininks-Oseretsky Test of Motor Proficiency |
| BOT-2 | Bruininks-Oseretsky Test, second edition |
| CI | Confidence interval |
| DXA | Dual-energy X-ray absorptiometry |
| ECEC | Early childhood education |
| FMS | Fundamental motor skills |
| KTK | Körperkoordinationtest für Kinder |
| LM | Locomotor |
| LPA | Light physical activity |
| LTPA | Leisure time physical activity |
| M-ABC/MABC-2 | Movement Assessment Battery for Children / second edition |
| MET | Metabolic equivalent |
| MS | Motor skills |
| MPA | Moderate physical activity |
| MSPA | Motor skills and physical activity Study |
| MVPA | Moderate-to-vigorous physical activity |
| OC | Object control |
| OSRAC-P | Observational System for Recording Physical Activity in Children – Preschool version |
| PA | Physical activity |
| PDMS -2 | Peabody Developmental Motor Scales – Second Edition |
| PSPCSA | Pictorial Scale of Perceived Competence and Social Acceptance |
| SB | Sedentary behavior |
| SD | Standard deviation |
| SES | Socioeconomic status |

| | |
|---|---|
| STEPS | Steps to the healthy development and well-being of children Study |
| TGMD-2 | Test of Gross Motor Development, Second Edition |
| TPA | Total physical activity |

# List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Matarma T, Koski P, Löyttyniemi E, Lagström H. The factors associated with toddlers' screen time change in the STEPS Study: A two-year follow-up. *Preventive Medicine*, 2016, Mar 84, 27-33.

II Matarma T, Tammelin T, Kulmala J, Koski P, Hurme S, Lagström H. Factors associated with objectively measured physical activity and sedentary time of 5–6-year-old children in the STEPS Study. *Early Child Development and Care*, 2016, 187(12), 1863-1873.

III Matarma T, Lagström H, Löyttyniemi E, Koski P. Motor Skills of 5-Year-Old Children: Gender Differences and Activity and Family correlates. *Perceptual and Motor Skills*, 2020. DOI: 10.1177/0031512519900732.

IV Matarma T, Lagström H, Tammelin T, Kulmala J, Hurme S, Barnett L, Koski P. Motor skills in association with physical activity, sedentary time, body fat, and day care attendance - the STEPS Study. *Scandinavian Journal of Medicine and Science in Sports*, 2018, 28(12), 2668-2676.

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# 1 Introduction

A physically active lifestyle in early childhood may predict a physically active lifestyle in adulthood as physical activity and sedentary behavior habits have shown to track at least moderately from different phases in childhood to adolescence or adulthood (Herman et al. 2004; Telama et al. 2005; Jones et al. 2013). Among many health benefits (Strong et al. 2005), physical activity is often argued to associate negatively with obesity (Epstein & Goldfield 1999; Goldfield et al. 2012; Hodges et al. 2013) even though in young children the body mass index (BMI, $kg/m^2$) or body fat remain as an inconstant correlate for physical activity (Hinkley et al. 2008; Bingham et al. 2016). The BMI, however, has been concluded to track well from youth to adulthood (Herman et al. 2009). Physical inactivity is a major concern worldwide because it has severe negative effects on public health (Lee 2012; Kohl et al. 2012). Targeting physical activity increase and physical inactivity decrease already in early childhood is of importance (Jones et al. 2013).

Fundamental motor skills (FMS) are often concluded to associate with physical activity (Lubans et al. 2010; Holfelder & Schott 2014), but it is also stated that the nature and strength of the association vary by physical activity intensity and the type of motor skills (Figueroa & An 2017). In addition, the association is argued to strengthen as children age and the associations are weak in early childhood (Stodden et al. 2008). Recent results on Finnish national tests of motor skills have raised concerns about school-aged children's motor skills, and for instance, mobility and ability to squat down raise concerns (Opetus- ja kulttuuriministeriö 2018). Physical activity levels of children are too low compared with recommendations and a minority fulfills them in Finland (LIKES & Opetus- ja kulttuuriministeriö 2016). It is of importance to understand more widely to which correlates practitioners should target when motor skills learning is in question (Barnett et al. 2016a), for instance, better motor skills may promote higher levels of physical activity (Van Capelle et al. 2017). Better fundamental motor skills have been argued to associate with weight status and cardio-respiratory fitness in children and adolescents (Lubans et al. 2010; Lima et al. 2018).

On a practical level, understanding the differences between boys and girls in their physical activity and motor skills is also important. Among children aged 3 to 6 years, the fundamental motor skills may be different between genders (Kokstejn et al. 2017). In some particular skills such as object control skills, the results have been inconsistent (Barnett et al. 2016a). The differences may be partially explained by different interests in some activities by boys and girls supported by teachers and parents (Morley et al. 2015; Gabbard 2018, 263). The parental role model may indeed affect their children's physical activity habits (Xu et al. 2015). The mechanisms behind the parental support are however multiple (Loprinzi et al. 2012). If fundamental motor skills learned in early childhood are insufficient, the child may be at risk of not developing refined skills later (Gallahue et al. 2012) or slip to a "negative spiral of engagement" with increased risk of overweight or obesity (Stodden et al. 2008). Thus, the role of physical activity and the differences between boys and girls in their motor skills is also of importance. The aim of this study is to understand the association between different types of motor skills, physical activity, and sedentary behavior in detail in preschool-aged children. Certain parental, behavioral, and anthropometric variables are included. This study also demonstrates the differences between male and female motor skills in early childhood.

# 2 Review of the Literature

The literature search on the latest studies assessing motor skills and related variables in preschool-aged children was conducted in PubMed, Embase, and Proquest databases in March and April 2019. In PubMed database, using search terms “motor skills” OR “motor competence” OR “motor proficiency” OR “motor development” OR “motor coordination” AND “measure” OR “measurement” OR “method/s” AND “child” OR “children” OR “preschool” OR “pre-school” OR “kindergarten” OR “nursery school” OR “nursery daycare” OR “daycare” found in title/abstract from 1st January 2016 onwards, the search resulted in 476 studies. After reading the titles and thereafter abstracts, the search resulted in 21 relevant studies. Further, reviews on motor skills research were searched by adding *review/meta-analysis/systematic review* and *birth to 18 years* as limitations for the above-described search. Five new relevant reviews that were yet unfamiliar were found in 227 studies that the search had offered. Also, other databases, namely Embase and Proquest, were used with identical search terms but they failed to provide any additional studies.

Studies assessing physical activity and its correlates in preschoolers were first searched in PubMed database with MeSH terms “physical activity” AND “preschool children” AND “correlate” in the title/abstract from 1st January 2010 onwards, which resulted in 36 studies of which five were yet unread and interesting ones. Replacing “correlate” with “association” in the title/abstract from 1st January 2016 onwards resulted in 140 studies. Five of these were yet unfamiliar and of interest. To find recent reviews on physical activity correlates, the term “association” was exchanged with “review” and the publication time limit expanded to 1st January 2010 onwards. The search in reviews gave 147 studies and lead to nine unread and interesting reviews, although none of them were focusing purely on correlates of physical activity but rather specifically on certain issues such as family-based interventions or the built environment related reviews. Also, motor skills correlates were searched in Embase and PubMed using terms “motor performance” AND “association” or “review” AND “preschool child” or “child”. One yet unknown relevant study was found but other relevant ones were already familiar.

Finally, the most recent reviews found were inspected manually to track down other relevant reviews of the themes in question (motor skills and physical activity association or physical activity or motor skills correlates) and this resulted in a few more reviews. A continuous manual search of interesting and relevant studies, as well as literature searches of studies on motor skills, physical activity, sedentary behavior, obesity, and physical activity and motor skill correlates, was used throughout the research process. Terminology and the main points in the development of motor skills were collected from the relevant motor skills development books.

## 2.1 Motor skills terminology, development, and assessment

The term *motor competence* is used in this study as an umbrella term for motor skills, when describing the overall proficiency of children's motor skills. Motor competence means child's ability to perform *fine and gross motor skills* needed in everyday tasks (Henderson & Sugden 1992). The term *fundamental motor skills (FMS)* is used for assessed motor skills. The term *motor skills* is used throughout the study when referring to fundamental motor skills and fine motor skills. Both *manipulative* and *object control* skills are used interchangeably in this study. In addition, both *stability* and *balance skills* are interchangeable terms in this study.
Fundamental motor skills can be divided into initial (2 to 3 years old), emerging (3 to 5 years old), and proficient (5 to 7 years old) stages composed of locomotor skills, manipulative skills, and stability skills (Gallahue et al. 2012, 446). Proficiency in a variety of sports is only possible when fundamental motor skills have been learned because they serve as building blocks for efficient and effective movements (Gallahue et al. 2012, 187; Logan et al. 2018). An aspect of locomotion movements is to "transport the body from one point to another through space"; for example, crawling, running, and jumping are locomotor skills. Locomotion skills are skills that develop more naturally than manipulative skills and less influenced by culture, formal instruction, or feedback. Aspects of manipulative and stability movements are to "impart force to an object or receive force from an object" and "place emphasis on gaining or maintaining balance in either static or dynamic movement situations", respectively. Striking, volleying, and writing are manipulative skills, for instance, and sitting, standing, and balancing on one foot are stability skills. These definitions are classified within functional aspects; thus the purpose of the movement is of interest, rather than the size or extent (muscular aspect), time series (temporal aspects), or environment (the context) of the movement (Gallahue et al. 2012, 16). Muscular aspects of classifying movement can be divided into gross and fine motor skills. Fine motor skills can be seen as part of manipulative skills. (Figure 1)

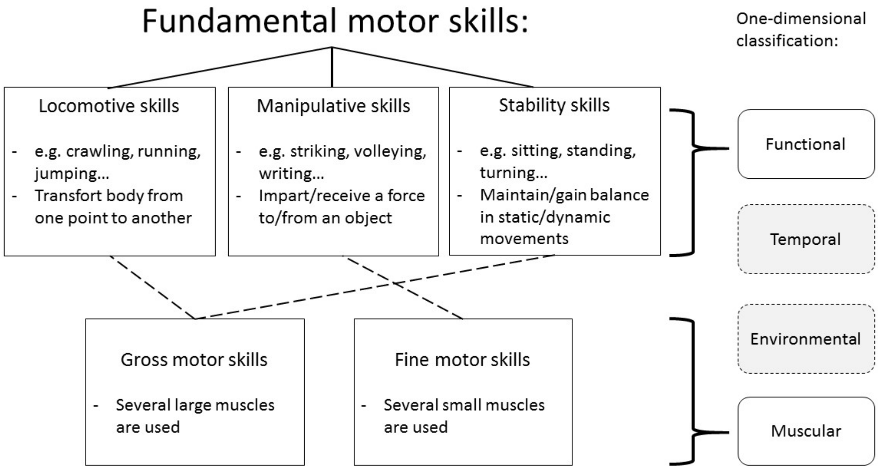


**Figure 1.** Classification of fundamental motor skills by functional and muscular aspects.

The classification to gross motor skills and fine motor skills is another way to classify motor skills; thus, the same skills can be locomotor and gross motor skills at the same time or manipulative and fine motor skills at the same time. The main aspect of this division is the muscular aspect, thus, which types of muscles are used in a motor task. Skill is gross motor if several large muscles are used, such as running, jumping, throwing, and catching. Skill is fine motor skill if several small muscles are used to perform for instance writing, knitting, or cutting (Gallahue et al. 2012, 16, 223). Fine motor skills are also essential in everyday activities such as eating, dressing, and some types of play, and includes also eye-hand coordination (Sigmundsson et al. 2016).

Sometimes motor skills and movements skills are used interchangeably. The definition is similar whether researchers had used *fundamental movement skills* or *fundamental motor skills* as their term even though the term fundamental movement skills is more frequently used in research on motor skills in the 21st century (Logan et al. 2018). *Motor skill* can be defined as “a learned, goal-oriented, voluntary movement task or action of one or more body parts”, whereas *movement skill* refers to the observed movement (Gallahue et al. 2012, 11–15). Both terms are used in research for describing the same thing (Logan et al. 2018).

The use of terms within studies that examine fundamental motor skills, however, is not districted to motor skills or movement skills. Terms such as *motor proficiency* (Morley et al. 2015), *motor competence* (Laukkanen et al. 2015) or *gross motor skills* (Veldman et al. 2018a) are utilized regardless if the skills measured are similar. Also, *motor coordination* is sometimes used in studies (Lopes et al. 2012). *Motor coordination* can be defined as “the ability to coordinate muscle activation in a sequence that preserves posture” (Cech & Martin 2012). *Motor coordination* is a motor fitness component including for instance hopping for accuracy, skipping, and ball dribble (Gallahue et al. 2012, 261). The issues with tests that evaluate motor skills are covered in a later chapter (2.1.3).

### 2.1.1 The development of motor skills

When it comes to motor development, it is good to distinguish development from growth, maturation, and learning. *Growth* can be used to refer to the physical change, whereas development refers to a continuous process (Gallahue et al. 2012, 12). In other words, growth is the change in size and development is the change in functioning (Gabbard 2013, 5). *Maturation* is tied to growth and development but the meaning of the term is different. Maturation refers to biological changes (Gabbard 2013, 7) or to qualitative changes which enable a higher functioning level (Gallahue et al. 2012, 13). Moreover, maturation is unaffected by environment, and is more like an inner process tied to genes. Finally, *learning* is a result of practice and experience, interacting with biological processes, and it is shaped by the state of an individual's development (Gallahue et al. 2012, 12–14; Cattuzzo 2018; Gabbard 2018, 7–8). Motor learning, an aspect of learning, requires movement and requires practice and is affected by past experiences (Gallahue et al. 2012, 14; Gabbard 2018, 7).

Development can be defined as a continuous process, related to age, and involves a sequential change (Haywood & Getchell 2014, 4–5) over time (Cattuzzo 2018). The development of the motor skills of children can be seen from various different perspectives, models or theories. Around the 1930s in the study of development the maturation theory was in a significant role, for example by Gesell, where motor development was understood as the result of heredity (Gabbard 2018, 21) and as an "internal process driven by a biological clock" (Haywood & Getchell 2014, 20). From the 1980s on, the ecological perspective has become increasingly dominant and it takes into account also the environment rather than only the individual maturation (Haywood & Getchell 2014, 24). By encompassing also the environment, the contemporary models of motor development aim to describe and explain behaviors and processes behind them (Haywood & Getchell 2014, 20; Gabbard 2018, 4–6).

A motor development can also be defined by a product based on motor performance and as a process based on the mechanisms of change (Clark & Whitall 1989). The division into product or process orientation may be confusing, but in fact, they are closely linked (Clark & Whitall 1989). When assessing motor competence, both the product and the process of the motor performance should be evaluated (Clark & Whitall 1989). Motor development indeed holds underlying as well as behavioral elements (Clark & Whitall 1989). Cattuzzo (2018) argued that in motor competence, the consistency as well as the constancy are of importance and are closely linked. Thus, the consistency of movements is a prerequisite for the constancy of movements (Cattuzzo 2018). The consistency of movements is to be adopted in childhood (Cattuzzo 2018). To sum up, motor development can be seen as a continuous process, of which the product is the actual performance. Some new insights for motor development theories have also been proposed lately, perhaps even replacing the process-orientation that is currently dominant (Cattuzzo 2018; Sigmundsson et al. 2016).

The levels of development can be classified related to chronological age. After the prenatal period, from birth to 24 months the period is *infancy* which again is divided to the neonatal period (birth to 1 month), early infancy (1 to 12 months), and later infancy (12 to 24 months). *The childhood period* from 2 to 10 years is divided into toddler period (24 to 36 months), early childhood (3 to 5 years), and middle/later childhood (6 to 10 years) (Gallahue et al. 2012, 9–10). Fundamental motor skills are developed in early childhood and more complex sports skills in later childhood (Gabbard 2018, 13). The chronological age categories for periods can vary a little between researchers. Figure 2 adopted and modified from Gabbard's book (2018, 13) shows slightly differently categorized phases throughout the life span than those introduced by Gallahue and colleagues (2012) described above.

| Stage | Prenatal | Infancy | | Early childhood | Later childhood | Adole-scence |
|---|---|---|---|---|---|---|
| Age | Birth | 0–6 months | < 2 years | 2–6 years | 6–12 years | 12–18 years |
| Phase | Reflexive/ spontaneous | Reflexive/ spontaneous/ rudimentary | Rudimentary skills | Fundamental skills | Sports skills | Refinement |

**Figure 2.** The developmental phases and stages adopted and modified from Gabbard (2018).

For the purposes of and according to the study sample of this research, the terms that are used in this study are infants or infancy (from birth to 2 years), toddlers (2 to 3 years), and early childhood (3 to 6 years).

### 2.1.2 Theories of dynamic systems and constraints

As described earlier, the contemporary models aim to describe behaviors and processes of an individual. Theoretical views from maturational to neurological all aim to describe the motor development from different points of view (Gabbard et al. 2018, 29). The biological systems theories include the dynamic systems theory, in which movement patterns are dynamic and self-organizing, affected by the environment stimuli and demands of the task under performance (Gabbard et al. 2018, 27, 29). Self-organization refers to the body of an individual, which is composed from cooperative subsystems, such as perceptual, postural, and muscular, as Gabbard and colleagues (2018, 197) interpret from Thelen (2005) and Thelen and Smith (1998). These subsystems can also be seen as constraints, such as flexibility or body fat (Gabbard et al. 2018, 197).

For describing motor development through childhood, the model of Newell (Newell 1986) was adopted in this study. *Newell's Model* considers that movements arise from the interactions of an individual, the environment, and the task - calling these *constraints* (Newell 1986; Haywood & Getchell 2014, 6–7). This model seems particularly useful in this study when the study subjects are children, who are constantly developing and influenced by family and peers. (Figure 3)

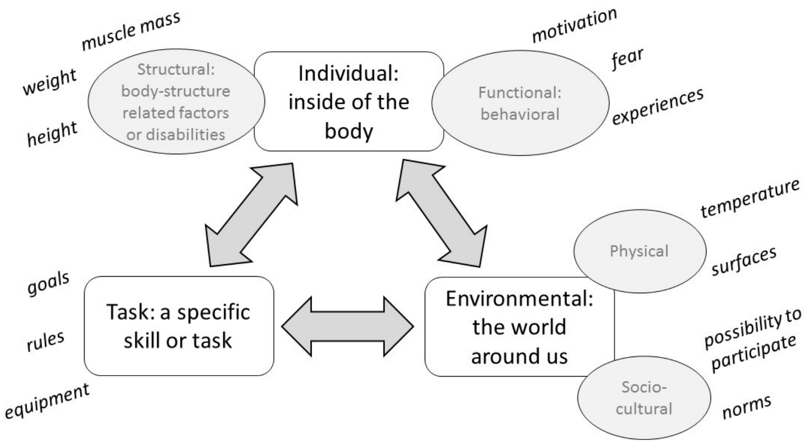


**Figure 3.** Newell's model of constraints adopted and modified from Haywood and Getchell (2014).

The *individual* constraints (Newell 1986; Haywood & Getchell 2014, 6–7) that affect a child's movements can be either structural or functional. Structural constraints such as height, weight, and other factors or disabilities related to body structure can affect the movements as well as the behavioral, thus functional constraints. For instance, motivation, fear, or experiences can shape the ability to move. Functional constraints can be surpassed by shaping the task or the environment which again may help in shaping the individual constraints. Human body includes many systems. Muscular, cardiovascular, and skeletal systems are more concrete and visible constraints, while less visible are the psychological factors such as motivation, fear of height, or past experiences (Gegen & Getchell 2006). *Environmental* constraints (Newell 1986; Haywood & Getchell 2014, 6–7) can also be divided to two: physical and sociocultural. Weather, surfaces, and cultural aspects such as a possibility to participate in sports are examples of environmental constraints. Temperature, variety of surfaces in a classroom from wood to carpet, social climate, or even lighting are examples of constraints from outside of the body (Gegen & Getchell 2006). *Task* constraints (Newell 1986; Haywood & Getchell 2014, 6–7) are indirectly related to, for example, motivation, but they are rather distinct goals of tasks such as making a goal within specific rules (Newell 1986). Task constraints can also be described as independent of the individual and environment, such as rules or equipment (Gegen & Getchell 2006). Overall, all constraints can be modified for each developmental period of a child (Gegen & Getchell 2006; Cattuzzo 2018). In fact, motor development is possible if the task performed is meeting its aim and the performer succeeds in the task frequently despite the challenges with the performance (Cattuzzo 2018). It is essential to be aware of these multiple and multidimensional constraints when practicing with young children or when examining their motor skills. It has been argued that the theory of constraints may be useful in manipulating the constraints to obtain better results in motor competence (Colombo-Dougovito 2016). Colombo-Dougovito (2016) found many studies that justified that manipulating one constraint can produce new behavior and ultimately result in better motor skills. Colombo-Dougovito (2016) also argues that while several studies have identified the usefulness of the dynamic and constraints theories in motor development studies, few have demonstrated their practicality by testing the effect of constraint modification to motor competence. However, some studies have concretely identified the usefulness of constraints-based theories. Vernadakis et al. (2015) found that task modification, in an exergame-based intervention, resulted in better motor skills over the control group. Ulrich and colleagues (1998) modified the surface for walking for 13-month-old children with the Down syndrome and results showed improvement in the walking by modifying the surface, thus, the environmental constraint.

Even though the Newell's model encompasses the entire course of life, only motor development from infancy to early childhood are described shortly with emphasis on preschooler age as it is the age group of main interest in this study.

#### 2.1.2.1 Infancy (from birth to 24 months)

The establishment of stability, locomotion, and manipulative skills starts from birth. The infant learns to turn, control the trunk, sit, and usually also to stand before the age of one year, thus, in the early infancy (Gallahue et al. 2012, 140–141). The infant period, from reflexes to walking, includes several motor milestones which are critical points for achieving the next milestone. For instance, sitting at the average age of seven months, standing with help and walking alone at the average ages of 8 and 15 months, respectively, are motor milestones (Haywood & Getchell 2014, 111–114). After the first year, the infant normally learns to walk. In infancy, the rudimentary movement abilities are developed and are building blocks for extensive fundamental motor skills in early childhood (Gallahue et al. 2012, 140–143). However, constraints that affect reaching these milestones may be for example culturally bound as parents may have different practices of handling their children, or the task itself may sometimes be a goal too difficult to obtain if, for instance, due to lack of sufficient strength, a child has yet a limited ability to hold their head for crawling (Haywood & Getchell 2014, 115). Or, altering the surface for walking may result in better walking skills, as Ulrich et al. (1998) found in their study with Down syndrome children. Thus, the individual, environment, and the task are in interaction with each other, even though the milestones are typically reached at certain ages in typically developing children. The motor development and milestones of infants are described in literature without separation between boys and girls, thus, no significant differences between genders are presumed to exist. However, individual constraints exist, such as sufficient strength to lift head and shoulders as described above. This may be affected by parenting practices such as holding their children for a long time instead of letting them lie on the stomach to make it possible to practice their strength (Haywood & Getchell 2014, 115).

#### 2.1.2.2 Toddler period (24 months to 3 years)

At the beginning of early childhood (24–36 months), children obtain the flight phase in running, some forms of jumping, and overall, the gross motor skills are developing rapidly (Gallahue et al. 2012, 175; Gabbard 2018, 13, 253, 257). Children are unable to perform well in coordination yet and they may be slow in their movements. Children can throw a ball, even though they may be yet unable to hit the target or hold a pen with three fingers (Kauranen 2011, 353). In this age period as well, the task itself, the individual characteristics, and the environment can pose constraints for practicing the skills. In the toddler period, there appear to be non-remarkable differences between boys and girls, but they seem rather similar in their skill level (Gallahue et al. 2012, 169). However, some indications are found that girls are superior to boys in hopping and skipping which may be due to interest in this type of activity (Gabbard 2018, 263). Girls and boys may also be encouraged towards different activities by those caregivers and parents who have more traditional views on girls' and boys' existing strengths (Morley et al. 2015).

#### 2.1.2.3 Early childhood (from 4 to 6 years)

In early childhood, children tend to play unless they are eating or sleeping (Gallahue et al. 172). Children develop rapidly in their fundamental motor skills, especially in gross motor control, and are very active and energetic (Gallhue et al. 2012, 175). Argued by Gallahue and colleagues (2012), one issue possibly affecting the practicing of motor skills through play, is the development of a sense of autonomy. This may become manifest when children are put in a situation of choosing whether to do something or not, thus when asked "do you want to…?", the child most likely naturally answers "no" as it is an expression of autonomy. Children at this age take initiative and like to engage in new experiences, such as climbing, running, and overall testing of their capabilities in practice (Gallahue et al. 2012, 174). In early childhood, children develop especially their gross motor skills through play and physical activity (Gallahue et al. 2012, 175). As early childhood is the period of developing the fundamental motor skills, it must be noted that the more opportunities the child gets for practicing these skills in different situations, the more these skills improve (Gallahue et al. 2012, 52, 187). The more competent children become in their fundamental motor skills as they mature, the more likely they are to do well in physical activities or sports in later childhood (Gallahue et al. 2018, 188). This again strengthens their perceived motor competence and feeling of "being good at sports" and more likely increases their participation in sports and physical activities. This type of circle is referred to as *a positive spiral of engagement* (Stodden et al. 2008; Gallahue et al. 2012, 188) and will be discussed later. At this age, children can run, combine movements better than earlier, jump and throw a ball to a target from three meters' distance (Kauranen 2011, 353). Children indeed develop rapidly in this age period and they start to master certain fundamental motor skills by the age of six (Gallahue et al. 2012, 198). Many constraints may affect practicing motor skills at this age as well. The constraints of environment (such as temperature), the task (such as the size of the equipment), or the individual (such as the ability for timing) can affect practicing the skill (such as hitting a ball with a bat) (Gabbard et al. 2018, 202).

Boys and girls are similar in their body and physics and no remarkable differences are seen (Gallahue et al. 2012, 175). However, motor skills may differ between boys and girls already in early childhood. The previous research shows that boys in early childhood tend to be superior to girls in manipulative skills (Olesen et al. 2014; Bardid et al.2016; Venetsanou & Kambas 2016) and strength and agility

(Venetsanou & Kambas 2016). Girls again tend to perform better than boys in fine motor skills and balance (Olesen et al. 2014; Morley et al. 2015; Venetsanou & Kambas 2016). Boys tend to outperform girls in throwing. This can be seen as an individual constraint within Newell's model and reasons for outperformance can be either or both the experience in throwing and the biological factors such as arm muscle and greater external to internal rotation (Gallahue et al. 2012, 198–199).

### 2.1.3 Assessment of motor competence

There are several methods for assessing the motor competence of preschool-aged children. Some of them are considered as the most qualified (Griffits et al. 2018) among preschool-aged children for assessing the fundamental motor skills. (Table 1)

The measures are typically either process- or product-oriented and thus they provide different information about motor competence (Logan et al. 2016). A product-oriented assessment method, such as Movement Assessment Battery, second edition (MABC-2), or Bruininks-Oseretsky Test, second edition (BOT-2), quantifies the results, e.g., how many jumping jacks one could perform during 15 seconds, or how many centimeters or inches one could jump. Thus, the outcome of the measure is of interest. In a process-oriented assessment method, such as Test of Gross Motor Development, second edition (TGMD-2), the characteristics of the patterns and processes of the movements are evaluated. Thus, the method is qualitative rather than quantitative (Gabbard 2018, 348).

**Table 1.** The most qualified test batteries of Fundamental Motor Skills (FMS) measurement and their division into product or process -orientation with relevant research among preschoolers.

| Test battery | Product/process | Task/composite | LM/OC/B | Gross/Fine motor | Research |
|---|---|---|---|---|---|
| MABC-2 [1] | Product | Aiming and catching (2 items) | LM/OC | Gross motor | Fisher et al. 2005; Piek et al. 2013; Kokstejn et al. 2017 |
| | | Manual dexterity (3 items) | OC | Fine motor | |
| | | Static and dynamic balance (3 items) | B | Gross motor | |
| TGMD-2 [2] | Process | Locomotion (6 items) | LM | Gross motor | Barnett et al. 2013, Foweather et al. 2015; Barnett et al. 2016b; Robinson et al. 2017; Veldman et al. 2017; Wasenius et al. 2018 |
| | | Object Control (6 items) | OC | Gross motor | |
| BOT-2 [3] | Product | Fine manual control (15 items) | OC | Fine motor | Wrotniak et al. 2006; Piek et al. 2013; Matarma et al. 2018; Santos et al. 2018 |
| | | Manual coordination (12 items) | OC/LM | Fine/gross motor | |
| | | Body coordination (16 items) | LM / B | Gross motor | |
| | | Strength and agility (10 items) | LM | Gross motor | |
| PDMS-2 [4] | Product/Process | Reflexes (8 items) | - | - | Wang 2004; Bellows et al. 2013; Veldman et al. 2018a |
| | | Stationary performances (30 items) | B | Gross motor | |
| | | Locomotion (89 items) | LM | Gross motor | |
| | | Object manipulation (24 items) | OC | Gross motor | |
| | | Grasping (26 items) | OC | Fine motor | |
| | | Visual-motor integration (72 items) | - | - | |

1 Henderson et al. 2007; 2 Ulrich 2000; 3 Bruininks & Bruininks 2005; 4 Folio & Fewell R 2000; LM = locomotor; OC = object control; B = balance; MABC-2 = Movement Assessment Battery, second edition; TGMD-2 = Test of Gross Motor Development, second edition; BOT-2 = Bruininks-Oseretsky Test, second edition; PDMS-2 = Peabody Developmental Motor Scales - Second Edition

Most tests are developed to detect motor delays which may have led to difficulties in discovering the level of motor skills in typically developing children. Recent research revealed that there are significant differences between certain process-oriented tests and product-oriented tests (Logan et al 2016; Ré et al. 2018). Logan et al. (2016) used the Test of Gross Motor Development-second edition (TGMD-2), Get Skilled Get Active (GSGA), developmental sequences, and product-items in their comparison of process- (TGMD-2, GSGA, and developmental sequences) and product- (long jump, hop, and throw) oriented assessments within groups of 4–5-, 7–8-, and 10–11-year-old children (Logan et al. 2016) of which the results in 4–5-year-old children are described here. Strong correlations were found between both hop and throw and the three process-oriented assessment methods. A moderate correlation was found between standing long jump and the three process-oriented assessments (Logan et al. 2016). Ré et al. (2018) used TGMD-2 (process) and Körperkoordinationstest für Kinder (KTK) (product) in children 5–10 years old. Low-to-moderate correlations as well as significant differences were found between the tests. Namely, TGMD-2 classified almost 40 percent to low motor competence whereas KTK classified 18% to low motor competence. They concluded that the examined tests may assess different aspects of motor competence (Ré et al. 2018). There exists also a third version from TGMD, TGMD-3 (Ulrich 2016), but the previous versions have been used more often in studies and TGMD-2 was used in the comparison of the test batteries by Griffits et al. (2018).

It was recommended to use both process- and product-oriented assessments to get a better understanding of motor skills (Logan et al. 2016; Ré et al. 2018). This could lead to a greater understanding of different aspects of motor skills as these assessment types provide different information about motor skills (Logan et al. 2016). However, when choosing the test, many aspects such as time, costs, expertise, and research purpose need to be considered (Cools et al. 2009; Logan et al. 2016). Some research has argued for the importance of including fine motor skills in the assessment of fundamental motor skills (D’Hondt et al. 2009; Sigmundsson et al. 2016). In addition, Cattuzzo (2018) also argued that both fine and gross motor skills should be assessed, preferably through the entire lifespan if the goal is the operational definition of motor competence.

### 2.1.4 Correlates of motor skils

There are a few consistent correlates of better motor skills in children, namely healthy weight, being male, and higher socioeconomic background. However, the association only exists in certain motor skills, instead of all (Barnett et al. 2016a). Physical activity has been found to correlate positively for motor coordination, but inconsistently with object control or locomotor skills. For biological and demographic correlates, age has been found to associate positively and strongly with object control, locomotor skills, and stability, but inconsistently with motor coordination. Higher BMI, waist circumference, and body fat percentage have all been found to be negatively associated with motor competence. Inconsistency has been found for socioeconomic background. For skill correlates, physical activity was found to be positively correlated with motor coordination and skill composite, but this conclusion consisted of studies that included mainly elementary school-aged children (Barnett et al. 2016a). The physical activity and motor skills associations are presented later.

In the early years, the adipose tissue increases until the age of 8 years and girls usually have more fat tissue than boys, but individual fatness varies widely during the early years (Haywood & Getchell 2014, 86). The measures for body composition, which is a description of the independent tissue components of lean body mass and body fat or lean tissue and adipose tissue (Haywood & Getchell 2014, 346; Gabbard 2018, 83), can be measured by underwater weighing, skinfolds, bioelectrical impedance, dual-energy X-ray absorptiometry, and BMI (Gabbard 2018, 84).

BMI has been found to be inversely associated with motor skills (Okely et al. 2004; Lopes et al. 2012; Barnett et al. 2016). Also, obesity (Gentier et al. 2013) and body fat (Morrison et al. 2012) have been found to associate with poorer motor skills or only with some types of motor skills such as jumping sideways (Kakebeeke et al. 2017). Different measures such as BMI and waist circumference (Okely et al. 2004; Lopes et al. 2012; Gentier et al. 2013, Kakebeeke et al. 2017) or skinfolds (Morrison et al. 2012; Kakebeeke et al. 2017) are, however, used in the earlier studies. The association between motor skills and body weight or body composition may exist already in early childhood. The risk of obesity may be associated with motor skills via physical activity and motor skills association as proposed in Stodden’s et al. (2008) model. Some research has found that especially in overweight or obese children, instead of only the gross motor skills also the fine motor skills levels are lower than in their healthy weight peers (Gentier et al. 2013; D’Hondt et al. 2009).There is evidence about the negative association between higher BMI and lower motor skills levels through childhood (Cheng et al. 2016). Lower physical activity levels are argued to implicate higher body fat percentages and vice versa (Gallahue et al. 2012, 255).

## 2.2 Children’s physical activity

### 2.2.1 Physical activity recommendations

The global recommendation of physical activity for children and young aged 5 to 17 years includes duration, intensity, and type of physical activity (WHO 2010).

Children should accumulate at least 60 minutes of moderate-to-vigorous physical activity daily, and all exercise in addition to the minimum of 60 minutes provides additional health benefits. Aerobic activities are recommended, including vigorous-intensity activities as well as muscle and bone-strengthening activities, such as turning, jumping, running, and playing games, at least three times a week (WHO 2010). For children under 5 years of age, WHO have recently launched new guidelines (WHO 2019). These guidelines focus on the combination of physical activity, sleep, and sitting time. The key is the pattern of 24-hour-activity aiming at replacing the sitting time with physically active play (WHO 2019). In addition, Canada and Australia have followed the 24-hour recommendations by launching similar new guidelines for young children, also including recommendations for older children (Canadian Society for Exercise Physiology 2019; Australian Government Department of Health 2019). For children aged 5−17 years, the recommendation is to sweat at least 60 minutes per day with moderate-to-vigorous intensity, step several hours, sleep uninterrupted for 9−11 hours, and sit no more than two hours per day (Canadian Society for Exercise Physiology 2019). The Australian recommendations are similar (Australian Government Department of Health 2019). The UK has also renewed their recommendations for physical activity for children aged 5−17 years (Department of Health and Social Care 2019). They also raise a concern about excessive sedentary behavior and recommend minimizing the amount of sedentary time. Different activities that develop movement skills as well as muscle and bone strength, should take at least 60 minutes per day throughout the week (Department of Health and Social Care 2019).

In Finland, the recommendations for physical activity in early childhood were also recently renewed. The earlier recommendations included at least two hours of brisk and versatile physical activity daily for children under eight years, along with other recommendations concerning surroundings, equipment, and co-operation (Sosiaali- ja terveysministeriö et al. 2005). In 2016 the recommendations were renewed and three hours of versatile activity in different intensity levels were recommended. The starting point for new recommendations is child-based. Thus, children are stated to “have the right to be and act like a child, and thus play, move, and familiarize themselves with things through the body” (Opetus- ja kulttuuriministeriö 2016).

### 2.2.2 Physical activity levels

Concerns on preschool-aged children’s physical activity levels have been raised in previous studies. In fact, concerns have been published already in 1992 in a review with children aged 3 to 11 years when the assessment methods centered on self-report or heart rate measures. It was concluded that activity levels were too low for enhancing the health status of young children (Cale & Almond 1992). This decade, similar interpretations of physical activity levels of young children have been made. In an accelerometer-derived meta-analysis it was concluded that preschoolers' physical activity levels are too low compared with the recommendations (Bornstein et al. 2011). In a study with 207 children aged 4.5 years, children spent 51 percent of their time as sedentary, 41 percent in light physical activity, and eight percent in moderate-to-vigorous physical activity, measured objectively with accelerometers. The study also showed that physical activity levels decreased as children got older (from preschool to primary and secondary school to adulthood) (Spittaels et al. 2012). In Finnish studies, the levels of moderate-to-vigorous physical activity have been similar. In a family-based intervention study, the control and intervention groups of 5-year-old children at a baseline of a study accumulated 5.73% respective 7.11% of moderate-to-vigorous physical activity per day (Laukkanen et al. 2015). Among Finnish 3-year-olds, children spent 9% of their time in moderate-to-vigorous physical activity measured objectively with accelerometers. Slightly more than half (53%) of the children spent less than one hour in moderate-to-vigorous physical activity and no-one exceeded the recommended level of over 120 minutes moderate-to-vigorous physical activity a day (Soini et al. 2013).

### 2.2.3 Physical activity correlates

Numerous factors may affect the physical activity levels of children, which again may be associated with some types of motor skills in young children (Figueroa & An 2017). The correlates of physical activity can be classified in five categories following the social-ecological framework: demographic/biological, psychological/cognitive/emotional, behavioral, social/cultural, and physical environment (Sallis et al. 2000; Hinkley et al. 2008; De Craemer et al. 2012; Bingham et al. 2016). The results should be interpreted with caution because reviews may also include older than preschool-aged children. In the review by Sallis et al. (2000), the age range for children's physical activity correlates was 3–12 years without providing more detailed ranges. This makes it difficult to interpret which correlates apply especially to preschoolers. In a review by Hinkley et al. (2008), the age range was 2–5 years; thus, the emphasis was on slightly younger children than in the thesis at hand. In studies from Bingham et al. (2016) and De Craemer et al. (2012), children aged 0–6 years and 4–6 years were included in the reviews, respectively. Van Der Horst et al. (2007) included children aged 4–12 years and Craggs et al. (2011) included children aged 4–9 years. Hesketh et al. (2017) reported qualitative results among children aged 0–6 years and Tonge et al. (2016) studied the correlates of children in early childhood education (ECEC) services. The variety of correlates for physical activity of children aged 0–12 years based on several reviews are synthesized in Appendices in Table 19.

Regarding young children, only a few consistent correlates or determinants for physical activity have been found. These correlates or determinants are sex, parental physical activity, and family support (Sallis et al. 2000; Van Der Horst et al. 2007; Hinkley et al. 2008; Craggs et al. 2011). Sex is the only correlate that has been found to be a constant correlate in the following reviews as well (De Craemer et al. 2012; Bingham et al. 2016; Tonge et al. 2016; Hesketh et al. 2017). In De Craemer et al. (2012) and Bingham et al. (2016) reviews the correlates with two dependents, overall physical activity and moderate-to-vigorous physical activity, were reported separately. Sex was a correlate with moderate-to-vigorous physical activity but uncorrelated with total physical activity among 4–6-year-old children (De Craemer et al. 2012).

In children aged 3–12 years (Sallis et al. 2000) and 2–5 years (Hinkley et al. 2008) the most often reported variable was sex and in 80–81% of the comparisons, males were more active than females. This result has remained constant to the present; boys are physically more active than girls (De Craemer et al. 2012; Bingham et al. 2016; Tonge et al. 2016; Hesketh et al. 2017). Body weight, BMI, or adiposity have been found to be inconstant variables for physical activity (Sallis et al. 2000; Hinkley et al. 2008; Bingham et al. 2016). To the authors' surprise, parental overweight was found as a positive correlate for child physical activity (Sallis et al. 2000). Parental education (Van der Horst et al. 2007; Olesen et al. 2013; Bingham et al. 2016) and parental working status (Bingham et al. 2016) are reported as inconsistent correlates with physical activity. Socioeconomic status was non-correlated (Sallis et al. 2000; De Craemer et al. 2012) with physical activity or the correlation was inconclusive (Craggs et al. 2011).

Reported psychological, cognitive, or emotional correlates of children's physical activity include perceived barriers (negative), intention to be physically active (positive), and preference for physical activity (positive). Perceived competence was an indeterminate correlate (Sallis et al. 2000; Craggs et al. 2011) whereas body image, self-esteem, and perceived benefits were non-correlates (Sallis et al. 2000). Self-efficacy has been found to be an indeterminate correlate (Sallis et al. 2000) and a correlate (Van der Horst et al. 2007).

Among behavioral correlates, a healthy diet, previous physical activity, access to facilities, and time spent outdoors have shown positive correlations to physical activity (Sallis et al. 2000). Bingham et al. (2016) reported correlates and determinants for light physical activity, moderate-to-vigorous physical activity, and total physical activity separately. Watching TV was found as an inconsistent correlate for total physical activity (Bingham et al. 2016) and the time spent in sedentary activities was also an inconclusive correlate for physical activity (Sallis et al. 2000; Hinkley et al. 2008). Motor coordination was found as a correlate for physical activity in early childhood education services (Olesen et al. 2013; Robinson et al. 2012) in Tonge et al. (2016) review, but inconsistently associated with total physical activity and moderate-to-vigorous physical activity in Bingham et al. (2016) review.

Among social and cultural correlates, parental physical activity (Sallis et al. 2000; Bingham et al. 2016) was found to be an indeterminate correlate for physical activity. Also, inconclusive association (De Craemer et al. 2012) and positive association among boys (Van der Horst et al. 2007) have been reported between a child's physical activity and parental physical activity. Time spent in sedentary activities was reported to have indeterminate association for physical activity also in an earlier review, but then again parental physical activity and parental interaction were found as a positive and consistent variable for physical activity (Hinkley et al. 2008). In the Bingham et al. (2016) review, parental interaction was, however, reported as an inconsistent correlate for total physical activity. A review by Hesketh and colleagues of qualitative literature identified many barriers and facilitators for physical activity among 0–6-year-old children. For instance, parents' lack of time and resources were perceived as barriers for their child's physical activity (Hesketh et al. 2017). Parental support was found as a positive correlate for children's physical activity in Van Der Horst et al. (2007) review, but the children included in the studies that found the association were elementary school-aged children or older. Hinkley et al. (2008) and De Craemer et al. (2012) both concluded that parental encouragement non-correlated with physical activity.

Environmental correlates include correlates related to the surrounding environment and opportunities. Access to facilities has been reported as a positive correlate for physical activity (Sallis et al. 2000), and season or weather as an indeterminate correlate (Sallis et al. 2000; Hinkley et al. 2008; Bingham et al. 2016). The weather has been reported as a correlate for physical activity with rainy days associated with lower moderate-to-vigorous physical activity levels (Olesen et al. 2013) and both as a facilitator and a barrier for physical activity (Hesketh et al. 2017). Time spent in places for play or outdoors was also later reported as a positive correlate for physical activity (Hinkley et al. 2008). The preschool attended was found a positive correlate with physical activity (Hinkley et al. 2008; Bingham et al. 2016). Later in a qualitative review, it was reported that caregivers considered themselves as facilitators for physical activity (Hesketh et al. 2017). Educator qualification, training, and presence were reported inconclusive correlates in studies that included children aged 5 to 6 years in the review by Tonge and colleagues (2016). Active opportunities (e.g. Sugiyama et al. 2012) and outdoor environments (e.g. Raustorp et al. 2012; Stephens et al. 2014) may also have a positive effect on children's physical activity (Tonge et al. 2016). Equipment was non-correlated with physical activity in De Craemer et al. (2012) review. Neighborhood safety was non-correlated with physical activity in the Sallis et al. (2000) review.

## 2.3 Children's sedentary behavior

Sedentary behavior is defined as low energy expenditure behavior while sitting, reclining, or lying down. Common behaviors as such include watching television, computer use, and reading. Watching television, playing video games, and computer use can be described with a collective term "screen time" (Tremblay et al. 2017). Research shows that sedentary behavior tracks from early childhood to middle childhood (Jones et al. 2013) and television watching already from infancy to early childhood (Certain & Kahn 2002). Environments today are filled with a variety of different digital media sources also other than traditional TV. Smart phones, video-chatting, apps, and interactive medias are examples of more modern technologies available today. These technological innovations affect the lives of infants and young children (AAP Council on Communications and Media 2016a).

### 2.3.1 Sedentary time recommendations and levels

In Finland, it is recommended for preschool-aged children to avoid periods of sitting or being sedentary over one hour at a time, but no actual recommendations have been given for constant sitting time (Opetus- ja kulttuuriministeriö 2016). In 2011, the American Academy of Pediatrics encouraged children under 2 years to watch no TV, web programs, smart phones, or DVD and for children over 2 years the recommendation is a maximum of 1–2 hours of media devices (Brown 2011). Recently, updates for young children's screen media use were published. For children under 18 months no screen media use other than video-chatting is recommended. After that, it is recommended that if digital media is to be introduced for children aged 18–24 months, parents should introduce only high-quality programs or apps for their child and watch them together with the child. Children older than 2 years should watch a maximum of one hour of high-quality programs and still preferably together with their parents (AAP Council on Communications and Media 2016a). With children aged 5 years and older, the emphasis is more on educational aspects and regular communication between the child and parent about media use (AAP Council on Communications and Media 2016b). Both recommendations from American Academy of Pediatrics conclude that families and other caregivers should pay attention to educating their children about the use of media and be aware of, for instance, cyberbullying and problematic internet use. Recently, WHO launched guidelines for physical activity, sedentary behavior, and sleep time for under 5-year old children (WHO 2019). For 3–4-year-old children, sedentary time should be restricted to less than 1 hour at a time and maximum screen time is 1 hour, although less is better (WHO 2019).

Measured with accelerometers it was recently concluded that children have high rates of sedentary time in preschool settings. Depending on the measurement device and the cut point used, the rates of sedentary time varied heavily from 12.38 min/hour to 55.77 min/hour. The measurements were done in preschool settings and thus compared with sedentary time prevalence outside preschool (O'Brien et al. 2018). In a large sample of children (n=2734) with average age of 8 years, children sat for 5.4 hours per day and their screen time was 2.8 hours for boys and 2.4 hours for girls per day (Hardy et al. 2018). Another large study concluded that among children aged 2–5 years, a large proportion are reported by their parents to watch 2 hours or more TV per day, even though decrease between 2001 and 2012 in TV watching was also discovered (Loprinzi & Davis 2016).

### 2.3.2 Correlates of sedentary behavior

The studies on motor skills and sedentary behavior association in young children are few. Study on Hispanic preschoolers showed an existing association between objectively measured sedentary time and both locomotor and manipulative skills measured with PE metrics (Gu et al. 2018). Further, few indications of association between young children's better motor skills and lower sedentary time exist (Williams et al. 2008; Laukkanen et al. 2014) as well as associations between sedentary behavior and weight status (Fuller-Tyszkiewicz et al. 2012).

Among infants and toddlers, the correlates of television watching include the ethnicity of the mother, the educational level of the mother, and being the child of an unmarried mother. In addition, the maternal education level has been found as a predictor for television watching at the age of six, controlled for the age of two (Certain & Kahn 2002). Maternal education along with maternal age and household income have also been found to be indeterminate correlates in children aged three to 5 years. A child's age has been found an inconsistent correlate for sedentary behavior and non-associated with television watching in children aged 3 to 5 years (Hinkley et al. 2010). However, with younger children, the association with age seems stronger when the outcome measure is television watching. Besides age, also other strong correlates of screen time for young children have been reported and they include ethnicity/race, BMI, and mother's TV watching (Duch et al. 2013). Also, family TV watching, parental body mass, parental rules, and media access have been identified as modifiable correlates for children's screen time (Cillero & Jago 2010). Based on a qualitative study, parents believe that friends and siblings influence their children's screen time behavior (Edwards et al. 2015). Siblings have more influence than peers since it is more tangible and direct (Edwards et al. 2015).

## 2.4 Physical activity and motor skills associations at preschool-age

Mainly low to moderate associations between children's physical activity and motor skills have been reported earlier in an effort to conclude the evidence on the matter. Conclusions on physical activity and motor skills association in children at the age of 5 to 6 years is difficult to achieve based on current research; thus, this is a clear gap in the research. The questions remain: is there an association between physical activity and motor skills in 5 to 6 years old children and if there is, what is the strength of the association? Are there some types of motor skills particularly that are associated with physical activity?

In addition, a developmental model for physical activity and motor skills association in early, middle, and later childhood was proposed over 10 years ago (Stodden et al. 2008). Stodden's model argues that motor skills are affected by perceived motor competence and that perceived motor competence affects physical activity in early childhood. In later and in middle childhood the interactions between these factors are bidirectional and thus, more complex (Stodden et al. 2008).

### 2.4.1 Reviews of physical activity and motor skills association

The conclusion in the frequently cited review by Lubans et al. (2010) on the health benefits of fundamental motor skills competency in children and adolescents was: "We found strong evidence for a positive association between fundamental motor skills competency and physical activity in children and adolescents". However, certain concerns emerge if this conclusion is applied as such to all children in all age groups. The review included studies with the age range of 3 to 18 years. Five of the included 21 studies included children aged 5 to 6 years. None of the studies including children aged 5 to 6 years were of high quality; however, they were of medium quality. The methods used for assessing physical activity in these five studies were questionnaires, a half-mile walk/run, and accelerometers – i.e. diverse methods. In addition, the motor skills assessments, as well as the research focuses, were different. The results in these five studies with 5 to 6 year-old children included in the Lubans and his colleagues' review may be weak considering the relationship between physical activity and motor skills. For instance, in the included study by Graf et al. (2004), the Körperkoordinationtest für Kinder (KTK) was used as their test for motor skills. However, that only assesses balance; their focus was on association between BMI, motor abilities, and leisure time habits rather than on physical activity and motor skills association; they found that being overweight/obesity was associated with poorer gross motor abilities (examined with balance tests); and that an active lifestyle (measured with parental questionnaire) correlated with better gross motor skills.

The other study focusing on preschoolers included in Lubans et al. (2010) review lacked the assessment of physical activity and assessed only motor skills and BMI. They found an association between motor skills and BMI (D'Hondt et al. 2009). In the other three studies including preschoolers some associations were found, e.g., a half-mile walk/run was associated with balance and bilateral coordination (Reeves et al. 1999). This review of Lubans et al. (2010) concentrated on health benefits instead of physical activity and motor skills association, which may have led to the lack of more specific conclusions on the relationship between physical activity and motor skills. In addition, the methods used for measuring both physical activity and motor skills, varied heavily. The proposed strong evidence may fail to fit children aged 5 to 6 years. (Table 2)

**Table 2.** Reviews on the relationship of fundamental motor skills and physical activity from 2010 onwards, motor skills assessment method, and the main results of included studies within the age group of 5–6-year-old children in each review.

| Research | Age group | MS assessment | Main results |
|---|---|---|---|
| **Lubans et al. 2010** | 3–18 years | process/product | Strong evidence on FMS and PA association |
| Martinek et al. 1978 | 6–10 years | KTK | FMS and self-concept improved |
| Reeves et al. 1999 | 5–6 years | BOTMP (three subtests) | Half-mile walk/run was associated with balance and bilateral coordination |
| McKenzie et al. 2002 | 3–6 years | e.g. lateral jump | No association |
| Graf et al. 2004 | mean 6.7 years | KTK | FMS and PA were associated |
| D'Hondt et al. 2009 | 5–10 years | M-ABC | FMS was higher in normal vs. obese/overweight peers |
| **Holfelder & Schott 2014** | 3–18 years | process/product | Positive relationship between FMS and organized PA |
| McKenzie et al. 2002 | 3–6 years | Lateral jump etc. | No relationship between movement skills and PA |
| Graf et al. 2004 | mean 6.7 years | KTK | FMS and PA were associated |
| Lopes et al. 2011 | 6–10 years | KTK | MC and PA associations found |
| Kambas et al. 2012 | 5–6 years | BOTMP (SF) | MS were associated with PA measured with pedometers |
| Robinson et al. 2012 | mean 57 months | TGMD-2 & PSPCSA | Locomotor skills were an influential factor to PA |
| Vandorpe et al. 2012 | 6–9 years | KTK | Sport participation and motor coordination levels were associated |

KTK=Körperkoordinationtest für Kinder, BOTMP (SF)=Bruininks-Oseretsky Test of Motor Proficiency (short form), M-ABC=Movement Assessment Battery for Children, TGMD-2=Test of Gross Motor Development, Second Edition, PSPCSA=the Pictorial Scale of Perceived Competence and Social Acceptance, FMS=fundamental motor skills, PA=physical activity, MC=motor coordination, MS=motor skills

| Research | Age group | MS assessment | Main results |
|---|---|---|---|
| **Logan et al. 2015** | 3–18 years | process | Low to moderate relationship between FMS and PA |
| Barnett et al. 2013 | 3–6 years | TGMD-2 | MVPA was associated with object control skill |
| Morgan et al. 2008 | 5–9 years | TGMD-2 | Low to moderate associations between FMS and PA |
| Robinson et al. 2012 | mean 57 months | TGMD-2 & PSPCSA | Moderate relationship between FMS and PA |
| **Figueroa & An 2017** | 3–5 years | process/product | 8/11 studies reported a significant relationship between MS and PA |
| Bellows et al. 2013 | 3–5 years | PDMS-2 | Intervention improved gross MS but failed to improve PA |
| Foweather et al. 2015 | 3–5 years | CHAMPS | Locomotor and object control skills may be important elements in promoting an active lifestyle |
| Jones et al. 2011 | 3–5 years | TGMD-2 | Children in the intervention group significantly improved in their overall movement skills |
| O’Neill et al. 2014 | 3–5 years | OSRAC-P | Children with highest locomotor skills danced more than children on lowest tertile |
| Robinson et al. 2012 | mean 57 months | TGMD-2 & PSPCSA | Locomotor skills were an influential factor to PA |

TGMD-2=Test of Gross Motor Development, Second Edition, PSPCSA=the Pictorial Scale of Perceived Competence and Social Acceptance, PDMS-2=Peabody Developmental Motor Scales - Second Edition, CHAMPS=Children’s Activity and Movement in Preschool Study, OSRAC-P=The Observational System for Recording Physical Activity in Children - Preschool Version, MVPA=moderate-to-vigorous physical activity, FMS=fundamental motor skills, PA=physical activity, MS=motor skill

Holfelder and Schott (2014) identified 23 studies in their review of fundamental motor skills and physical activity in children and adolescents of which six studies included children aged 5 to 6 years. One study measured motor skills with balance, agility, and eye-hand coordination and habitual physical activity by questionnaires; three measured gross motor skills with Körperkoordinationtest für Kinder (KTK) (i.e. dynamic balance skills) and habitual physical activity with questionnaires; one used Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) short form and pedometers; and one used the Test of Gross Motor Development, second edition (TGMD-2) and pedometers. Again, the assessment methods varied and were very different between studies. However, the writers of this review including studies with children and adolescents of age 3 to 18 years confirmed that "high level of fundamental motor skills competency is certainly related to an increase of physical activity and vice versa." (Holfelder & Schott 2014).

Furthermore, in the review by Logan et al. (2015) the age groups in the included studies were 3 to 5 years, with the mean age in each study being approximately 4 years, and 6 to 12 years, and almost none of them focused on 5−6-year-old children. Only Barnett et al. (2013) had included children of the age range 3 to 6 years, and Morgan et al. (2008) had studied children aged 5 to 9 years, but the latter study focused only on obese/overweight children. Based on this review by Logan et al. (2015) the association between object control and moderate-to-vigorous physical activity was reported in the Barnett et al. (2013) study in children aged 3 to 6 years, and a low association between object control and physical activity in 5 to 9 years old obese boys (Morgan et al. 2008). Both Barnett and Morgan with their colleagues used the same methods, i.e. accelerometers for physical activity and TGMD-2 (that assesses the process) for motor skills.

Finally, in a recent review about motor skills competence and physical activity in 3−5-year-old children by Figueroa and An (2017) it was concluded, that the association between physical activity and motor skills competence is reported invariably. They also underlined that the role of the environment in this relationship should be examined among preschoolers (Figueroa & An 2017). They found in their review that the strength and nature of the physical activity and motor skills relationship varied by physical activity intensity and type of motor skill. Also, differences between the sexes were identified in a few studies. In the studies included in the review some specific associations were reported. For instance, preschool boys benefited from playing with parents with regard to better gross motor skills whereas girls lacked that benefit (Sääkslahti et al. 1999) and object control skills were associated with light-intensity physical activity on weekdays (Foweather et al. 2015). The studies included in the review were reported to have limitations due to their measures of physical activity and motor skills as they were diverse and thus failed to facilitate the comparison between studies (Figueroa & An 2017).

Based on current evidence on the relationship between physical activity and motor skills, it seems that certain associations exist, but they are inconsistent. Even though the results and conclusions in evidence so far suggest that the relationship of motor skills and physical activity does exist, the research on the relationship between physical activity and motor skills could benefit from more comprehensive assessments of motor skills, by including the whole spectrum of motor skills as well as measuring motor skills with both product- and process-oriented tests (Logan et al. 2016).

Preschool-aged children have been reported to have significant, but small, improvements in their fundamental motor skills in teacher-educated interventions (Engel et al. 2018). Preschoolers would need at least three training times per week in fundamental motor skills to improve proficiency and increase intensity of physical activity (Engel et al. 2018). In overweight or obese children, the results have been promising. Based on 17 studies (of which five included children aged 5 to 6 years) it was concluded that fundamental motor skills can be improved with interventions in overweight and obese children (Han et al. 2018). Van Capelle et al. (2017) concentrated on children aged 3 to 5 years with the mean age of 4.3 years in the 20 studies included and concluded that interventions improve fundamental motor skills, but more study is needed in day care settings. Wick et al. (2017) collected evidence on the subject in their review on interventions to promote fundamental motor skills in childcare settings. They found that low-quality evidence was discovered for relevant effectiveness of programs improving fundamental motor skills in healthy children and that long-term follow-ups would be needed.

### 2.4.2 A developmental model of motor skills and physical activity association

The fundamental motor skills learned in early childhood have a crucial impact on later childhood when more complex skills are learned in a specialized movement phase (Gallahue et al. 2012, 187). It was suggested over ten years ago that the role of motor skills competence in physical activity is more dynamic and synergistic than was assumed. As a result, the developmental model on the role of motor skills competence in physical activity was proposed (Stodden et al. 2008). The model emphasizes the understanding of motor development through a childhood and argues for its impact in engagement in physical activities. It is already well proven that fundamental motor skills developed in early childhood are the building blocks for more complex skills. However, Stodden’s model (2008) argues that fundamental motor skills are important also for lifelong physical activity. In addition, they argued that the actual motor competence is not strongly associated with the perceived one in early childhood (Stodden et al. 2008), because children may perceive themselves as highly skilled even if they actually are not. This might, however, be beneficial for practicing the skills they think they master (Stodden et al. 2008). The high expectations that young children usually have of their actual motor skills should be encouraged by offering physical activity opportunities. Children may assess themselves to be the more competent the younger they are (Niemistö et al. 2019). Indeed, age is relevant in the assessment of motor skills and physical activity associations. The model "should be conceptualized as a dynamic model in terms of developmental approaches" and when assessed, the age should be taken into account (Estevan & Barnett 2018). The role of perceived motor competence was suggested one-directional towards actual motor competence in early childhood and bidirectional in later childhood (Stodden et al. 2008). (Figure 4)

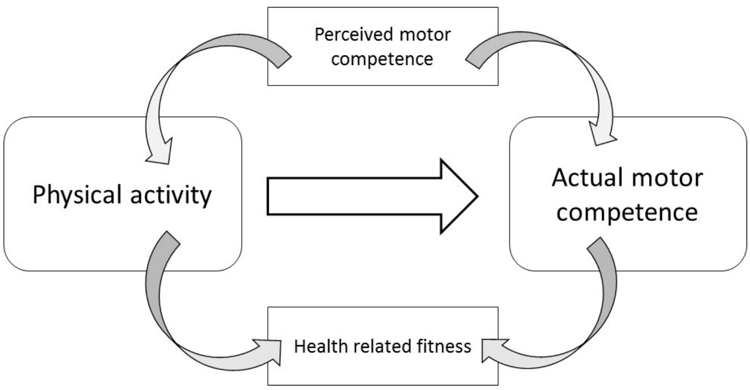


**Figure 4.** A developmental model of physical activity and motor competence association in early childhood, modified from Stodden et al. (2008) developmental perspective of perceived motor competence in physical activity.

Thus, on the overall, the developmental and dynamic perspective is of importance when considering the motor skills of children. In Stodden's model, it is suggested that the relationship between motor skills competence and physical activity strengthens over time and that physical activity may drive the motor skills development. Indeed, based on several physical activity interventions in preschoolers, physical activity has managed to improve motor skills in the experiment groups (Jones et al. 2011; Bellows et al. 2013; Roth et al. 2015; Aivazidis et al. 2018). However, the lack of follow-ups (e.g. Aivazidis et al. 2018) may question the stability of the positive outcomes. In addition, it is suggested that parents and families should be involved in the interventions more strongly (Roth et al. 2015) to gain more permanent positive changes in motor skills and physical activity.

The Newell's theory of constraints includes individual structural constraints, as described earlier (Newell 1986; Haywood & Getchell 2014, 6–7). These structural constraints include the human body systems; muscular, skeletal, and cardiovascular (Gegen & Getchell 2006). All these systems can be practiced with physical activity; physical activity can strengthen the bones, muscles, and cardiovascular system (WHO 2019). Physical activity may affect individual structural constraints, in the means of practiced or unpracticed human body systems. Of importance, thus, is to understand the correlates associated with physical activity as well. Other possible variables associated with motor competence may also be considered as constraints for motor development. Parental education and attendance in day care as environmental constraints, and gender and body composition as individual constraints may also be of importance in early childhood motor development. This thought of variables associated with motor competence handled as constraints (Newell 1986), in addition to a developmental model of physical activity and motor competence association from Stodden et al. (2008), is the theoretical framework for this study at hand.

### 2.4.3 Rationale of the study

First, young children are more and more sedentary based on research. It is known that family has a stronger effect on a child's behavior in the early years whereas elementary school children are more strongly affected by their peers. It has not been studied how the screen time, one measure of sedentary behavior, develops over the early years and which family-related factors associate strongest with the screen time change among 1–3-year-old children. This study fills this gap by studying the family demographics and family physical activity and sedentary behavior correlates associated with the screen time change of young children. The results will provide knowledge about the family-related factors that may prevent excessive screen time in the early years and, thus, will help practitioners, politicians, caregivers, and parents focus their actions to overcome the challenge of increasing sedentariness from early years on.

Second, a large proportion of children are not meeting the recommendations for physical activity both worldwide and in Finland. Numerous studies have identified correlates for physical activity of young children. However, objective measures for physical activity along with other potential variables associated with children's physical activity are not often included in the same study. Physical activity is not reported to have been objectively measured simultaneously from young children and their parents. This study assesses 5–6-year-old children and their parents' physical activity levels simultaneously for one week. This study also tests a wide selection of factors that, based on previous literature, may be associated with physical activity of young children. To add, the same selection of hypothesized factors associated with sedentary time is also studied. This study will add knowledge about parental influence on a child's physical activity and sedentary behavior. The results will hopefully challenge parents to consider their own physical activity and sedentary behavior habits because these habits may have a strong influence on their children.

Third, it is well known that physical activity is a prerequisite for developing motor skills and that adequate physical activity may associate with better motor skills. The studies that have found positive associations between physical activity and motor skills have used a variety of methods, as described earlier in this chapter, thus, the methodology used is not consistent. Motor skills and physical activity associations appear to be stronger in elementary school children; then again, less data exist on younger children. This study measures the association between different types of motor skills and objectively measured physical activity of preschool-aged children. This study will add detailed knowledge to earlier research on physical activity and motor skills associations among young children. The results will help practitioners to rethink their physical education programs. The ideas from the framework of Newell's theory of constraints are discussed. In terms of the development of children, it is known that boys and girls develop in different phases and their motor skills are no exception. Boys are often reported to possess better object control skills and girls fine motor skills and balance compared with the other gender. However, the methods used in studies vary and therefore results are not consistent. It is not reported to which extent daily activities and family-related correlates associate with motor skill differences between boys and girls. This study adds to literature knowledge on differences in motor skills between boys and girls in their preschool years and finds out which daily activities and family-related correlates are associated with different types of motor skills. This study challenges to think how girls and boys differ in their motor skills and which behavioral and family-related correlates may advance these differences during early years. The conclusions regarding the gender differences can also lead to seeing children as individuals with different interests rather than as girls and boys with gender-related stereotypical interests and behaviors. These results can be applied to early education physical activity programs.

Finally, there is evidence that BMI is negatively associated with motor skills, thus, it can act as an individual constraint for motor skills development. However, it is not known whether, for example, physical activity has a stronger influence on motor skills than the BMI. It is unclear which variables − physical activity, sedentary behavior, or BMI/body fat % − is most strongly associated with different types of motor skills. This study adds to literature knowledge on associations between body fat % and different types of motor skills. This study also compares the motor competence between children with healthy weight and those with overweight or obesity. Weight status is also one of the variables used in studying the factors associated with different physical activity intensity levels.

# 3 Aims

The main aim of this study was to examine the association between different types of fundamental motor skills and physical activity and sedentary behavior in early childhood. Moreover, the aim was to assess biological, behavioral, and family-related variables associated with fundamental motor skills, physical activity, and sedentary behavior. The developmental perspective is included and discussed in the light of the results. The objectives were:

1. To study how socioecological, behavioral, and anthropometric variables associate with screen time change in children aged 1 to 3 years during a two-year follow-up. (Study I)
2. To determine which factors are associated with objectively measured physical activity of children 5 to 6 years old with special focus on the objectively measured physical activity of the parents and their children. (Study II)
3. To study the gender differences in motor skills of 5-year-old children and examine whether time spent in different activities are associated with motor skills. (Study III)
4. To examine whether objectively measured physical activity, sedentary time, body fat, and day care attendance are associated with motor skills of 5 to 6 years old children, and to compare motor skill competence of normal weight versus overweight or obese children. (Study IV)

# 4 Materials and Methods

## 4.1 Study design and subjects

Pregnant women (n=1797) and their spouses (n=1658) were recruited at maternity clinics in Southwest Finland and Turku University Hospital from September 2007 to March 2010 to participate in the study called "Steps to healthy development and well-being of children (the STEPS Study)". Totally 1827 children were born in these families (Lagström et al. 2013).

The numbers of children whose parents answered the questionnaires at ages 13 months, 24 months, and 3 years were 940, 825, and 845, respectively, of whom 634 children had answers to all screen time questions. (Study 1) The number of children who participated in the study visit at the age of 5 years and completed BOT-2 (short form) motor skills -test was 824, of whom 712 were aged 5 years to 5 years and less than 4 months. (Study III)

Families, who answered the annual STEPS Study questionnaire at the age of 5 years during March 2013 and October 2014 (n=398) were invited to participate in the Motor skills and physical activity (MSPA) Study. Of those families, 172 agreed to participate, and of them, 158 came to the study visit; 140 of the children had valid accelerometer measures and 129 also had a valid BOT-2 motor skill-test (long form). (Study II and Study IV) (Figure 5)

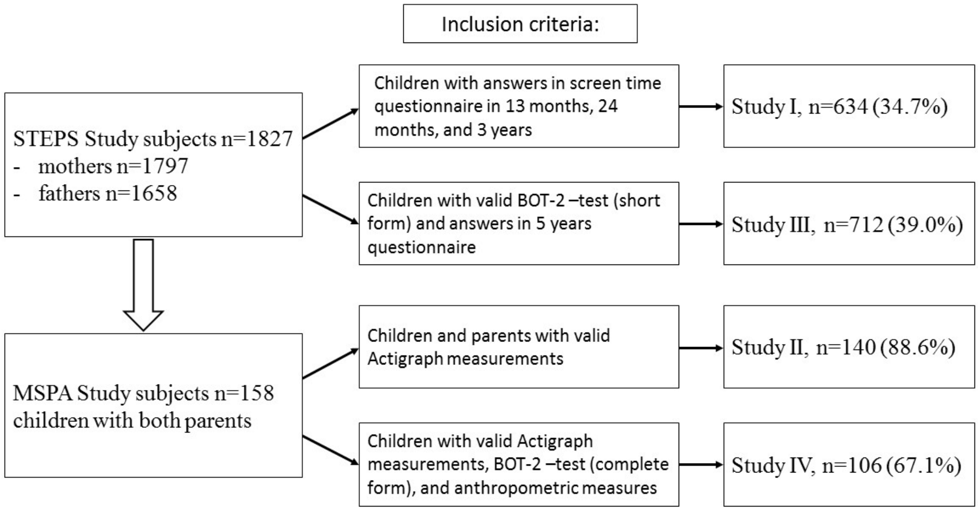


**Figure 5**. Inclusion criteria for studies I–IV.

Both longitudinal (Study I) and cross-sectional study designs were used (Study II, Study III, Study IV).

## 4.2 Data collection and methods

Data in this study were collected with questionnaires from the STEPS Study and the MSPA Study, with anthropometric measures (STEPS Study), with objective physical activity measurements (MSPA Study), and motor skills tests (STEPS Study and MSPA Study). The demographic information of mothers and fathers, including parents' age, marital status, education, income, working status, and number of children in the family, were collected at the recruitment, at 10$^{th}$ gestational week (Study I). The child-related questionnaires at 13 months, 24 months and 3 years were used to obtain information of the screen time change (Study I) and attendance in day care (Study I). The child-related questionnaires from 5 years of age of the STEPS Study (Study III) and 5 to 6 years of age of the MSPA Study (Study II) were used, including day care attendance (Study II, III, and IV) and attendance in organized physical activity (Study II). Data for physical activity were collected the following week after the MSPA study visit (Study II and IV). Data of motor skills were collected from STEPS Study participants at the age of 5 years at the STEPS Study visit, with BOT-2 short form (Study III) and in more detail from MSPA participants at the age of 5 to 6 years at a separate study visit with BOT-2 complete form (Study IV).

STEPS Study visits were conducted in the Child and Youth Research Institute at the University of Turku in Southwest Finland. The study visits included anthropometric measures (at 13 months, 24 months, 3 years, 5 years) and a motor skills test (at 5 years) conducted by a research nurse. The MSPA study visit took place in a municipal sports hall and two different halls were used. Study visits were conducted by a researcher and two research assistants.

## 4.3 Physical activity and sedentary behavior measurements

Physical activity was measured with STEPS Study questionnaires as metabolic equivalents (MET hours / week) (Study I). Broadly used indicators of sedentary behavior 'screen time' and 'sitting time' (Study I) was also used as well as the time spent in different activities including screen time and physically active play (Study III). Physical activity and sedentary time were measured objectively with accelerometers in children and parents who attended the MSPA Study (Study II, Study IV). All physical activity and sedentary behavior measurements are described in detail in the following sections.

### 4.3.1 LTPA and MET

Parents' leisure time physical activity was measured with three questions at 13 and 24 months, and 5 years measurement points. The questions included the frequency, intensity, and duration of the physical activity. After this, leisure-time physical activity was quantified as metabolic equivalent (MET) -hours per week by multiplying the scores of the questions as in an earlier study (Raitakari et al. 1996). One MET is "a resting metabolic rate obtained during quiet sitting". The range of activities can vary from sleeping (0.9 METs) to running at 10.9 mph (18 METs) (Ainsworth et al. 2000). The weekly MET-hours varied from 0–93.35, when the intensity level scores were 4 (not sweating or getting out of breath), 6 (some sweating and getting out of breath), and 10 (profuse sweating and getting out of breath), and for the frequency the multipliers varied from 0.17 to 1.33 and for duration from 0 to 7.019 (Raitakari et al. 1996). For the analyses the scores were divided into two predefined categories; 0–3.74 for low leisure-time physical activity and more than 3.75 for moderate or higher leisure-time physical activity (WHO 2010; Moore et al. 2003; US Department of Health and Human Services 2008).

### 4.3.2 Screen time and sitting time

The children's screen time, including watching TV, DVDs, or videos and using computer were reported by the parents at 13 month's, 24 month's, and 3 year's measurement points. At the first measurement point (13 months) we asked the parent

“How much time does your child spend watching TV/videos/DVDs per day?” At 24 months and 3 years measurement points we asked “How much time does your child spend watching TV/videos/DVDs or using the computer per day?” At all measurement points the answers were given in hours and minutes. Both questions were asked separately for weekdays and weekends. The screen time during weekdays and weekends were weighted and counted together and then divided by seven to obtain the screen time per day. The screen time change was used in the analyses. The change in the children’s screen time from 13 months to 3 years was measured by subtracting the 13 months’ screen time from 3 years’ screen time to obtain the screen time change during two years.

Parents sitting time and screen time were measured as indicators of sedentary behavior at the measurement points of 13 months, 24 months, and 3 years. Sitting time was asked with five separate questions to both parents as follows: “How much time do you spend sitting at the office during a workday?“, “--at home watching TV or videos?”, “--at home at the computer?”, “--in a vehicle?” and “--somewhere else (where)?” The answer was given in hours and minutes for each question. The answers were then added up to obtain the sitting time per day. Parents’ screen time was measured adding up the answers from the questions “How much time do you spend sitting at home watching TV or videos?” and “--at home in front of the computer?” Both self-reported sitting time and screen-time measurements have been widely used in previous studies (Thorp et al. 2011).

### 4.3.3 Accelerometers and physical activity intensity levels

In this study, the Actigraph accelerometers (GT3X) (Actigraph, Pensacola, FL, USA) with diaries covering the use of the meters were used to assess physical activity and sedentary time of children and their parents (Study II, Study IV). Accelerometer counts are reported to have moderate to high correlation with energy expenditure and they also have fair to excellent accuracy in detecting different intensity levels in children (Rowlands & Eston 2007) and reliability among adults (Aadland & Ylvisåker 2015). Diaries were used to exclude the sick days of the participants.

There are a few methodological choices to be made in order to achieve the actual physical activity results. First, before the data collection, epochs have to be chosen based on the study population. One minute epoch length has been used for adults (Troiano et al. 2008). However, with young children’s tendency to move in sporadic bursts (Cliff et al. 2009), the shorter epoch length (from one to 15 seconds) in data collection provide more accurate results (Cain et al. 2013). Thus, in this study, the 15 second and 60 second epochs for children and adults were used, respectively.

Second, in the data processing, certain settings have to be determined. These settings are the nonwear time, definition of a valid day, number of valid days included, and the use of counts' cut off points for the different intensity levels (counts per minute or intensity levels) (Cain et al. 2013). Nonwear time is the number of consecutive zero counts. In this study, 30 minutes (children) and 60 minutes (adults) of consecutive zero counts were used for the definition of nonwear time. A valid day had to contain at least 480 minutes/day of wearing time for children and at least 600 minutes/day for adults. Valid data had to contain at least three weekdays and one weekend day. These decisions adapt the recent review about data collection and processing criteria with one exception. It was recommended to use ≥ 10 hours of wearing time also for children (Migueles et al. 2017). In this study, eight hours was used as a criteria for valid wearing time. However, the wearing time of all children with valid measures in our data clearly exceeded the recently recommended 10 hours.

Third and last, the choice has to be made whether to use the actual raw counts per minute or predefined cut points to obtain the intensity levels for physical activity and sedentary time. Intensity levels were chosen to be used in this study. The predefined and widely utilized cut points of physical activity levels and sedentary time for children (Evenson et al. 2008) and adults (Troiano et al. 2008) were used in this study. The cut points of intensity levels used in the main analysis of this study for sedentary time (≤100 counts/60) is also recommended to be used for children by a study on classification accuracy of the physical activity cut points (Janssen et al. 2013). For the purpose of the independent samples t-test, mother's and father's moderate-to-vigorous physical activity was divided into low and high moderate-to-vigorous physical activity based on the median of the moderate-to-vigorous physical activity of valid data. (Study II)

### 4.3.4 Activity variables

Parents were asked by questionnaires how much time their children spent daily in different activities when the children were 5 years old. Parents had to evaluate the time separately for weekdays and weekends. The activities were watching TV/DVD, playing computer/console games, drawing/doing handicrafts, physically active play outdoors, and physically active play indoors. The time scale was never, less than 15 minutes, 15–30 minutes, 30–60 minutes, 1–2 hours, 2–3 hours, and more than 3 hours. To form high and low categories, the variables were computed together to identify children who spent 60 minutes per day on weekdays and on weekends in each activity (high) or spending less than 60 minutes a day in the activity (low). The limit was set to 30 minutes for playing computer/console games per day because, on average, the activity levels were low in this behavior.

## 4.4 Motor skill test BOT-2

In this study, the purpose was to assess motor skills in detail: for this reason a more complex BOT-2 -test that includes both gross and fine motor assessments was chosen with 53 test items (Complete Form), fully aware that conducting the test would be time consuming with approximately 45–60 minutes administration time. The BOT-2 -test includes also a shorter version with 14 tests (Short Form), which is suitable for testing larger populations with approximately 15–20 minutes administration time (Bruininks & Bruininks 2005). The test has been identified as having strong internal consistency and test-retest reliability, and to be one of the most reliable assessment tools for children (Griffits et al. 2018). In addition, the test age range is 4 to 21 years, and as such it is suitable for children aged 5 to 6 years old, as well as being well suited to research purposes (Bruininks & Bruininks 2005). The BOTMP-test, which is the previous version of BOT-2, was designed as a screening tool for motor control deficits for practitioners, such as occupational therapists or teachers, and it can identify mild to moderate motor control problems (Bruininks & Bruininks 2005). The BOT-2-test is the second version of BOTMP and includes more tasks and extended age range (Bruininks & Bruininks 2005).

### 4.4.1 Complete form

The complete form of BOT-2 provides a reliable measure of overall motor proficiency (Bruininks & Bruininks 2005). It has eight subtests which are combined to four composites of fine manual control, manual coordination, body coordination, and strength and agility. The items require and assess both gross and fine motor skills, as well as manipulative, locomotor, and stability skills. Raw scores are obtained from each task. Raw scores vary from 0 to 51 and over, depending on the task. These scores are thereafter converted to point scores according to the scoring sheet. Point scores can be further converted to standardized scores by sex and age. The standardized scores enable a child to be compared against the average performance of the same age and sex.

Fine manual precision and fine motor integration compose the composite of fine manual control. Tasks in the fine motor precision requires precise control of fingers and hands. This test composite has five drawing tasks, one cutting task, and one paper-folding task. Errors in two tasks of drawing lines are calculated and less errors results to better scores. The scores of other tasks are calculated with a specific ruler and measurement sheet. Fine motor integration includes tasks that require precise finger and hand movements but also ability to integrate visual stimuli. All the tasks in fine motor integration are about copying a shape, thus reproduce various shapes from circle to a more complex ones by drawing. The scoring of these shapes is based on the resemblance of the original shape, including scoring of closure, edges, orientation, overlap, and overall size. The number of scored aspects varies from four to six, depending on the shape, and each aspect is either correct (1 point) or not (0 points). These tasks of drawing shapes give directly the point scores.

Manual dexterity and upper-limb coordination are subtests for manual coordination composite. Manual dexterity includes tasks such as sorting cards and transferring pennies, which require accuracy and involves grasping, reaching, and bimanual coordination. The scores are calculated based on 15 seconds, thus, e.g., how many cards one can sort and how many pennies one can transfer from one pegboard to another. The maximum scores vary in each task from 10 to 51 and more, but they are converted to point scores from 0−9. Upper-limb coordination measure arm and hand coordination with visual tracking and includes tasks of catching, dribbling, and throwing. The scoring is based on successful catches, dribbles, or throws. The catching and throwing tasks in this subtest have maximum attempts and raw and point scores of five. The maximum point score for continuous dribbling is seven, which is obtained with ten correct and continuous dribbles.

Bilateral coordination and balance subtests make up the composite of body coordination. The tasks in bilateral coordination are sequential movements such as jumping jacks or tapping feet and fingers and they require body control and coordination of upper and lower limbs. The full scores for touching nose with index fingers with eyes closed is four touches and that gives full point scores four. For jumping tasks and pivoting fingers, five correct jumps or pivots give full point scores of three. The maximum score for tapping tasks is ten, which give point scores of four. Tasks in balance assess the ability to maintain posture with tasks such as standing on a balance beam or walking forward on a line. These tasks mostly require stability of the trunk. Two types of scoring exist for these tasks. A maximum of successful steps in walking tasks are six steps, which gives full point scores of four. Other balance tasks allow ten seconds time to stay in each position either on a balance beam or on a line. Staying in a position for 0−0.9 seconds results in 0 points and full 10 seconds in full point scores of four or five, depending on the task.

Running speed and agility and strength makes up the composite of strength and agility. Tasks in running speed and agility subtest include shuttle run, stepping over a balance beam, and different hop tasks. The scoring in other tasks is similar to the shuttle run. The 15-meter shuttle run gave full point scores of 12 if the time spent on the run is 5.9 seconds or less, and 0 points if time is 16 seconds or more. Other tasks allow 15 seconds time to conduct each task. Either 40 or more or 50 or more correct hops or taps, depending on a task, in 15 seconds result in full point scores of ten. The strength measuring tasks assess the trunk, upper, and lower body strength with specific tasks of push-ups, sit-ups, wall sit, v-up, and standing long jump. The examinee may choose either knee or full push-ups and there are different conversions in scoring for both. For scoring, 36 or more correct sit-ups or push-ups in 30 seconds gave full point scores of nine, whereas staying in a wall-sit and v-up for full 60 seconds gave full six point scores. Standing long jump for 85 inches or more, thus 215.9 centimeters, gave full point scores of 12.

The tasks in the complete form measure skills that are required in daily activities (Bruininks & Bruininks 2005, 5–6). For instance, manual dexterity tasks are similar to those needed in daily routines such as holding cutlery or sorting coins, and many bilateral coordination skills are needed in playing sports and recreational games. Strength is needed in many gross motor skills in daily activities (Bruininks & Bruininks 2005, 5–6). (Table 3)

### 4.4.2 Short form

The short form of BOT-2 is a quick and easy tool for screening purposes. It includes 14 tasks that are carefully selected to represent the variety of tasks in the complete form and it has tasks from each subtest in the complete form. It has four items from the composite of fine manual control, three items from the composite of manual coordination, four items from the composite of body coordination, and three items from the strength and agility composite. The scoring is the same as in the complete form. The short form provides a standardized score for overall motor proficiency.

**Table 3.** The BOT-2 complete form's composites, subtests, tasks, and point score range per task. Tasks included in the short form in bold font.

| Composite | Subtest | Tasks in complete form / **in short form** | Point score range |
|---|---|---|---|
| Fine manual control | Fine motor precision | Filling in shapes – circle | 0–3 |
| | | Filling in shapes – star | 0–3 |
| | | **Drawing lines through paths - crooked** | **0–7** |
| | | Drawing lines through paths - curved | 0–7 |
| | | Connecting dots | 0–7 |
| | | **Folding paper** | **0–7** |
| | | Cutting out a circle | 0–7 |
| | Fine motor integration | Copying a circle | 0–4 |
| | | **Copying a square** | **0–5** |
| | | Copying overlapping circles | 0–6 |
| | | Copying a wavy line | 0–4 |
| | | Copying a triangle | 0–5 |
| | | Copying a diamond | 0–5 |
| | | **Copying a star** | **0–5** |
| | | Copying overlapping pencils | 0–6 |
| Manual coordination | Manual dexterity | Making dots in circles | 0–9 |
| | | **Transferring pennies** | 0–9 |
| | | Placing pegs into a pegboard | 0–9 |
| | | Sorting cards | 0–9 |
| | | Stringing blocks | 0–9 |
| | Upper-limb coordination | **Dropping and catching a ball - both hands** | **0–5** |
| | | Catching a tossed ball - both hands | 0–5 |
| | | Dropping and catching a ball - one hand | 0–5 |
| | | Catching a tossed ball - one hand | 0–5 |
| | | Dribbling a ball - one hand | 0–7 |
| | | **Dribbling a ball - alternating hands** | **0–7** |
| | | Throwing a ball to a target | 0–5 |

| Composite | Subtest | Tasks in complete form / **in short form** | |
|---|---|---|---|
| Body coordination | Bilateral coordination | Touching nose with index fingers - eyes closed | 0–4 |
| | | Jumping jacks | 0–3 |
| | | **Jumping in place - same sides synchronized** | **0–3** |
| | | Jumping in place - opposite sides synchronized | 0–3 |
| | | Pivoting thumbs and index fingers | 0–3 |
| | | **Tapping feet and fingers - same sides synchronized** | **0–4** |
| | | Tapping feet and fingers - opposite sides synchronized | 0–4 |
| | Balance | Standing with feet apart on a line - eyes open | 0–4 |
| | | **Walking forward on a line** | 0–4 |
| | | Standing on one leg on a line - eyes open | 0–4 |
| | | Standing with feet apart on a line - eyes closed | 0–4 |
| | | Walking forward heel-to-toe on a line | 0–4 |
| | | Standing on one leg on a line - eyes closed | 0–4 |
| | | **Standing on one leg on a balance beam - eyes open** | 0–4 |
| | | Standing heel-to-toe on a balance beam | 0–4 |
| | | Standing on one leg on a balance beam - eyes closed | 0–5 |
| Strength and agility | Running speed and agility | Shuttle run | 0–12 |
| | | Stepping sideways over a balance beam | 0–10 |
| | | **One-legged stationary hop** | **0–10** |
| | | One-legged side hop | 0–10 |
| | | Two-legged side hop | 0–10 |
| | Strength | Standing long jump | 0–12 |
| | | **Knee push-ups or full push-ups** | **0–9** |
| | | **Sit-ups** | **0–9** |
| | | Wall sit | 0–6 |
| | | V-up | 0–6 |

# 4.5 Anthropometric measurements

## 4.5.1 Body mass index

At the child's age of 5 years, the height and weight of the children were measured by a health care professional during the STEPS study visit. Weight was measured to the nearest 0.1 kg with an electronic scale (WB110MA, Tanita Corporation. Tokyo, Japan) and height was measured to the nearest millimeter with a wall-mounted stadiometer (Holtain, Crymych, UK). The BMI was calculated as $kg/m^2$. The new Finnish Growth References for Children were used to determine whether the participant was overweight or obese (Saari et al. 2011). These new growth references for children include age- and sex-specific BMI cut points, wherein age is determined by 0.01 year accuracy from 2 years of age onwards. Age-specific BMI was calculated as body weight (kg) divided by body height squared ($m^2$). For the purpose of the analysis, the children were divided into healthy weight or overweight/obese according to above-mentioned growth references (Study II).

## 4.5.2 Body composition

Children's body fat percentage was measured at the study visits by a study nurse. The device that was used in this study was Inbody®J10, which uses three different frequencies at each five segments of the body. The device uses 8-point tactile electrodes with direct segmental multi-frequency bioelectrical impedance analysis method (DSM-BIA) and is suitable for 3–99-year-old subjects. Percentage of body fat was measured using segmental multifrequency bioimpedance analysis (BIA) (InBody® J10 device, Biospace, Seoul, Korea). Shoes and socks were removed before stepping on to the scale and children were told to stand in a straight upright position.

# 4.6 Statistical analyses

The data were analyzed with SAS 9.3 for Windows (Study I), SAS 9.4 for Windows (Study III), and IBM SPSS Statistics version 22 (Study II, Study IV) and 25 (Study III). Two-sided p-values below 0.05 were considered statistically significant.

## 4.6.1 Descriptives, collinearity test, and preliminary analysis

Descriptive statistics are presented as means (SD) (Study I–IV) or as medians (q1, q3) (Study I–II) depending on the normality tests of the measurements. In the study

III, the distributions of some of the single tasks were skewed, but the means (SD), however, are presented for each task instead of medians, because of informative purposes in the study. In the study I, parents' sitting time and screen time were skewed, but they are presented as means (SD) for illustrative purposes. Leisure-time physical activity of parents are presented as medians with upper and lower quartiles (q1, q3). Frequencies and percentages are used for categorical variables.

Possible collinearities were tested between different factors before constructing models. The collinearity was tested with chi-square for mother's and father's leisure-time physical activity, sitting time, screen time, education, income, working status, social class of the family, age, and BMI (Study I). If collinearity was found, the mother's variable was chosen for the models. Mothers most often stayed at home at the time when the study was conducted, and thus spent more time with their child compared with the father. (Study I). Correlations were tested for mother's and father's education, moderate-to-vigorous physical activity, and sedentary time with Pearson correlation or chi-square (Study II). Due to statistically significant correlations found for each variable, each model was tested with mother's variables and father's variables separately. (Study II). Mother's and father's education, watching TV/DVD (child), and playing computer/console games (child) were tested with Pearson chi square (Study III). The correlating variables of education were tested in initial models and after that, father's education instead of mother's education was chosen due to the stronger indication of association. (Study III).

The differences between the screen time, sitting time, and leisure-time physical activity of the mothers and the fathers were tested with a Wilcoxon rank sum test (Study I). The levels of children's physical activity (light, moderate, vigorous, moderate-to-vigorous) and sedentary time were analysed by gender, weight status, season, having siblings or no siblings, attendance in day care, attendance in organized physical activity, parents' education, and parents' moderate-to-vigorous physical activity levels of low and high with independent samples t-test (Study II). Independent samples t-tests and chi-square-test were used to compare healthy weight children and overweight/obese children with respect to their motor skill scores, anthropometric measures, physical activity, and sedentary time (Study IV). For the differences between genders in motor skills tasks, the Cochran Armitage test for trend was used (Study III). Spearman correlation coefficients were calculated for individual tasks and the total point score to see which items correlate the strongest and which items the weakest with total motor skills.

### 4.6.2 Factors associated with screen time change

For analyzing demographic, behavioral, and physiological associations with children's screen time change, linear mixed model analysis was used. The initial model included the mother’s education (basic/advanced), working status (full-time/other), age, BMI at the recruitment, LTPA at 13 months, the family income (low/high), the mother’s and father’s screen-times at 13 months, the mother’s and father’s sitting time at 13 months, the BMI of the child at 13 months, the gender of the child, first child (yes/no), the day care status at 36 months, and the screen-time of the child at 13 months. The normality assumption was checked from studentized residuals. Non-significant factors were excluded one at a time. The final model included the mother’s professional education, screen-time, working status and age, the father’s sitting time, the day care status, the BMI of the child and the screen-time of the child at 13 months. (Study I)

### 4.6.3 Mother’s, father’s, and child’s physical activity

The child’s moderate-to-vigorous physical activity and sedentary time was used separately as a dependent variable in linear models. The independent variables were gender, age, and BMI of the child, the season of the physical activity measurement, whether the child had siblings or no siblings, attendance in day care, attendance in organized physical activities, the mother’s and the father’s education and moderate-to-vigorous physical activity or sedentary time. Analyses were conducted separately of the mother’s and the father’s variables to avoid collinearity. The interactions were checked and if no interactions were found, they were excluded from the model. Normality of residuals was checked for each analysis. In two models residual distributions were skewed, which is why a logarithmic transformation (ln) was conducted for dependent variable and after that the analyses were repeated. Marginal means of the model and estimates of slopes with 95% confidence intervals (CI) were used for quantifying the results. (Study II)

### 4.6.4 Associations with children’s motor skills

Associations with MVPA and motor skills composites, and sedentary time and motor skills composites, were first observed with scatter plots with regression lines. Also correlation coefficients were reported. Each composite of motor skills was used as a dependent variable in linear regression models. The primary analyses were conducted before the final analyses. Variables tested were moderate-to-vigorous physical activity/sedentary time, attendance in day care, body fat percentage and as adjusting variables the child’s age, sex, and mother’s and spouse’s education separately. Interactions between moderate-to-vigorous physical activity/sedentary time and sex, moderate-to-vigorous physical activity/sedentary time and attendance in day care, moderate-to-vigorous physical activity/sedentary time and the mother’s and spouse’s education, and body fat percentage and sex were included, and if no interactions were found they were excluded from the final models. Marginal means of the model and estimates of slopes with 95% confidence intervals (CI) were used for quantifying the results. Normality of residuals was checked for final models visually and with Kolmogorov-Smirnov test. (Study IV)

### 4.6.5 Motor skills with activity and family-related variables

Motor skills tasks (14) were summed to fine manual control (four tasks), manual coordination (three tasks), body coordination (four tasks), and strength and agility (three tasks) composites. Potential explaining variables were examined with analysis of covariance (ANCOVA). Each motor skills composite was a dependent variable, gender a categorical variable, and one activity variable at a time was an explaining variable. Of five activity variables, playing indoors physically actively was unrelated to any motor skills and was excluded from the analyses. Approaching significance was decided to be sufficient to keep in the following analyses. Variables chosen for final ANCOVA models were father's education, attendance in day care, having siblings or no siblings, watching TV/DVD less or more than 60 minutes per day, playing computer/console games less or more than 30 minutes per day, drawing/doing handicrafts less or more than 60 minutes per day, playing physically actively outdoors less or more than 60 minutes per day, and gender and age as adjusting variables. Interactions between gender and each activity variable were checked and if no interactions were found, they were excluded from the model. (Study III)

## 4.7 Ethics

The STEPS Study protocol was approved by the Ethics Committee of the Hospital District of Southwest Finland in February 2007. The MSPA study protocol was approved by ethical committee of the University of Turku in April 2013. Written informed consent was obtained from all participants. The children's consent was given by parents. Subjects were free to dropout from the study at any time without giving any specific reason. The protocol of the STEPS Study is consistent with the principles of the Declaration of Helsinki.

# 5 Results

## 5.1 Characteristics of the study participants

The mean age of the mothers and fathers in the STEPS study at recruitment was 30.7 years (SD 4.6) and 32.8 years (SD 5.5), respectively. Mothers were more often highly educated than fathers. Of mothers, 60.5% and of fathers 46.0% had a higher education, such as a bachelor's, master's, licentiate, or doctoral degree. Over a half of the parents (58%) were married and for 53% of them, the child was their first. The demographic characteristics of the parents at the recruitment are presented in Table 4.

**Table 4.** Parents' demographics at the recruitment of the STEPS Study.

| | Recruitment (n=1797) (Study I) | |
|---|---|---|
| Parents' demographics | Mothers (n=1797) | Fathers[a] (n=1658) |
| Age, years, mean (SD) | 30.7 (4.6) | 32.8 (5.5) |
| Education, high[b], n (%) | 1051 (60.5) | 776 (46.0) |
| Working full-time, n (%) | 1165 (66.1) | 1480 (85.5) |
| Marital status, married, n (%) | 1025 (58.0) | 1025 (58.0) |
| Family incomes over 2000e, n (%) | 1356 (77.6) | 1356 (77.6) |
| First child, n (%) | 962 (52.9) | 962 (52.9) |

[a] Fathers also included spouses who were the child's non-biological father and women who lived in a registered relationship with the biological mother.
[b] Secondary level degree or higher

Of children with STEPS Study parents, 52.2% were boys. At the age of 3 years, 66.4% and 65.4% of boys and girls attended day care, respectively. At the age of 5 years the equivalent attendance rates were 84.6% and 83.0%, respectively. Approximately half of the children had one or more siblings at the recruitment. Later at the age of 5 to 6 years, approximately 89% had one or more siblings. Characteristics of children at different time points with screen time measures (I), with BOT-2 short form measures (III) and valid BOT-2 complete form and accelerometer measures are presented in Table 5. The number of subjects is different in the main results from that presented in this table due to other variables taken into account in the further analysis.

**Table 5**. Children’s characteristics at the age of 3 years (Study I), 5 years (Study III), and 5 to 6 years who had valid accelerometer and motor skills assessments (Study II, Study IV).

| | STEPS Study 3 years (n=845) (Study I) | | STEPS Study 5 years (n=712) (Study III) | | MSPA Study 5-6 years (n=129) (Study II, IV) | |
|---|---|---|---|---|---|---|
| Children’s characteristics | Boys n=443 | Girls n=402 | Boys n=372 | Girls n=340 | Boys n=54 | Girls n=75 |
| BMI, mean (SD) | 16.3 (1.2) | 16.2 (1.2) | 16.2 (1.3) | 16.2 (1.6) | 15.9 (1.2) | 16.3 (1.5) |
| At day care, n (%) | 294 (66.4) | 263 (65.4) | 242 (84.6) | 219 (83.0) | 39 (78.0) | 57 (82.6) |
| Has siblings, n (%) | 339 (78.8) | 288 (73.3) | 253 (88.5) | 224 (84.8) | 47 (88.7) | 63 (92.6) |
| Total motor score[a] | - | - | 52.32 (7.4) | 54.62 (7.5) | 49.3 (7.4) | 50.8 (7.6) |
| MVPA[b] | - | - | - | - | 8.6 (2.7) | 7.9 (2.4) |
| Sedentary time[b] | - | - | - | - | 49.3 (5.7) | 50.5 (4.7) |

BMI = body mass index, MVPA = moderate-to-vigorous physical activity, [a] Standardized scores, [b] % time from the total wearing time

# 5.2 Physical activity

## 5.2.1 Physical activity of parents

At the 13 months and 24 months measurement points mothers’ and fathers’ leisure-time physical activity, measured with questionnaires as weekly metabolic equivalent (MET) -hours, was 5.0 hours (1.9, 12.5) and 8.0 hours (2.5, 16.0) for mothers and 8.3 hours (1.2, 20.8) and 13.3 hours (3.0, 26.7) for fathers. Fathers’ were significantly more active physically than mothers in both measurement points (p<0.001). (Table 6) (Study I)

**Table 6.** Leisure time physical activity (LTPA) of parents at 13 months (n=986–1055) and 24 months (n=786–858) measurement points presented as weekly median hours (q1, q3). (Modified from Matarma et al. 2016)

| Variable | 13 months | 24 months | p-value [a] |
|---|---|---|---|
| LTPA | | | p<0.001 |
| mother | 5.0 (1.9, 12.5) | 8.0 (2.5, 16.0) | |
| father | 8.3 (1.2, 20.8) | 13.3 (3.0, 26.7) | |

LTPA = leisure time physical activity, [a] = Wilcoxon rank sum test

### 5.2.2 Physical activity of children aged 5 to 6 years

At the age of 5.1 years (SD 0.6) 65.7% of children were playing physically actively outdoors 60 minutes or more per day. Of boys (n=282) 70.2% and of girls (n=263) 60.8% were playing outdoors >60 minutes per day and that difference was statistically significant (p=0.021). (Study III)

Measured objectively with accelerometers at the age of 5.6 years (SD 0.3), children (boys n=62, girls n=78) spent time in moderate-to-vigorous physical activity and as sedentary 61.5 minutes per day (SD 18.8) equaling 8.2% of a day, and 375 minutes per day (SD 38.3) equaling 50% of a day, respectively. Less than half of the children (47.1%) exceeded the recommended >60 minutes of moderate-to-vigorous physical activity daily. Only one child in this sample (0.7%) exceeded two hours of moderate-to-vigorous physical activity per day. Children (n=140) spend on average 41.7% (SD 4.3) on light physical activity, 6.0% (SD 1.6) in moderate physical activity, 2.2% (SD 1.1) in vigorous physical activity, 8.2% (SD 2.5) in moderate-to-vigorous physical activity, and 50.0% (5.1) in light-to-vigorous physical activity per day. Thus, children were physically active at any intensity level half (50%) of their day. Boys were physically and statistically significantly more active than girls in moderate-intensity physical activity (boys 6.5% (SD 1.8) per day vs. girls 5.6% (SD 1.5) per day, p=0.003). Statistically significant differences between boys and girls were not found in other physical activity intensities. (Table 7) (Study II)

At child's age of 5.6 years mothers (n=138) and fathers (n=136) spent time in moderate-to-vigorous physical activity for 33 minutes (SD 16) and 38 minutes (SD 19) per day, respectively. They spend time being sedentary 60% and 61% per day, thus equaling 9.0 hours (SD 1.3) for mothers and 9.3 hours (SD 1.3) for fathers per day. Overall, fathers had only slightly higher activity levels than mothers in moderate physical activity (3.7% vs. 3.3% of wearing time), vigorous physical activity (0.5% vs. 0.4% of wearing time), and moderate-to-vigorous physical activity (4.1% vs. 3.7 of wearing time) intensities but also in sedentary time (60.8% vs. 60.3% of wearing time). Mothers had slightly higher light physical activity intensity levels than fathers (36.0% vs. 35.1% of wearing time). The differences between mothers' and fathers' intensity levels are minimal, as for instance the light physical activity intensity of 36% of mothers equals 5 hours 22 minutes and 35.1% of fathers equals 5 hours 21 minutes. All objective measurements for children and their parents are presented in Table 7. (Study II)

**Table 7.** The valid accelerometer data for children (all, boys, girls) and their parents in the MSPA Study presented as means (SD) and p-values for gender differences in physical activity intensity levels.

| Measurement | Children n=140 | Boys n=62 | Girls n=78 | p-value | Mothers n=138 | Fathers n=136 |
|---|---|---|---|---|---|---|
| Wearing time, min/day | 750.5 (49.5) | 755.0 (46.6) | 746.9 (51.7) | .343 | 894.4 (68.2) | 915.3 (79.9) |
| Light PA[a], % | 41.7 (4.3) | 42.1 (4.6) | 41.5 (4.1) | .398 | 36.0 (8.1) | 35.1 (8.3) |
| Moderate PA[a], % | 6.0 (1.6) | 6.5 (1.8) | 5.6 (1.5) | **.003** | 3.3 (1.6) | 3.7 (1.9) |
| Vigorous PA[a], % | 2.2 (1.1) | 2.2 (1.1) | 2.2 (1.1) | .982 | 0.4 (0.6) | 0.5 (0.8) |
| MVPA[ab], % | 8.2 (2.5) | 8.7 (5.6) | 7.8 (2.3) | .050 | 3.7 (1.8) | 4.1 (2.1) |
| Sedentary time[a], % | 50.0 (5.1) | 49.2 (5.6) | 50.7 (4.7) | .094 | 60.3 (8.6) | 60.8 (8.7) |
| Steps/day | 9222 (1802) | 9583 (1854) | 9014 (1743) | .126 | 7979 (2329) | 8310 (2508) |
| Counts per minute | 653.6 (139.7) | 667.9 (134.4) | 642.1 (143.6) | .279 | 338.8 (108.0) | 364.2 (119.9) |

[a] % time from the total wearing time, PA = physical activity, [b] MVPA = Moderate-to-vigorous physical activity, SD = standard deviation

### 5.2.3 Factors associated with children's physical activity

At the age of 5.6 years, the children's physical activity was tested with associating variables. Background variables were first tested with different physical activity intensity levels with independent samples t-tests. The amount of light physical activity varied by season (autumn-winter 41.3% vs. spring-summer 43.0%) (p=0.036). Children who had never attended day care outside the home were physically active in light intensity 44.0% (SD 4.2) of their day, whereas children attending day care were physically active in light intensity 41.3% (SD 4.2) of their day (p=0.024). No other significant differences were found with the examined variables in light intensity physical activity. In addition to being male which induced higher percentages in moderate physical activity (p=0.003), also having no siblings (6.9 % compared with having siblings 5.9%, p=0.041) and attending day care outside the home (6.1% compared with non-attendants 5.0%, p=0.010) induced higher moderate physical activity. Also, vigorous physical activity varied significantly (p=0.012) between children attending day care (2.3%, SD 1.0) or non-attendants (1.6%, SD 1.0). Moderate intensity approached significance with p-value of 0.75.

Vigorous physical activity varied between children whose mothers had low moderate-to-vigorous physical activity (2.0%, SD 0.8) comparing with mothers with high moderate-to-vigorous physical activity (2.5%, SD 1.3) (p=0.032). Thus, the more active the mother was, the more active her child was.

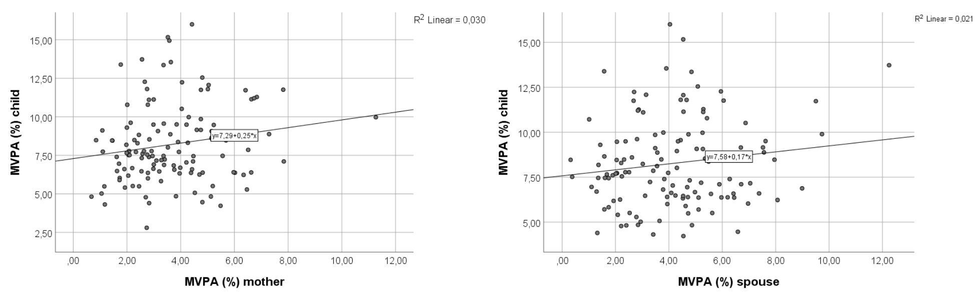


**Figure 6.** The mothers' and spouse's MVPA compared to the child's MVPA. Variables are standardized against the total wearing time, showing percentage values from the total daily wearing time of accelerometer.

Mother's and child's physical activities in moderate-to-vigorous intensity showed a linear association in a scatter plot. In addition, spouse's and child's moderate-to-vigorous intensity physical activities were also in linear association. (Figure 6)

When analyzed further with linear models, mother's and child's moderate-to-vigorous physical activity were positively associated (p=0.049), whereas that of father's and child's failed to associate. (Table 8)

**Table 8.** Log-MVPA of the child as dependent variable, n=100. The results are in logarithmic (ln) scale. (Matarma et al. 2017)

| Log-MVPA, child | | Marginal mean | Slope | CI 95 % | p |
|---|---|---|---|---|---|
| MVPA, mother | | | 0.033 | 0.00 to 0.07 | 0.049* |
| In day care | Yes | 2.10 | | 2.04 to 2.16 | 0.005* |
| | No | 1.85 | | 1.67 to 2.01 | |
| MVPA, father*educ., father | | | MVPA: | | 0.021* |
| Education, father | Low | | -0.022 | -0.06 to 0.02 | (0.274) |
| | High | | 0.042 | 0.00 to 0.08 | (0.033) |

MVPA = moderate-to-vigorous physical activity

However, higher educated father's moderate-to-vigorous physical activity (slope=0.042, p=0.033) was associated with the child's moderate-to-vigorous physical activity (p=0.021). Attending day care (yes, mean 2.10; no, mean 1.85, both in logarithmic scale) was associated with the child's moderate-to-vigorous physical activity (p=0.005). The child's age, sex, season, mother's education, or having siblings were unassociated with the child's moderate-to-vigorous physical activity. The results indicate that children attending day care are physically more active than their peers who do not attend day care. Children who have physically active mothers are more likely physically active themselves. Fathers' physical activity was only associated with that of their children if the fathers were highly educated.

## 5.3 Sedentary behavior

### 5.3.1 Screen time change of toddlers and associated factors

Measured with parental questionnaires, children's median (q1, q3) screen time at the age of 13 months, 24 months and 3 years was 10 (0.0, 30.0), 51 (30.0, 77.1), and 69 (45.9, 90.0) minutes per day, respectively. Children's screen time increased remarkably during 2 years, i.e. from 13 months to 3 years. From 13 months of age to 3 years of age, the mean screen time change was a 55-minute increase. (Study I) (Table 9)

**Table 9.** Sedentary behavior measurements of parents and screen time of children at 13 months, 24 months, and 3 years measurement points presented as mean (SD) hours or median minutes (q1, q3)*. The number of respondents vary at each measurement point (n=787-1142). (Modified from Matarma et al. 2016)

| Variable | 13 months | 24 months | 3 years | p-value [a b] |
|---|---|---|---|---|
| Sitting time | | | | p<0.001 |
| mother | 4.0 (3.0) | 4.8 (3.1) | 5.3 (3.2) | |
| father | 6.7 (3.5) | 6.7 (3.3) | 7.5 (3.2) | |
| Screen time | | | | p<0.001 |
| mother | 1.9 (1.5) | 1.8 (1.4) | 1.9 (1.4) | |
| father | 2.2 (1.4) | 2.1 (1.4) | 2.4 (1.4) | |
| child*[c] | 10.0 (0.0, 30.0) | 51 (30.0, 77.1) | 69 (45.9, 90.0) | |

[a] = Wilcoxon rank sum test, [b] = at each measurement point, [c] = minutes

Mothers spent less time sitting at each measurement point (13 months, 24 months, 3 years) than fathers. Mothers spent time sitting on average 4 hours per day whereas fathers spent time sitting on average 6 hours and 42 minutes per day ($p<0.001$) when the child was 13 months old. One year later, at 24 months measurement point, mothers spent time sitting on average 4.8 hours (SD 3.1) and fathers 6.7 hours (SD 3.3) per day ($p<0.001$). When the children were 3 years, mothers spent on average 5.5 hours (SD 3.2) and fathers 7.5 hours (SD 3.2) time sitting per day ($p<0.001$). The screen time and LTPA, which was measured with metabolic equivalent (MET) - hours per week, also differed statistically significantly ($p<0.001$) between parents. (Study I) These results mean that mothers and fathers differ significantly in their physical activity and sedentary behavior habits when their children are 1−3 years old. Young children keep their mothers physically more active than they keep their fathers.

Children in day care had a lower screen time change than children never attending day care (59 minutes vs. 67 minutes, $p<0.05$). Children, whose fathers sat four hours or more daily, had smaller increase in screen time than children, whose fathers sat less than four hours per day (57 minutes vs. 69 minutes, $p \leq 0.001$). With mothers' screen time the results were similar, but controversial and with the exception that mothers with screen time less than two hours, rather than four, had children with lower screen time increase than children whose mothers' screen time was more than two hours (57 minutes vs. 69 minutes, $p<0.05$). Mother's higher education level, mother's younger age, and mother's working status (working other than full-time) were also associated with children's lower screen time change.

Finally, children with a lower BMI at the age of 13 months, had lower increase in screen time than their peers. (Table 10)

**Table 10**. Statistically significant factors affecting the screen-time change from 13 months to 36 months (F value) in the final model. The number of respondents may vary. (Modified from Matarma et al. 2016)

| | F value | estimates (se) | p-value |
|---|---|---|---|
| Sitting time 13 months, father | 11.29 | | 0.001 |
| 4 hours or less | | 69.3 (3.4) | |
| More than 4 hours | | 56.6 (2.5) | |
| Screen time 13 months, mother | 8.63 | | 0.004 |
| 2 hours or less | | 57.1 (2.3) | |
| More than 2 hours | | 68.7 (3.6) | |
| Education, mother | 6.97 | | 0.009 |
| Basic | | 68.13 (3.3) | |
| Advanced | | 57.7 (2.7) | |
| Age, mother | 6.39 | | 0.012 |
| All[a] | | 1.01 (0.4) | |
| BMI[b], child at 13 months | 6.02 | | 0.015 |
| All[c] | | 3.13 (1.3) | |
| Working status, mother | 5.76 | | 0.017 |
| Working full-time | | 67.5 (2.7) | |
| Other | | 58.3 (3.2) | |
| Day care child at 3 years of age | 5.56 | | 0.019 |
| Never in day care | | 67.3 (3.3) | |
| In day care | | 58.6 (2.6) | |

[a] Mother's age was analyzed as a numerous variable, and therefore given no classification
[b] Body mass index
[c] Classification was impossible, since no cut points exist for 13 months old children

Screen time change was first tested including also other variables (initial model). In the initial model, sitting time at 13 months of mother, screen time at 13 months of father, leisure-time physical activity at 13 months of mother, child's gender, income of the family, mother's BMI, and being a first child were statistically non-significantly associated with child's screen time change. (Study I)

### 5.3.2 Sedentary time of preschoolers

Of sedentary activities, watching TV/DVD, playing computer/console games, and drawing/doing handicrafts measured at the age of 5 years (n=546), 30.8%, 13.7%, and 11.4% of children, respectively, were engaged in these activities for more than 60 minutes per day. Girls and boys were similar in their TV/DVD watching habits, but statistically significantly (p<0.001) more boys (19.4%) played computer/console games >60 minutes per day than girls (7.3%). Of girls, 18.7% did drawing/handicrafts >60 minutes per day and this was a statistically significantly bigger proportion than that of boys with 4.6% (p<0.001). (Study III) These results show that boys and girls are different in their interests, as boys play more computer games than girls, and girls draw or do handicrafts more than boys at the age of 5 years.

Measured objectively with accelerometers at the age of 5.6 years (SD 0.3), there were no statistically significant differences between the genders in time spent sedentary (p=0.094). Boys spent 49.2% (SD 5.6) of their day equaling 6 hours 11 minutes as sedentary and girls spent 50.7% (SD 4.7) of their day equaling 6 hours 19 minutes as sedentary of the total wearing time of accelerometers. Comparing sedentary time with independent samples t-test with other background variables, sedentary time varied (p=0.032) between children whose mothers' had low moderate-to-vigorous physical activity (51.3%, SD 4.7) compared with children whose mothers had high moderate-to-vigorous physical activity (49.3%, SD 5.5). This indicates that children are less sedentary if their mothers are physically active. Compared with weight status, season, having siblings or no siblings, attending day care or never attending day care, attending organized physical activity or never attending organized physical activity, parents' educational level, or father's moderate-to-vigorous physical activity, no significant differences in children's sedentary time was observed. (Study II)

Analyzed with linear models, mother's sedentary time (slope=0.144) was associated with child's sedentary time (p=0.013). In addition, father's sedentary time and child's sedentary time were associated among fathers with higher education (sedentary time child, slope=0.186) compared with fathers with lower education (sedentary time child, slope=0.094) (p=0.017). (Table 11) Other variables, namely the season of the measurement, having siblings, attendance in day care, and attendance in organized physical activity, showed no statistically significant associations with children's sedentary time. (Study II)

**Table 11.** Child's sedentary time as a dependent variable, n=100. The results are in logarithmic (ln) scale. (Modified from Matarma et al. 2017).

| Sed time, child | | Slope | CI 95 % | p |
|---|---|---|---|---|
| Sed time, mother | | 0.144 | 0.03 to 0.26 | 0.013* |
| Sed time, father*educ. father | | Sed time: | | 0.017* |
| Education, father | Low | 0.094 | -0.26 to 0.07 | 0.257 |
| | High | 0.186 | 0.02 to 0.35 | 0.021* |

Sed time=Sedentary time, * $p<0.05$, adjusted for age, gender and BMI, $p=0.10$, $r^2=0.168$

# 5.4 Motor skills

## 5.4.1 Motor skills of 5–6-year-old children

Most of the children in the Study III (75.3%) and IV (82.9%) obtained average scores for total motor competence. In study III, 4.8% were below average and in study IV, 10% of children were below average. The children above average in their motor competence, had also higher scores in each composite of fine manual control (FM), manual control (MC), body coordination (BC), and strength and agility (SA) in both short and complete BOT-2 tests. (Table 12)

**Table 12.** Mean total standard scores (SD) and composite scores (point scores for short form and standardized scores for complete form) of children in study III and study IV, in groups of below average, average, and above average of BOT-2 normative sample (Bruininks & Bruininks 2005).

| **BOT-2 SHORT (Study III)** | n (%) | Mean (SD) total standard score | Mean (SD) FM point score sum | Mean (SD) MC point score sum | Mean (SD) BC point score sum | Mean (SD) SA point score sum |
|---|---|---|---|---|---|---|
| Below average | 34 (4.8) | 36.65 (3.7) | 5.18 (2.7) | 3.44 (1.3) | 7.62 (2.6) | 4.18 (2.5) |
| Average | 536 (75.3) | 51.76 (4.8) | 12.40 (3.7) | 5.87 (2.2) | 12.21 (2.1) | 9.15 (3.0) |
| Above average | 142 (19.9) | 63.7 (3.4) | 17.91 (3.2) | 8.60 (2.4) | 14.08 (1.2) | 12.49 (1.8) |
| **BOT-2 COMPLETE (Study IV)** | n (%) | Mean (SD) total standard score | Mean (SD) FM standardized composite score | Mean (SD) MC standardized composite score | Mean (SD) BC standardized composite score | Mean (SD) SA standardized composite score |
| Below average | 13 (10.1) | 38.00 (1.7) | 42.92 (6.6) | 41.15 (4.5) | 38.00 (4.3) | 41.62 (4.8) |
| Average | 107 (82.9) | 50.33 (5.3) | 53.91 (7.5) | 48.03 (6.0) | 49.59 (6.5) | 50.82 (6.1) |
| Above average | 9 (7.0) | 65.89 (4.4) | 64.56 (7.7) | 56.56 (3.6) | 61.56 (4.1) | 61.33 (4.6) |

Measured with short BOT-2 motor skills test at the mean age of 5.1 years, the mean score for total point score and total standard score of children (n=712) was 41.4 (SD 9.0) and 53.4 (SD 7.6), respectively. Boys (n=372) and girls (n=340) differed statistically significantly (p<0.001) in total point scores (boys 39.0 (SD 9.0), girls 44.07 (SD 8.2)) and in total standard scores (boys 52.32 (SD 7.4), girls 54.62 (SD7.5)). (Study III)

Measured with complete BOT-2 motor skills test at the age of 5.6 years, the mean scores of children (n=111) aged 5.57 years (SD 0.4) for motor skills composites were 52.40 (SD 10.6) for fine manual control, 27.09 (SD 6.7) for manual coordination, 40.01 (SD 8.1) for body coordination, and 35.15 (SD 7.3) for strength and agility as total point scores. Motor skills scores were standardized against predefined norms for different age groups by sex. Norms were provided by the test manufacturer (Bruininks & Bruininks 2005). (Study IV)

Of 14 single tasks, statistically significant differences (p<0.001) were found in eight of the tasks between boys and girls, in favor of girls. Boys had slightly higher scores than girls in upper-limb coordination tasks (*dropping and catching a ball - both hands and dribbling a ball - alternating hands*) and in one task of strength (*push-ups*). However, none of these differed statistically significantly between genders. Girls were statistically significantly better in all four fine motor tasks (p<0.001), in body coordination tasks (p<0.001) of *jumping in place - same sides synchronized* and *standing on one leg on a balance beam - eyes open*, and in strength and agility tasks (p<0.001) of *one-legged stationary hop* and *sit-ups*. (Table 13) (Study III) The results of all tasks are presented in detail in the original publication.

On a practical level, 52.2% of boys and 86.2% of girls made five or less errors in *drawing lines through paths - crooked* -task (fine motor precision). Of boys 62.1% (mean 3.98, SD 1.7) and of girls 75.0% (mean 4.47, SD 1.2) (p<0.001) got full five points for *copying a square* (fine motor integration), whereas 13.2% of boys and 5.9% of girls failed to copy a square (0 points).

**Table 13.** Mean point scores (SD) and percentage distributions in fine manual control tasks (0−7 points) and body coordination tasks (0−4 points) of BOT-2 short form for boys (n=372) and girls (n=340) with p-values.

| FINE MANUAL CONTROL | Gender | Mean score (SD) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Drawing lines through paths – crooked | Boys | 4.38 (1.7) | 1.6 | 1.6 | 9.7 | 21.0 | 15.9 | 25.3 | 10.5 | 14.5 | <0.001 |
| | Girls | 5.14 (1.4) | 0.3 | | 4.4 | 9.1 | 15.6 | 31.2 | 16.5 | 22.9 | |
| Folding paper | Boys | 2.66 (1.9) | 14.0 | 16.7 | 20.4 | 17.7 | 12.1 | 12.1 | 3.0 | 4.0 | <0.001 |
| | Girls | 3.85 (1.9) | 5.0 | 7.9 | 10.0 | 20.9 | 16.5 | 20.0 | 9.7 | 10.0 | |
| Copying a square | Boys | 3.98 (1.7) | 13.2 | 0.3 | 1.1 | 8.9 | 14.5 | 62.1 | | | <0.001 |
| | Girls | 4.47 (1.2) | 5.9 | 0.3 | 0.3 | 2.9 | 15.6 | 75.0 | | | |
| Copying a star | Boys | 0.67 (1.5) | 80.9 | 0.3 | 3.0 | 5.4 | 7.3 | 3.2 | | | <0.001 |
| | Girls | 1.30 (1.9) | 65.0 | 0.6 | 2.1 | 11.8 | 12.6 | 7.9 | | | |

| BODY COORDINATION | Gender | Mean score (SD) | 0 | 1 | 2 | 3 | 4 | p-value |
|---|---|---|---|---|---|---|---|---|
| Jumping in place - same sides synchronized | Boys | 2.01 (1.2) | 22.6 | 6.5 | 18.0 | 53.0 | | <0.001 |
| | Girls | 2.41 (1.0) | 11.8 | 3.8 | 15.6 | 68.8 | | |
| Tapping feet and fingers - same sides synchronized | Boys | 3.66 (1.0) | 5.4 | | 2.2 | 8.6 | 83.9 | 0.52 |
| | Girls | 3.70 (0.9) | 4.1 | 0.6 | 1.8 | 8.2 | 85.3 | |
| Walking forward on a line | Boys | 3.97 (0.3) | 0.5 | | 0.5 | | 98.9 | 0.33 |
| | Girls | 3.99 (0.2) | 0.3 | | | | 99.7 | |
| Standing on one leg on a balance beam | Boys | 2.21 (1.2) | 3.8 | 29.0 | 29.0 | 18.8 | 19.4 | <0.001 |
| | Girls | 2.83 (1.1) | 2.4 | 10.9 | 28.2 | 18.2 | 40.3 | |

Half of the boys (53.0%) and two thirds of the girls (68.8%) performed full five *jumps in place with same sides synchronized* whereas 22.6% of boys and 11.8% of girls failed to perform any correct jumps (bilateral coordination). For balance, 19.4% of boys and 40.3% of girls could stand full ten seconds *on one leg on a balance beam* ($p<0.001$). For running speed and agility, 57.4% of boys and 65.0% of girls managed to perform more than 30 *one-legged stationary hops* during 15 seconds. Finally, 12.4% of boys and 6.5% of girls failed to perform any *sit-ups* (0) and the majority of boys (29.0%) and girls (36.8%) succeeded in 6–10 sit-ups during 30 seconds (Strength). (Study III).

At the age of 5 years, the Spearman correlation coefficients between the 14 tasks and the total point score varied between 0.105–0.589 and they were all of statistical significance ($p<0.001$). The highest correlations with total point score were *one-legged stationary hop* ($r_s=0.589$) and *drawing lines through paths - crooked* ($r_s=0.556$) and the lowest were *walking forward on a line* ($r_s=0.105$) and t*apping feet and fingers - same sides synchronized* ($r_s=0.327$). Among boys (n=372) the highest correlations with total point score were *one-legged stationary hop* ($r_s=0.616$) and *sit-ups* ($r_s=0.518$), whereas within girls (n=340) the highest correlations were *drawing lines through paths - crooked* ($r_s=0.563$) and *standing on one leg on a balance beam - eyes open* ($r_s=0.525$). The lowest correlations were the same among boys and among girls. (Study III)

### 5.4.2 Variables associated with motor skills

The variables that were studied against motor skills were objectively measured physical activity and sedentary time, daily activities (drawing or doing handicrafts, physically active play, watching TV or DVD, and playing computer or console games), body fat percentage and body weight, attendance in day care, and parental education.

#### 5.4.2.1 Physical activity and sedentary time

At the mean age of 5.1 years, drawing or doing handicrafts > 60 minutes per day was associated with better fine manual control skills (mean 14.95, CI 95% 13.64 to 16.26) compared to those drawing or doing handicrafts less (mean 12.36, CI 95% 11.57 to 13.16) ($p<0.001$).

**Table 14.** ANCOVA models with summed point scores of fine manual control (Model FM) and strength and agility (Model SA) as dependent variables, n=506.

| Model FM, p<0.001, $r^2$=0.193 | | Marginal mean | 95% CI | p |
|---|---|---|---|---|
| Gender | Boy | 12.15 | 11.14 to 13.17 | <.001** |
| | Girl | 15.16 | 14.19 to 16.13 | |
| Drawing/handicrafts daily | > 60 minutes | 14.95 | 13.64 to 16.26 | <.001** |
| | < 60 minutes | 12.36 | 11.57 to 13.16 | |
| TV/DVD daily | > 60 minutes | 13.27 | 12.21 to 14.33 | .053 |
| | < 60 minutes | 14.04 | 13.11 to 14.97 | |
| Computer/console daily | > 30 minutes | 13.20 | 11.97 to 14.43 | .093 |
| | < 30 minutes | 14.11 | 13.26 to 14.97 | |
| Play outdoors daily | > 60 minutes | 13.64 | 12.70 to 14.58 | .940 |
| | < 60 minutes | 13.67 | 12.63 to 14.72 | |
| Siblings | Yes | 13.93 | 13.16 to 14.70 | .326 |
| | No | 13.38 | 12.08 to 14.68 | |
| Attendance in day care | Yes | 13.69 | 12.84 to 14.54 | .887 |
| | No | 13.62 | 12.43 to 14.82 | |
| Education, father | High | 13.71 | 12.70 to 14.73 | .757 |
| | Low | 13.60 | 12.64 to 14.56 | |

| Model SA, p<0.001, r2=0.064 | | Marginal mean | 95% CI | p |
|---|---|---|---|---|
| Gender | Boy | 8.25 | 7.44 to 9.05 | <.001** |
| | Girl | 9.60 | 8.83 to 10.37 | |
| Attendance in day care | Yes | 9.39 | 8.71 to 10.06 | 0.017* |
| | No | 8.46 | 7.51 to 9.41 | |
| Play outdoors daily | > 60 minutes | 9.25 | 8.50 to 10.00 | 0.034* |
| | < 60 minutes | 8.59 | 7.77 to 9.42 | |
| Drawing/handicrafts daily | > 60 minutes | 8.91 | 7.87 to 9.95 | .953 |
| | < 60 minutes | 8.94 | 8.30 to 9.57 | |
| TV/DVD daily | > 60 minutes | 8.72 | 7.88 to 9.56 | .199 |
| | < 60 minutes | 9.13 | 8.39 to 9.86 | |
| Computer/console daily | > 30 minutes | 9.17 | 8.20 to 10.15 | .245 |
| | < 30 minutes | 8.67 | 7.99 to 9.35 | |
| Siblings | Yes | 9.31 | 8.69 to 9.92 | .085 |
| | No | 8.54 | 7.77 to 9.42 | |
| Education, father | High | 9.04 | 8.24 to 9.85 | .401 |
| | Low | 8.80 | 8.04 to 9.56 | |

* p<0.05, ** p<0.001

Playing outdoors physically actively 60 minutes or more per day was associated with better strength and agility scores (mean 9.25, CI 95% 8.50 to 10.00) compared to those being less active (mean 8.59, CI 95% 7.77 to 9.42) ($p<0.001$). (Table 14) (Study III) These or any other activity variables (TV/DVD watching and playing computer/console games) were unassociated with these or other motor skills, namely summed point scores of manual coordination or body coordination. (Study III)

From the data on Motor Skills and Physical Activity Study participants (n=129), each motor skills composite standardized for age and sex was visually examined with moderate-to-vigorous physical activity and sedentary time separately in scatter plots without taking other variables into account as yet. The regression lines' declines and inclinations were mild or even flat. Mild inclinations were seen for each motor skills composite with moderate-to-vigorous physical activity, of which manual coordination and moderate-to-vigorous physical activity dyad showed highest inclination ($r^2=0.019$). (Figure 7)

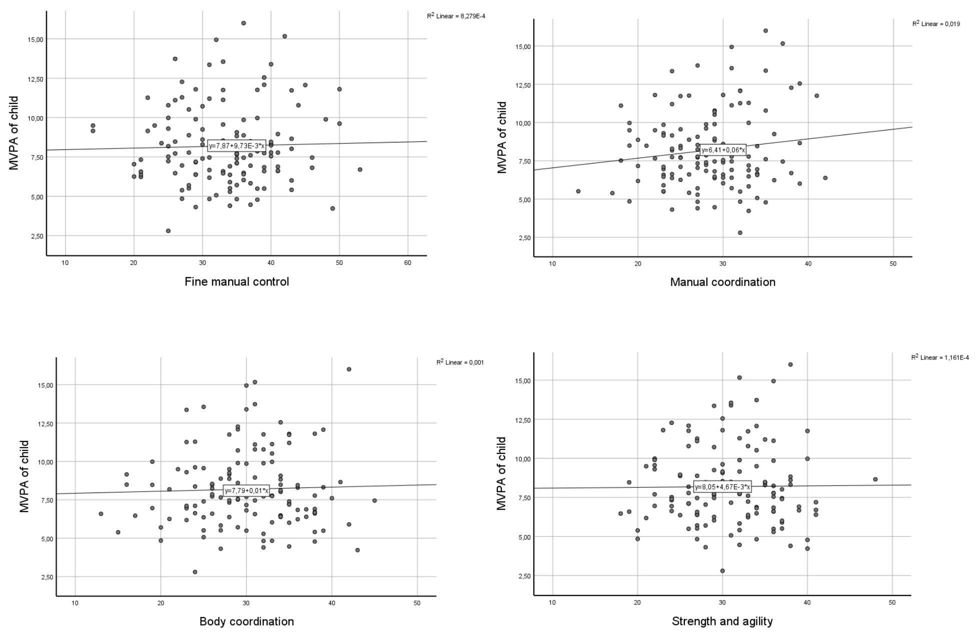


**Figure 7.** Scatter plots with regression lines on associations between moderate-to-vigorous physical activity and motor skills composites, n=129. (Modified from Matarma et al. 2018)

The associations between sedentary time and motor skill composites were slightly steeper than with moderate-to-vigorous physical activity.

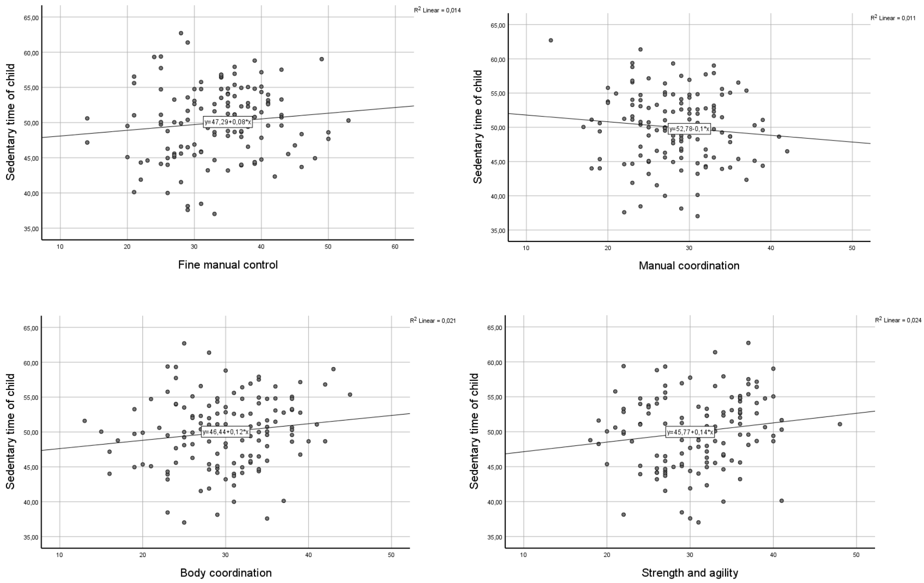


**Figure 8.** Scatter plots with regression lines on associations between sedentary time and motor skills composites, n=129. (Modified from Matarma et al. 2018)

For fine manual control, body coordination, and strength and agility the regression lines were inclining and only for manual coordination the line was declining as expected. Thus, the higher sedentary time children had, the higher scores they had in all motor skills composites except in manual coordination. (Figure 8)

When examined further with linear models, no associations were found for any of the motor skill composites (fine manual control, manual coordination, body coordination, strength and agility) measured with BOT-2 complete form and moderate-to-vigorous physical activity or sedentary time measured objectively with accelerometers among 5–6-year-old children. (Table 15, Table 16) (Study IV) However, other variables were found associated with some of the motor skill composites, namely with body coordination and strength and agility composites, and these results are presented next.

**Table 15.** Statistically significant linear regression models with body coordination (Model 1) and strength and agility (Model 2) as a dependent variable with means, slopes, 95% confidence intervals (CI), and p-values, n=106. (Modified from Matarma et al. 2017)

| Model 1. $p<0.001$, $r^2=0.256$ | | Marginal mean | Slope (β) | 95% CI | p |
|---|---|---|---|---|---|
| Day care attendance | Yes | 40.22 | | 38.26 to 42.18 | .028* |
| | No | 34.87 | | 30.43 to 39.31 | |
| MVPA (%) | | | 0.164 | -.448 to .776 | .596 |
| Sex * fat mass % | | | Fat mass %: | | .018* |
| | Boys | | 0.481 | -.083 to1.046 | .094 |
| | Girls | | - 0.346 | -.698 to .005 | .053 |

| Model 2. $p<0.001$, $r2=0.328$ | | Marginal mean | Slope (β) | 95% CI | p |
|---|---|---|---|---|---|
| Day care attendance | Yes | 35.69 | | 33.98 to 37.40 | .007* |
| | No | 29.91 | | 26.05 to 33.78 | |
| MVPA (%) | | | 0.028 | -.505 to .561 | .918 |
| Sex * fat mass % | | | Fat mass %: | | .018* |
| | Boys | | 0.031 | -.461 to .523 | .900 |
| | Girls | | - 0.690 | -.996 to -.384 | <.001** |

* $p<0.05$, ** $p<0.001$

**Table 16.** Statistically significant linear regression models with body coordination (Model 1) and strength and agility (Model 2) as a dependent variable with means, slopes, 95% confidence intervals (CI), and p-values, n=106. (Modified from Matarma et al. 2017)

| Model 1. $p<0.001$, $r^2=0.256$ | | Marginal mean | Slope (β) | 95% CI | p |
|---|---|---|---|---|---|
| Day care attendance | Yes | 40.09 | | 38.09 to 42.09 | .027* |
| | No | 34.72 | | 30.38 to 39.07 | |
| Sedentary time (%) | | | 0.079 | -.213 to .371 | .595 |
| Sex * fat mass % | | | Fat mass %: | | .036* |
| | Boys | | 0.417 | -.154 to .988 | .150 |
| | Girls | | - 0.335 | -.689 to .019 | .064 |

| Model 2. $p<0.001$, $r2=0.338$ | | Marginal mean | Slope (β) | 95% CI | p |
|---|---|---|---|---|---|
| Day care attendance | Yes | 35.47 | | 33.74 to 37.20 | .011* |
| | No | 30.14 | | 26.38 to 33.89 | |
| Sedentary time (%) | | | 0.157 | -.095 to .410 | .219 |
| Sex * fat mass % | | | Fat mass %: | | .045* |
| | Boys | | - 0.046 | -.540 to .447 | .854 |
| | Girls | | - 0.667 | -.973 to .360 | <.001** |

* $p<0.05$, ** $p<0.001$

### 5.4.2.2 Body composition and body weight

At the age of 5.6 years, the standard scores of motor skills were statistically significantly lower ($p<0.05$) for overweight/obese compared with healthy weight children in total motor score and in each composite ($p<0.05$) except fine manual control ($p=0.146$). (Table 17) (Study IV)

**Table 17**. Descriptive table of motor skills in children categorized with BMI to healthy weight and overweight including obese, analyzed with independent samples t-test. (Modified from Matarma et al. 2017)

| | Healthy weight n=92 | Overweight/obese n=19 | p |
|---|---|---|---|
| Fine manual control[a] | 54.4 (9.3) | 51.16 (5.9) | .146 |
| Manual coordination[a] | 48.63 (6.6) | 43.79 (5.6) | .003* |
| Body coordination[a] | 50.26 (7.7) | 45.11 (8.2) | .011* |
| Strength and agility[a] | 51.49 (6.7) | 45.85 (8.1) | .002* |
| Total motor score[a] | 51.37 (7.7) | 44.89 (6.7) | <.001* |

[a] standardized scores, * $p<0.05$

Analyzed with linear models with moderate-to-vigorous physical activity in the model, the interaction of sex and body fat percentage was statistically significantly associated with body coordination ($p=0.018$) in 5 to 6 year-old children ($n=106$) showing positive association for girls and negative for boys. The interaction of sex and body fat percentage was also statistically significantly associated with strength and agility ($p=0.018$) and among girls the body fat percentage was negatively and statistically significantly associated (slope -0.690, $p<0.001$). (Table 15) (Study IV) Body fat percentage was unassociated with other motor skill composites, namely fine manual control and manual coordination. (Study IV) The results show that body fat % was significantly different between boys and girls and this difference interacted with both body coordination and strength and agility scores. These results show that girls with higher body fat % were less competent in strength and agility than girls with lower body fat %.

When replacing moderate-to-vigorous physical activity with sedentary time and repeating the analyses in the same manner, the results were similar to the ones when moderate-to-vigorous physical activity was used in the model. Thus, same variables were associated with the same motor skills composites in a similar manner. Moreover, statistically non-significant slopes were positive with sedentary time and motor skill composites of body coordination and strength and agility. (Table 16)

### 5.4.2.3 Other factors (Study III, Study IV)

Children who attended day care outside home, were more competent in their motor skills than the peers not attending day care outside home in Study IV. (Figure 9, Figure 10)

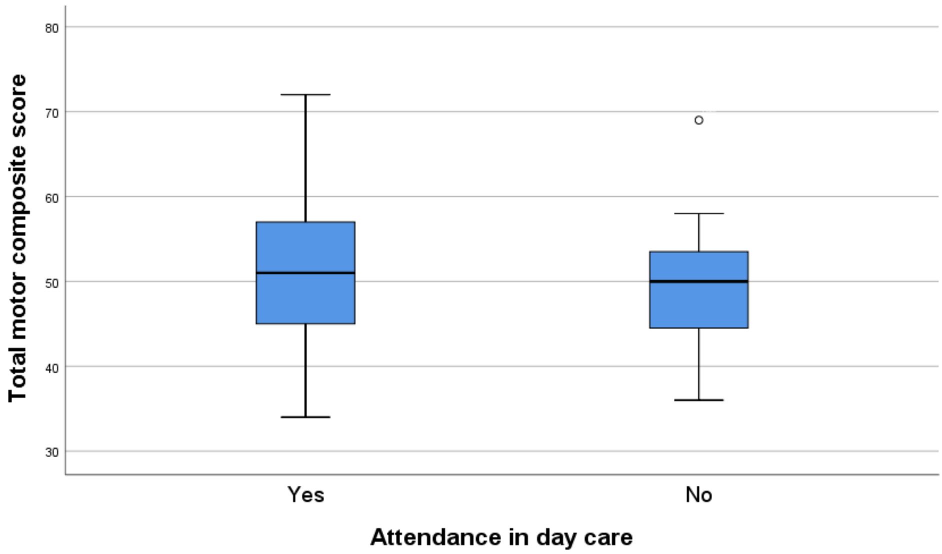


**Figure 9.** Standardized total motor composite score of children attending day care (n=98) and not attending day care (n=23) outside home among children with valid complete BOT-2 test and valid accelerometers measures.

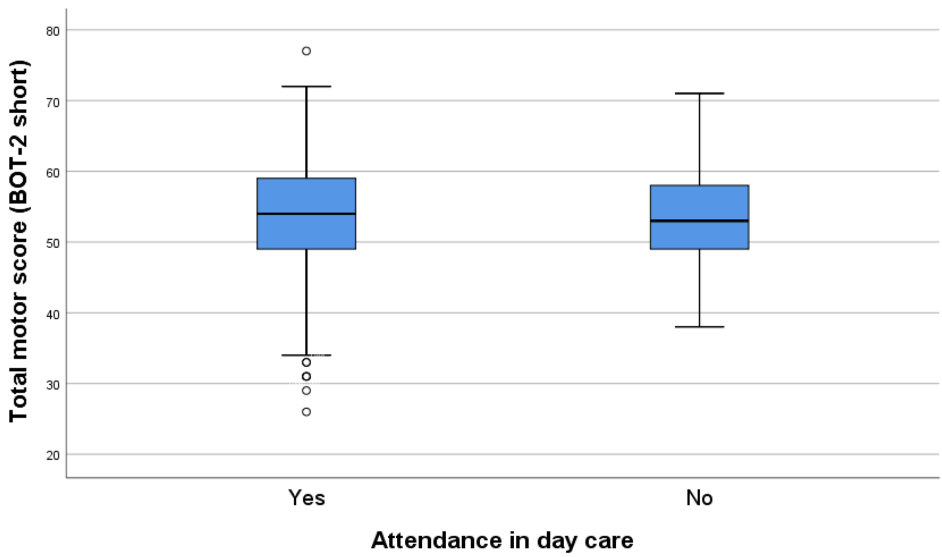


**Figure 10.** Standardized total motor score of children attending day care (n=461) and not attending day care (n=89) outside home among children with valid short BOT-2 test.

Tested with short BOT-2 test at the age of 5.1 years, the differences between children attending day care and not attending day care outside home were not large when inspected visually (Figure 10). At the age of 5.6 years, measured with complete BOT-2 test, children appeared more competent in their total motor skills, if they attended day care (Figure 9).

Analyzed with linear models (n=106), the attendance in day care was positively and statistically significantly associated with body coordination (p=0.028) and with strength and agility (p=0.007) in 5.6 years old children. (Table 15) (Study IV) Analyzed with ANCOVA from 5-year-old children (n=506), children attending day care had better scores in strength and agility (mean 9.39, CI 95% 8.71 to 10.06) than children never attending day care (mean 8.46, CI 95 % 7.51 to 9.41) (p=0.017). (Table 14) (Study III) Day care attendance was unassociated with summed scores of fine manual control and manual coordination in 5-year-old children, in Study III.

Children with higher educated fathers had better scores in body coordination (mean 12.30, CI 95% 11.73 to 12.87) than children with lower educated fathers (mean 11.83, CI 95% 11.29 to 12.36) (p=0.020). (Table 18) (Study III)

**Table 18.** ANCOVA models with summed point scores of body coordination (Model 1) as a dependent variable, n=506.

| Model BC, p<0.001, r2=0.080 | | Marginal mean | 95% CI | p |
|---|---|---|---|---|
| Gender | Boy | 11.50 | 10.94 to 12.07 | <.001** |
| | Girl | 12.62 | 12.08 to 13.16 | |
| Education, father | High | 12.30 | 11.73 to 12.87 | .020* |
| | Low | 11.83 | 11.29 to 12.36 | |
| TV/DVD daily | > 60 minutes | 11.98 | 11.63 to 12.67 | .437 |
| | < 60 minutes | 12.14 | 11.38 to 12.57 | |
| Computer/console daily | > 30 minutes | 11.91 | 11.21 to 12.60 | .302 |
| | < 30 minutes | 12.22 | 11.74 to 12.70 | |
| Drawing/handicrafts daily | > 60 minutes | 11.85 | 11.12 to 12.59 | .202 |
| | < 60 minutes | 12.27 | 11.83 to 12.72 | |
| Play outdoors daily | > 60 minutes | 12.27 | 11.74 to 12.80 | 0.58 |
| | < 60 minutes | 11.86 | 11.27 to 12.44 | |
| Siblings | Yes | 12.25 | 11.82 to 12.68 | .237 |
| | No | 11.88 | 11.15 to 12.61 | |
| Attendance in day care | Yes | 11.92 | 11.44 to 12.39 | .290 |
| | No | 12.21 | 11.54 to 12.88 | |

* p<0.05, ** p<0.001

# 6 Discussion

## 6.1 Main findings

The main finding in this thesis was that objectively measured physical activity and sedentary time were unassociated with any motor skills types in 5 to 6 years old children. Instead, associations were found between body fat percentage and body coordination and body fat percentage and strength and agility, but the association was lacking between body fat percentage and fine manual control or manual coordination. Moreover, healthy weight children had better scores than their overweight or obese peers in all motor composites except in fine manual control. Attendance in day care and parents' higher education were positively associated with some types of motor skills. Parental physical activity and sedentary behavior were associated with those of the children. Mothers' and child's moderate-to-vigorous physical activity (5 to 6 years old), mothers' and child's sedentary time (5 to 6 years old), and mothers' and child's screen time (1 to 3 years old) were all positively associated. When motor skills were compared between genders in children of the same age, girls outperformed boys in almost all tasks. Boys spent more time being physically active outdoors than girls (5 years old), but no interaction was found between time spent outdoors and gender for motor skills, even though being physically active outdoors was associated with strength and agility. Girls also spent more time drawing/doing handicrafts than boys, but only drawing/doing handicrafts was associated with fine manual control and no interaction of gender and drawing/doing handicrafts were found.

## 6.2 Motor skills, physical activity, sedentary time, and body fat % associations

### 6.2.1 Physical activity, sedentary time, and motor skills

In this study, no associations were found between objectively measured physical activity or sedentary time and any motor skills types when children were 5 to 6 years old. Controversial results exist on physical activity and motor skills associations in young children. The controversial results of positive association found and not found

(Holfelder & Schott 2014) may exist because different methods were used in studies such as Movement Assessment Battery, second edition (MABC-2) (Fisher et al. 2005; Kokstejn et al. 2017), the Test of Gross Motor Development, second edition (TGMD-2) (Barnett et al. 2013; Foweather et al. 2015), Peabody Developmental Motor Scales - Second Edition (PDMS-2) (Veldman et al. 2018b) or Bruininks-Oseretsky Test, second edition (BOT-2) (this study). For instance, when assessed with TGMD-2, the moderate-to-vigorous physical activity (MVPA) and motor skills have been significantly associated (Morgan et al. 2008; Barnett et al. 2013; Foweather et al. 2015). The study sample of Foweather et al. (2015) was however composed of toddlers, whereas the study of Morgan et al. (2008) and Barnett et al. (2013) included preschool-aged children with mean ages of 8.3 years and 4.1 years, respectively. With PDMS-2 and a sample of toddlers as well, the association with moderate-to-vigorous physical activity was not found (Veldman et al. 2018b). Measured with MABC with 4-year-old children in the study, the association between fundamental motor skills and moderate-to-vigorous physical activity was significant, but weak (Fisher et al. 2005).

When comparing the results of studies that have used the BOT-2 or BOTMP as a method for motor skills assessment and accelerometers (Wrotniak et al. 2006; Santos et al. 2018) or questionnaires (Morrison et al. 2018) for physical activity assessment, they all show positive association between physical activity and motor skills. The associations are weak but indicative and the samples consist of 8 to 11 years old children. For instance, positive correlation of 0.226 (p=0.025) was found for moderate physical activity and strength and agility (Santos et al. 2018). Motor skills total score and activity counts per minute, moderate physical activity, and moderate-to-vigorous physical activity were correlated with correlations of 0.30–0.33 (Wrotniak et al. 2006), and physical activity participation and motor skills had low correlations among boys (0.191) and girls (0.185) (Morrison et al. 2018). In the Wrotniak et al. (2008) study also sedentary time was significantly associated with motor skills. The associations were weak but statistically significant with correlation of -0.31 (p=0.012).

The assessment methods are all very different even though they measure the same thing in general, thus, motor skills. However, in more detail, the MABC-2 has only eight tasks, TGMD-2 measured the process of the skills with qualitative methods, and BOT-2 measures similar but a wider variety of skills than MABC-2. The product-oriented tests such as MABC-2 and BOT-2 assess the quantitative results whereas the process-oriented tests such as TGMD-2 assess the qualitative aspects of movements. Some studies have compared different methods for motor skills assessment. It is reported that in detecting motor impairments, the BOTMP, M-ABC, and Developmental Coordination Disorder Questionnaire showed less than 80% overall agreement between the methods (Crawford et al. 2001). Between

Körperkoordinationtest für Kinder (KTK) and BOT-2 short form, from weak to high correlations have been found between different composites. Weak correlations were found between KTK Motor Quotient and BOT-2 short form fine motor composite score and moderately high correlation between total and gross motor scores between tests. It was also suggested that different assessment tools should be used because of low agreement in children within low and high competence levels (Fransen et al. 2014). Logan et al. (2016) suggested the use of both product- and process -oriented tests when assessing motor skills levels of children. This conclusion is due to former studies in comparing the tests with different orientations and their own results of comparison between TGMD-2 and Get Skilled Get Active tests (Logan et al. 2016). The former results between developmental sequences (such as whole-body developmental sequences (see also Gallahue et al. 2012, 234–235)) and quantitative scores (such as the distance of standing long-jump) have been mixed (Roberton & Koczak 2001; Stodden et al. 2006a; Stodden et al. 2006b; Fountain et al. 1981 in Logan et al. 2016).

The different methods for measuring physical activity also complicate the comparability of the results (Kokstejn et al. 2017). For instance, some specific associations were found earlier such as positive association between object control skills and light physical activity on weekdays (Foweather et al. 2015) or playing with parents with better gross motor skills among boys only (Sääkslahti et al. 1999). When it comes to accelerometers, they are poor at detecting the type and place of physical activity and the upper body movements when worn on hip (Kelly et al. 2016; Lee & Shiroma 2014). Even with their limitations in some aspects as described above, accelerometers have been proven to be valid at detecting different intensity levels of physical activity as well as overall physical activity (Rowlands & Eston 2007; Lee & Shiroma 2014). The activity counts cut points however vary between studies and it may affect the results (Bornstein et al. 2011; Janssen et al. 2013). For instance, in a study of 4.5-year-old children, the cut point for moderate-to-vigorous physical activity was 2000 counts measured with Actigraphs (Spittaels et al. 2012) and in a study with 4-year-old children it was 1600 measured with Actihearts (Hesketh et al. 2014b). These studies produced different amounts of moderate-to-vigorous physical activity, i.e. 12% (Hesketh et al. 2014b) and 8% (Spittaels et al. 2012). In Finnish studies both Soini (2013) and Laukkanen (2015) with their colleagues used a cut point of 2340 for moderate-to-vigorous physical activity and they found that children at the age of 3 years (Soini et al. 2013) and at the age of 5 years (Laukkanen et al. 2015) spent on average 9% and approximately 6% of their days in moderate-to-vigorous physical activity, respectively. In the study at hand, the cut point for moderate-to-vigorous physical activity was then again 2293 (Evenson et al. 2008) and children spent on average 8% of their days in moderate-to-vigorous physical activity.

In this study with the objective measures and complete version of BOT-2 at the average age of 5.6 years, no associations were found between physical activity or sedentary time and motor skills, but when measured earlier with the questionnaires and the short version of BOT-2 at the average age of 5.1 years, some associations were found. Children’s physically active play outdoors was indeed associated with strength and agility, however, with other motor skills types (fine manual control, manual coordination, and body coordination) the association was lacking. It can be speculated that playing outdoors is perhaps versatile and encourages children to test their limits and thus practice their motor skills (Gallahue et al. 2012, 54, 174, 187). In a systematic review by Gray et al. (2015) it was shown that even though motor skills were found to be inconsistently associated with outdoor time, they were associated with physical activity, sedentary behavior, and cardiorespiratory fitness. The association between outdoor time and motor skills was measured only in one study and revealed a positive association (Sääkslahti et al. 1999). Later in a Finnish study it was found that 4-year-old children attending day care had statistically significantly higher levels of physical activity in outdoor settings than in indoor settings (Iivonen et al. 2016). In addition, also motor skills were almost statistically significantly higher in children who showed more outdoor physical activity intervals in the study in question (Iivonen et al. 2016). Accelerometers fail to measure the versatility of physical activity as stated earlier. This may explain the different results between studies, measured with different methods in this study as well as in earlier studies (Holfelder & Schott 2014). Thus, the amount of physical activity may be less important for motor skills development than the versatility and quality of motor skills practice, which often happens through play in early childhood and perhaps rather outdoors than indoors. Indeed, when practicing fundamental motor skills, the skills develop better when more frequent and versatile opportunities are provided for children (Gallahue et al. 2012, 52, 187).

Mother's screen time associated with their children's screen time change (change from 13 months to 3 years), so the parental role in sedentary behavior tracking may be of importance. The parental role is discussed in a later chapter. Some associations between motor skills and sedentary time have been found earlier. For instance, measured with Children’s Activity and Movement in Preschool Study (CHAMPS) with 3–4-year-old children, children with lower scores in locomotor and object control skills had higher sedentary time percentages compared with children with intermediate and higher scores (Williams et al. 2008). However, the differences between low and intermediate and low and high level of locomotor skills and sedentary time were statistically significant. Statistical non-significance was found between object control skills levels and sedentary time. Statistical significance between locomotor skills and sedentary time was detected in all children and in 4-year-olds, but undetected in 3-year-olds (Williams et al. 2008). In a study with KTK and objectively measured sedentary time and children aged 5–8 years, gross motor skills associated negatively with sedentary time among preschool boys (Laukkanen et al. 2014). In addition, height jumping (one of the items in KTK -test) also correlated with sedentary time in preschool boys (Laukkanen et al. 2014). The results of this thesis are controversial compared with the above mentioned. The reason for the absence of the association between motor skills and sedentary time can be for instance methodological as discussed earlier in the section on accelerometer measurement issues.

Overall, depending on the measurement method for physical activity, association between motor skills and physical activity was found for one type of motor skill, i.e. strength and agility, in this study. Even though this one association between physically active play outdoors and strength and agility was found, it is no strong evidence for physical activity and motor skills association in early childhood. Indeed, as proposed by Stodden et al. (2008), the association may strengthen when children approach middle or later childhood and that may well happen with the children in this study as well. To support this thought, the findings of Wrotniak and colleagues suggest that 8 to 10 years old children with the highest motor skills were also physically more active than children with lower scores. In fact, children in the lower tertiles had all similar physical activity levels (Wrotniak et al. 2006).

The assessment methods for both motor skills and physical activity are numerous. Each of the measures assesses certain aspects of the behavior or skill. The results of this study and the earlier findings may indicate that in the development and practicing of motor skills, attention should be paid to many other aspects in addition to the amount of physical activity. The quality and versatility of physical activity may be more important than the amount, in the means of motor skills development. However, the amount of physical activity should not be overlooked because the recommended levels of physical activity have positive health effects. To sum up, the association between motor skills and objectively measured physical activity in early childhood may not be visible as yet, but the association may become stronger in later childhood as the earlier studies indicate. Or, the versatility rather than the amount or intensity of physical activity already in the early childhood is more important for motor skills development, as was shown in this study when physical activity was assessed with outdoor physical activity with questionnaires, which is assumed to indicate versatility. Finally, the assessment methods vary between studies and when comparing the results, attention must be paid to what is measured and how before drawing conclusions on physical activity and motor skills associations.

### 6.2.2 Overweight and obesity with motor skills and physical activity

Rather than physical activity or sedentary time, in this study a child's body weight and body composition were associated with motor skills. Healthy weight children had better scores in motor skills than their overweight/obese peers in 5–6-year-old children in our study. Also, body fat percentage in girls was associated with some types of motor skills. Similar results have been found in earlier studies. (Lopes et al. 2012; Gentier et al. 2013; Barnett et al. 2016a; Augustijn et al. 2018) In the Barnett et al. (2016a) review including children aged 3 to 18 years it was concluded that higher BMI was negatively associated with motor coordination, measured with the KTK-test. No evidence for object control and BMI association was found, locomotor skills and BMI association revealed indeterminate results, and higher waist circumference and body fat percentage were found to be negatively associated with motor competence. Lopes et al. (2012) found that the negative correlation between motor coordination and BMI strengthens in children from 6 to 11 years. Gross motor skills as well as fine manual skills were weaker in obese children compared with healthy weight children based on another study with children aged 7 to 13 years (Gentier et al. 2013). In a recent longitudinal study, it was found that higher BMI predicted lower scores in standing long jump in 3–5-year-old children. Also, other tasks were tested within the motor skills test battery but no other associations were found between BMI and e.g. running speed, balance, or throwing a tennis ball (Antunes et al. 2018). With 9-year-old children, the motor competence was lower in obese children than healthy weight children, and this occurred in body bearing skills such as balance and also in manual dexterity and general motor competence (Augustijn et al. 2018). Moreover, in another study it was concluded that obesity at the age of 5 years affects motor skills negatively in middle childhood. However, the poorer motor skills failed to predict obesity. In addition, the differences in motor skills between healthy weight, overweight, and obese children seemed to increase with age. Thus, obese children had poorer motor skills at the ages 5 and 10 years (Cheng et al. 2016). Even though different methods were used (from BMI to waist circumference and from KTK to BOT-2 for instance) in these studies, based on the evidence of earlier research and this study it is concluded that BMI or body composition may have a strong impact on many types of motor skills as well as total motor competence in early childhood. The impact seems to be stronger at the school age. It has also been previously suggested that developing positive motor competence pathways could help to protect children from overweight and obesity. Indeed, if children failed to develop in their motor skills as much as their peers during primary school, they were many times more at risk of becoming overweight or obese (Rodrigues et al. 2016).

When it comes to weight or body composition associations with physical activity, no statistically significant associations between different physical activity intensity levels with weight status or BMI were found in this study at hand. Physical activity levels are argued to be associated with body fat percentage (Gallahue et al. 2012, 255). However, body weight, BMI, or adiposity are constantly found unassociated with physical activity in early childhood (Sallis et al. 2000; Hinkley et al. 2008; Bingham et al. 2016). It must be noted, that in this study, the normal weight children had higher physical activity on all intensity levels than their overweight/obese peers, but the differences remained statistically non-significant. Thus, early childhood may be the critical period in developing a physically active lifestyle and protecting children from overweight and obesity. If adequate physical activity is insufficiently adopted in early childhood that may lead to a negative spiral of engagement and eventually to an increased risk of obesity (Stodden et al. 2008), even though the correlation would be invisible in the early childhood. Some studies, however, have found significant associations between weight status and physical activity. Namely, in 3–5-year-old children, overweight and physical activity were associated among boys (Trost et al. 2003). Also, BMI increase was found to be lower in children who participated in organized team sports outdoors at least twice per week compared to peers who never participated in such activity (Dunton et al. 2012). Overweight and obesity are also believed to raise a barrier to physical activity based on a qualitative review concerning 0–6-year-old children (Hesketh et al. 2017).

It has been hypothesized that young children's motor skill competence and physical activity are weakly related in early childhood but will strengthen as the children age, and that motor skills competence will drive physical activity levels (Stodden et al. 2008). Also, perceived motor competence, health-related physical fitness, and obesity interact with this relationship between motor skills and physical activity (Stodden et al. 2008). The spirals, positive and negative, are suggested by Stodden et al. (2008). Moving towards either spiral is due to higher or lower level engagement in physical activity providing more or fever opportunities for learning motor skills. Perceptions of motor skills are lower or higher due to engagement in physical activity, and thus, physical activity will be both fun and rewarding or fail to be fun and rewarding. This will ultimately lead to either healthy weight or unhealthy weight or obesity (Stodden et al. 2008). The hypothesis by Stodden and colleagues about the strengthening relationship from childhood to adolescence was supported for early and middle childhood. Namely, a weak relationship was found for early childhood and moderate for middle childhood, but again weak for adolescence. However, the number of studies (n=2) was low for adolescence, and for this reason drawing strong conclusions may be questionable (Logan et al. 2015). Then again among children aged 8 to 11 years, i.e. in middle childhood, motor performance, socioeconomic status, or BMI failed to explain physical activity participation whereas perceived athletic competence did (Morrison et al. 2018). In that study, physical activity was measured with questionnaires and motor skills with a product-oriented test of Bruininks-Oseretsky Test, second edition (BOT-2). Conclusions were drawn that their choices of methods may have weakened the relationship (Morrison et al. 2018). In another study, health-related physical fitness and object control association was found to increase as children got older (Stodden et al. 2014) thus, indirectly supporting Stodden's model (Stodden et al. 2008). In addition, a recent meta-analysis found moderate to strong relationship between motor skills and physical fitness. The association also increased with age (Utesch et al. 2019).

To sum up, excessive body weight or body fat may serve as individual constraint for motor skills development. Physical activity, however, seems to be weakly associated with body weight in preschoolers, even though some indications have been found between physical activity and weight status or BMI in young children. In addition, the foundations for a physically active lifestyle may be established already in early childhood. Physical activity protects more strongly against overweight and obesity in later childhood and adolescence than in the early childhood. In addition, perceived competence in motor skills may have an indirect effect on overweight or obesity indirectly by physical activity. The results of the earlier research and the study at hand indicate that healthy weight is something to try to achieve already in early childhood because it is associated with better motor competence and higher physical activity levels. Even though physical activity is not directly associated with weight status based on the results of this study, earlier research suggests that adequate physical activity may protect from overweight and obesity. Practitioners working with children may benefit from a stronger knowledge about the consequences of childhood overweight or obesity and they should have better tools to help children who already are overweight or obese. These tools should be developed in collaboration between behavioral experts, scientists, and even nutrition experts, and the practical challenges that families face in their daily lives should be considered in the developmental process. Parents need to be included in the education of maintaining healthy weight among their children and interventions should perhaps be developed.

## 6.3 Motor skills differences between boys and girls

The results of this study were partially controversial in comparison to previous studies on differences in motor skills between genders in early childhood. In earlier studies at the age of 5 years, boys have usually performed better than girls in manipulative skills (Olesen et al. 2014; Bardid et al. 2016; Venetsanou & Kambas 2016). Measured with Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) or Bruininks-Oseretsky Test, second edition (BOT-2), boys have been significantly better than girls in throwing a ball at a target (Wrotniak et al. 2006; Venetsanou & Kambas 2016), in catching and dribbling (Morley et al. 2015), in running speed and agility (Wrotniak et al. 2006), and in strength and agility (Santos et al. 2018). In this study, boys were better than girls in catching and dribbling but the difference was non-significant. Of three strength and agility tasks, boys were non-significantly better in push-ups, but girls were significantly better in one-legged stationary hop and sit-ups. Thus, for strength and agility and for object control skills with non-significant associations in this study, no clear support for previous studies can be given. When it comes to fine manual control and balance, the results of this study support the previous studies. In these skills girls were significantly better than boys in this study as well as in many earlier studies (Olesen et al. 2014; Morley et al. 2015; Venetsanou & Kambas 2016).

Within a sample of 6-year-old Belgian children, boys outperformed girls with scores of 52.8 versus 48.9 in total motor skills measured with BOT-2 (Fransen et al. 2014). The study in question lacked the statistical significance tests between boys and girls, but boys had better overall scores and girls had better scores in nine out of 14 tasks. Boys in that study had better scores than girls in drawing lines, in catching, and dribbling a ball -tasks, knee push-ups, and one-legged hop -tasks. With children aged 10 and 11 years, the differences between boys and girls in most tasks seemed to level off (Fransen et al. 2014). In the study at hand it was shown that the tasks which correlate most with total motor skill score were different among girls and among boys. One-legged stationary hop from running speed and agility subtest and sit-ups from strength subtest correlated highest with total motor skills in boys. In girls, the tasks that impact total motor skills were drawing lines through crooked paths and standing on one leg on a balance beam eyes open, i.e. fine motor and balance skills. Thus, attention should be paid to underlying skills behind the total motor scores.

Overall, girls performed better in motor skills at the age of 5 years while boys were not statistically significantly better than girls in any of the 14 tasks in this study at hand. The results are somewhat similar to those in another study with a similar assessment method (MABC-2) with children of the same age (Kokstejn et al. 2017). In the study in question, no gender differences were found at the age of 5 years. However, at the age of 6 years, boys were better in aiming and catching skills (Kokstejn et al. 2017). These results may indicate that differences between genders become more evident in favor of boys when approaching middle childhood. In the study at hand, even though girls outperformed boys in motor skills at the age of 5 years, boys were more physically active outdoors than girls. This association, however, failed to reveal significance in statistical models. Thus, at the age of 5 years, being a girl was one factor in better motor skills, but there were other factors as well, such as attending day care. Similar results have been reported earlier. Even though boys were physically more active than girls, their motor skills were non-significantly different in a Finnish study with 5-year-old children (Laukkanen et al. 2015). These results support the conclusion that when trying to target motor skills development, it may indeed be a good idea to try to find the role of many correlates of motor skills (Barnett et al. 2016a).

When looking at the differences in skills at the age of 5 years, the competence in a single task may also be environmentally bound. In this study, girls outperformed boys for instance in jumping and hopping tasks. Girls tend to be superior to boys in hopping and skipping in the early years and that may be due to greater interest in this activity (Gabbard 2018, 263). The differences could also be due to stereotyped activities supported by school and home environments (Morley et al. 2015). Moreover, girls did more drawing/handicrafts than boys in this study and they were also better in fine manual control that is in drawing lines through crooked paths, folding paper, and copying a square and a star. The association was indeed clear, but surprisingly the interaction between gender and drawing/handicrafts to fine manual control skills remained non-significant in statistical models. The explanation for superiority in these skills may be found in the child's practice or interest in these types of activities as an individual, rather than as a representative of a certain gender. For parents and practitioners at ECEC, it would be valuable to have more knowledge on individual differences in activities that may be associated with certain motor skills. Thus, this knowledge would help to promote and even tailor certain exercises to children with different strengths and weaknesses in their motor skills. In addition, the tools for recognizing the strengths and weaknesses in certain motor skill types would help in emphasizing the exercises that strengthen those skills that are the weakest. Overall, one way to level off the differences in motor skills between individuals, thus strengthen those skills that are weak, is to offer exercises evenly to all children, not only to those that already are interested and competent in the skills in question.

## 6.4 Parental role modeling, education, and day care attendance

The findings in this study revealed the significant role of parental physical activity and sedentary behavior in those of their children. The screen times of toddlers and mothers were positively associated and also mothers and child's moderate-to-vigorous physical activity and sedentary time were associated at the age of 5 to 6 years in this study. Mothers whose screen time was two hours or less per day, compared with those mothers whose screen time was two hours or more per day, had children with significantly lower screen time change from 13 months to 3 years of age. Also, the mother's younger age and full-time working status was associated with a lower screen time change of children. Children's and parents' objectively measured physical activity does not reveal whether the positive association found in this study was due to the mother being a role model, mother's participation simultaneously in physical activity with their child, or both. Earlier studies on screen time associations (Hoyos & Jago 2010; Duch et al. 2013; Lauricella et al. 2015) and physical activity associations with parents (Taylor et al. 2009; Hesketh et al. 2014a; Jago et al. 2014) are supported by the results of this study. In a recent review moderate to strong evidence has been found between parents' physical activity levels and those of their young children aged 6 years or younger (Xu et al. 2015). Parental encouragement and support have been linked with children's physical activity. Parents may also influence children's screen time through parenting practices, although the evidence is mixed and weak. For instance, TV rules may lead to lower screen time for a child. Moderate evidence has been found for parents' screen time and children's screen time (Xu et al. 2015). The importance of the parents' role in their children's physical activity was highlighted in a review by Loprinzi et al. (2012). They argue that the mediating role of parents happens through multiple mechanisms such as the child's own perception of their parents' attitudes towards physical activity or through parental support via parental orientation. Thus, the amount of physical activity and also the parents' perceptions of physical activity and support of physical activity may influence children's physical activity behavior.

Children's higher, objectively measured physical activity was associated with the moderate-to-vigorous physical activity of fathers with higher education in this study. Thus, children whose fathers had a lower education level, had lower moderate-to-vigorous physical activity levels. In addition, mother's higher education was associated with the lower screen time change of children in their early years. In earlier study, socio-economic status was found to significantly associate with physical activity participation, but with low correlation. Moreover, when other variables were included in the statistical model, socioeconomic status failed to explain much of the variance in physical activity participation (Morrison et al. 2018). Parental education has been found to be unclearly associated with physical activity of children aged 5 to 6 years. Parental educational level in the study in question was however based on earlier data from 2006 (Olesen et al. 2013) which may perhaps explain the unclear results.

In this study, parental education status was associated with children's body coordination, but lacked association with other motor skills types. Children whose fathers had high level education had better body coordination skills than children of fathers with a lower education. In previous studies, similar indications have been found of socioeconomic status and motor skills associations. Higher socioeconomic status was significantly associated with total motor skills as well as fine and gross motor skills of children (Morley et al. 2015). Morley and colleagues' study was conducted among 4 to 7 year-old children in the UK and the measure of socioeconomic status was formed on the basis of the schools' indices of multiple deprivation in the UK. In another study measured with balance sub test of Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), the differences were significant in different socio-economic status groups (Habib et al. 1999). Social disadvantage has also been found to be associated with motor skills (McPhillips & Jordan-Black 2007; Tsapadikou et al. 2014). In another study, the motor coordination was not associated with socioeconomic status but the sports participation was. It was suggested that providing equal opportunities for sport participation should be considered, as the sport participation might have influence on motor skills as well even though a direct association was non-existent (Vandendriessche et al. 2012).

Attending day care outside the home was associated with lower screen time change, higher moderate physical activity levels, higher moderate-to-vigorous physical activity, with better body coordination, and with strength and agility skills in this study. In previous reviews the preschool attendance has been concluded as a positive correlate with physical activity (Hinkley et al. 2008; Bingham et al. 2016). Within included studies in reviews from Hinkley and colleagues it was concluded that the role of preschool environments is of importance (Boldemann et al. 2006), the childcare center explained almost 50% of the variance in physical activity counts (Finn et al. 2002), and that the preschool attendance was a significant predictor of children’s vigorous physical activity (Pate et al. 2004). Bingham et al. (2016) also reported that preschool setting/type associated positively with moderate-to-vigorous physical activity. Perhaps versatile outdoor spaces experienced in day care centers are influential with regard to children’s physical activity levels as argued earlier.

Overall, based on the results of this study, parents have a strong influence on their children’s physical activity and sedentary behavior habits. The more physically active parents, especially mothers, are, the more physically active their children are. The results showed similar, but negative, association with sedentary behavior habits. To add, higher education of parents seems to be associated with physical activity habits of parents and their children. Finally, attending day care resulted to higher physical activity and lower sedentary time levels and better motor skills. It might be valuable if parents are offered more tools to help being physically active with their children and also avoid sedentary activities. Parents are in a key role in encouraging their preschool-aged children towards physical activities by being role models and practicing physical activities together with their children. More research is needed to resolve which of these three methods has the biggest influence on children: being a role model, practicing physical activities together, or encouraging and supporting children to be physically active.

## 6.5 Thoughts on constraints of motor skills development

In early childhood, Stodden's model (2008) suggests that physical activity affects motor competence, and motor competence is affected by perceived motor competence. Finally, motor competence affects health related fitness. Perceived motor competence affects physical activity and physical activity affects health related fitness. Physical activity then again leads to either healthy weight or unhealthy weight or obesity. These associations become bidirectional in middle and later childhood; for instance, physical activity affects perceived motor competence as well and actual motor competence affects perceived motor competence. The more opportunities a child gets for physical activity in the early childhood the more competent the child becomes in their motor skills which again feeds their perceived motor competence. This, however, is more influential in middle or later childhood than in the early childhood. The positive spiral feeds itself, as does the negative spiral when less opportunities are available and thus lower motor competence may be the result. Lower physical activity can lead to unhealthy weight or obesity which again affects child's motor competence either directly or through perceived motor competence (Stodden et al. 2008).

This study at hand did not assess children's perceived motor competence but only the actual motor competence. If the measures used in this study were replicated in later childhood, added with perceived motor competence assessment, Stodden's model (2008) could be evaluated. Children with a healthy weight had better motor skills than those with overweight or obesity according to this study at hand. Thus, hypothetically, children with overweight or obesity in early childhood may face challenges with their motor competence in later childhood. Follow-ups and longitudinal studies are essential in the future to test Stodden's model and the strength of the positive and negative spirals. Also other aspects would be valuable to consider in the model, such as the sedentary behavior and characteristics of the family, but these suggestions for future are discussed in following chapters. Perhaps body weight already in early childhood is of importance in the development of children's motor competence. Indeed, as based on the constraints model from Newell (1986), the task, the individual, and the environment all associate with each other. Thus, the individual characteristics such as overweight, may pose a constraint to practicing a motor task. (Figure 11)

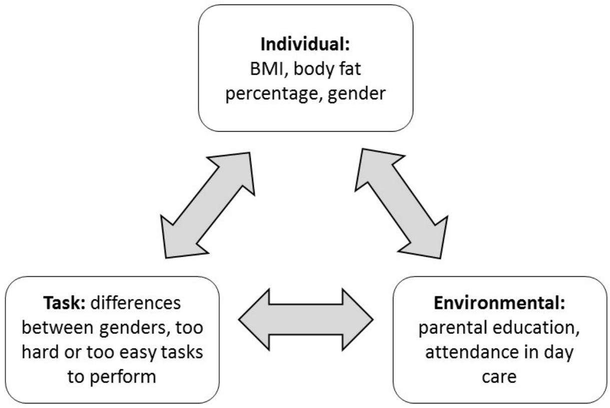


**Figure 11.** Constraints of motor skills and the concluded results of this study.

Excessive body weight can act as a constraint for motor skill development. As proposed by the model of constraints, the power, the speed, or overall the muscular, skeletal, and cardiovascular systems of the human body can all affect motor development. As described in the literature review, physical activity helps strengthen the human body systems, and in contrary, unhealthy weight may be due to low levels of physical activity and consequently, lack of an adequate reinforcement of the human body systems. In this study at hand, physical activity levels were not significantly associated with body weight; however, children with healthy weight had higher physical activity levels than their overweight or obese peers even though the difference remained statistically non-significant. Motor skills may indeed be affected by weight status which may serve as an individual constraint towards a task. Weight status can be associated with physical activity or sedentary time, as some indications for that have been found in earlier studies.

Also other possible constraints were found for motor skills of preschool-aged children. This study has given some additional perspectives on the variables that associate the strongest with motor competence in early childhood, namely, parental role modelling for physical activity and sedentary behavior, attending day care outside the home, parental education, and daily activities. Parental physical activity and sedentary behavior associated with those of children, as did parental education and attendance in day care with the physical activity and sedentary behavior of children. Parental physical activity may indirectly associate with motor competence of children; via children's physical activity as it may strengthen the human body systems as described above. According to the results of this study, parental, especially maternal, physical activity associated significantly with the physical activity of their children.

Association between father's high education and body coordination was found in this study. Previously, associations between motor skills and socioeconomic status have been found (Morley et al. 2015). As for day care, day care may provide qualified instructor-led activities to practice motor skills (Robinson & Goodway 2009). Robinson and Goodway found that appropriate instructional climate improved the object control skills over comparison group with developmentally delayed children as for their motor competence in a randomized comparison group design study. Gagen and Getchell (2006) have also argued for the importance of social climate, among other constraints.

In addition to the individual and environmental characteristics, the tasks themselves may act as constraints as for instance in this thesis, some tasks were clearly too easy and some too difficult for 5–6-year-old children. For instance, 68.5% and 72.9% of boys and girls respectively failed to perform any push-ups and 80.9% and 65.0% of boys and girls respectively failed to copy a star in a fine motor integration task. Then again nearly 100% of children got full scores in walking forward on a line-task which measures balance. These results may indicate problems with either the BOT-2 test in terms of certain items' reliability in the age group of 5 years to 5 years and 3 months, or then the tasks that were the hardest to perform acted as constraints towards the skill that was measured. Fortunately, only three of these items were clearly almost impossible to perform or too easy as to distinguish the participants and in most of the tasks the variation in the results was broader.

The development of adequate motor skills in early childhood may be affected by body weight, parental educational level, attendance in day care, and interest in certain activities related to specific motor skills types. A child's physical activity and sedentary behavior is then again associated with parental physical activity and sedentary behavior habits. There may be associations underlying between physical activity and motor skills, physical activity and body weight, as physical activity may have an indirect impact towards healthier body weight or through versatile opportunities for practicing motor skills. The variables associated with motor competence identified in this study at hand may represent constraints for motor skills. Other constraints that were not studied, may also exist. It is suggested that early childhood educators should have knowledge on how motor skills develop during the early years (Gagen & Getchell 2006). Motor skills development through physical activity does not only mean practicing of sports skills, such as striking with a bat, but requires also understanding of the constraints that each individual face when practicing the skill (Gagen & Getchell 2006). If a teacher has only one bat and one ball in one size, it may be impossible for some individuals to overcome the constraint that a wrong sized bat or ball sets (Gagen & Getchell 2006). Thus, it is argued that early childhood educators should have more knowledge on theories of motor development, especially on the constraints affecting the motor development, in order to be able to provide appropriate activities with keeping in mind the individual, environmental, and task constraints (Gagen & Getchell 2006). In fact, the results of this study indicate that the physical education programs in preschool settings are working well in Southwest Finland. Children attending day care had better motor skills and higher physical activity levels than children not attending day care. Perhaps, educational programs should be offered to parents in terms of motor development.

Paying attention to children, choosing appropriately fitting equipment, and considering the surface and adjusting the task to these constraints can easily be done by early childhood educators (Gagen & Getchell 2006). Without appropriate and adequate fundamental motor skills in early childhood, it is hard to achieve more complex sport skills (Gallahue et al. 2012, 187; Logan et al. 2018). For this reason it is crucial to deepen the knowledge on motor skill development among those who educate children in their early years, especially parents.

## 6.6 Strength and limitations

The strengths of this study include the choice of appropriate assessment methods and large sample sizes in Study I and Study III. All main measures used are valid and reliable. This study also provides new information on objectively measured physical activity simultaneously from children and their parents. The limitations of this study include choices of certain questions that lack or have questionable reported validity or reliability, and small sample sizes in two of the four studies. In addition, cross-sectional study design in three out of four studies is considered a limitation.

### 6.6.1 Sample sizes

The large data samples in studies I and III gives volume and strength to the results. With over 600 and 500 children in multivariable models in studies I and III, the results can be generalized to similar populations without caution. The two other sub studies had slightly lower sample sizes of approximately 100. However, the objectives of those two sub studies were different and thus the lower sample sizes were justified. The objective and time consuming measurements would have been impossible to carry out among the over 500 families in this study frame.

In studies II and IV, data from the MSPA Study was used. Almost 400 families were invited and 158 of them attended the study visit. The number of participants was appropriate concerning the available resources of the study. However, as no associations were found for motor skills and physical activity, it can be questioned whether the power of the study was sufficient to detect the association. The correlation lines between motor skills composite and moderate-to-vigorous physical activity were however fairly flat so that even with larger sample size it is likely that no associations would have been found. Also earlier research supports this argument, as the association is believed to strengthen as children get older (Stodden et al. 2008). Selection bias may, however, exist, as from the invited families, 43.2% accepted the invitation. Participating families may have been more oriented towards physical activity than those who did not participate.

### 6.6.2 Physical activity and sedentary behavior assessments

There are a number of measurement methods for assessing physical activity and sedentary behavior. Applying the correct measures is unsystematic in the research and there is lacking consensus about the definition and utilization of physical activity and sedentary behavior measurements (Bowles 2012; Kelly et al. 2016). The difficulty in measuring these behaviors lies in that they are multi-faceted and can be described by so many domains, dimensions, correlates, or determinants. The validity and reliability are often discussed in studies but they have been argued to miss the complexity of studied behaviors such as physical activity. The often assumed “golden standard” of double labelled water may fail to actually be the best “golden standard” for all measurements. Double labelled water held as the “golden standard” often leads researchers to think that objective measures are the best, as double labelled water indeed converts the measures into the energy based physiological metrics (Kelly et al. 2016). Thus, the golden standard should be chosen for each measurement separately, depending on what is being measured.

The choice of the assessment method of physical activity depends on what the aspect of interest is (Kelly et al. 2016). In this study, the Actigraph accelerometers (GT3X) were used to assess children’s and their parents’ physical activity and sedentary time simultaneously. In recent years, accelerometers have become a widely used method for assessing young children’s physical activity (Janssen et al. 2013; Troiano et al. 2014). Accelerometers are good at assessing the total physical activity but at the same time they lack the ability to detect the type and place of the physical activity (Kelly et al. 2016) and there have been challenges in determining the accurate cut points for different intensity levels (Janssen et al. 2013). When worn over the hip, they lack in measuring the upper body movements (e.g. weight lifting, throwing or catching a ball), and they are not able to detect if a person carries any weight. In addition, sitting and standing may be undetected or undistinguished with accelerometers (Lee & Shiroma 2014). Still, accelerometer counts are reported as having moderate to high correlation with energy expenditure and they also have fair to excellent accuracy in detecting different intensity levels among children (Rowlands & Eston 2007) and reliability among adults (Aadland & Ylvisåker 2015). In a study of Actigraph validity and classification accuracy in young children, the recommendation was to use the cut points of 1680 for moderate-to-vigorous physical activity for preschoolers of 4–6 years (Janssen et al. 2013), which is the cut-off point by Pate et al. (2006). However, the cut points from Pate and colleagues were validated and calibrated against 3–5-year-old children. In Janssen and colleagues' research it was also discussed that slightly higher cut points (≥2292) showed the best classification accuracy in children aged 5–15 years (Trost et al. 2011; Janssen et al. 2013), which was chosen for this study.

The measure of LTPA is used for young people and adults (Raitakari et al. 1996; Lehtonen-Veromaa et al. 2000). Using reported measure, thus questionnaires, is a quick and efficient way for collecting large samples in a study. The limitations of this measure include reliance upon the recall as well as the accurate estimation of the respondent of their physical activity frequency, intensity, and duration. However, sufficient validity exists (Troiano et al. 2012).

When it comes to sedentary behavior, the most often used objective methods have been reported to be direct observation, accelerometers, and pedometers, and subjective methods to be questionnaires and diaries (Nascimento-Ferreira et al. 2019). The screen time was recently defined as "time spent on screen-based behaviors" with a mention that these behaviors can be performed while sedentary or physically active. Screen time could also be subdivided into recreational, stationary, sedentary, and active screen time, where active screen time refers to "using a screen-based device while being non-stationary" (Tremblay et al. 2017). In this study, the screen time measured at ages 13 months, 24 months and 3 years was undefined in subdivisions of recreational, stationary, sedentary or active. The use of mobile devices was not asked. However, mobile devices were less common at the time of the measurement than they are today. In addition, young children may be less frequent users of mobile devices than their preschool- or elementary school-aged peers. Screen time as a measure of sedentary behavior has been reported to have a convergent validity (Stamatakis et al. 2009). On the contrary, it is also reported that children's self-reported TV watching vs. objectively measured sedentary behavior has negative agreement (Nascimento-Ferreira et al. 2019). However, to refer to afore-mentioned choice of "golden standard", having direct observation instead of accelerometers as comparison method for TV viewing, moderate to strong correlation was found. Thus, it was suspected that the agreement between questionnaires and accelerometers was actually due to the choice of accelerometers as a reference method instead of the subjective method itself (Nascimento-Ferreira et al. 2019). The measures of screen time have no reliability or validity reports, but convergent validity is reported (Statamakis et al. 2009). The self-report of sitting has a good reliability (Rosenberg et al. 2008).

The subjective questionnaires may serve a purpose when large populations are in question (Troiano et al. 2012). It would be valuable to use only question batteries that have reported validity and reliability. However, in this study, also non-validated methods were used. Parents were asked about their children's daily habits of watching TV/DVD, playing console/computer games, drawing/doing handicrafts, and playing outdoors physically actively. The reliability of these questions is not established and no validity reports have come across. However, as similar measures for sedentary activities such as physical activity questionnaire (PAQ) have been used at least concerning sedentary behavior, the measure was considered useful (Wen et al. 2009; Bringolf-Isler et al. 2012). Validity and reliability of these questions should be analyzed in further studies as they may serve as useful and quick methods for assessing young children's physical activity and sedentary behavior habits by asking about their daily activities.

### 6.6.3 Motor skills assessment

The Bruininks-Oseretsky test, second edition (BOT-2), includes tests of a variety of motor skills. The test is also suitable for research purposes and it is relatively easy to conduct. Both complete and short forms of BOT-2 were used in this study. The short version is validated against the complete form and the correlation of content validity have been reported as 0.80 (Cools et al. 2009). The short version with 15–20 minutes of administration time is quicker to conduct than the complete version with 45–60 minutes of administration time. Thus, the short form suits well of studies that have a large sample size as in this study with 824 children tested. Then again, when a deeper understanding of motor skills is warranted the complete version can be a good choice as it was in this study, with the smaller sample size of 158 children tested with complete form. The test–retest reliability and inter-rated reliability have been reported with ≥ 0.90 (Bruininks & Bruininks 2005).

Even though the motor skills test in this study, i.e. BOT-2, is seen as a strength, some recent findings reveal concerns as well. Recently, the structural validity of BOT-2 was examined. The research assessed subscales' and composite scales' dimensionality, hierarchical ordering, differential item functioning, and reliability. Of eight subscales four (the fine motor integration, bilateral coordination, balance, and running speed and agility) and the body coordination composite appeared to meet no adequate requirements of structural validity and only some of BOT-2 subscales were reported to be used with confidence. However, item reliability of all eight subscales was reported to be excellent with a coefficient of >.95 (Brown et al. 2019). Regarding the recent concern about structural validity, it has to be noted that results on associations with body coordination, fine manual integration, and running speed and agility, may be better to adopt with this caution in mind. On the other hand, as the reliability of each subscales being excellent and the content validity reported as good as mentioned in strengths section, the results of this study concerning also the controversial subscales ought to be reliable. Another limitation concerning the BOT-2 is that it is a norm-referenced test with a sample from the

United States (Bruininks & Bruininks 2005). Thus, the lack of Finnish norms is seen as a limitation. However, as this study was cross-sectional and the aim was to compare the samples against other variables rather than understanding the actual level of Finnish children's motor skills, the limitation is of a small significance.

### 6.6.4 Anthropometric measures

A major strength in this study is that the weights, lengths, and body composition of the children and mothers were measured by health care professionals. The measurement done by health care professionals prevented possible under-reporting or over-reporting.

To determine overweight or obesity at 24 months of age and to calculate weight-for-height and weight-for-height standard deviation score (SDS), The new Finnish Growth References for Children were used (Saari et al. 2010). These new growth references for children include age- and sex-specific cut-off points for BMI. Age is determined by 0.01 year accuracy from 24 months of age onwards and can be considered as a reliable reference for growth in Finnish children.

Anthropometric measures, including BMI, obesity index and skinfold thickness, are easy methods used to assess anthropometrics in the clinical field. However, they fail at being accurate or precise (Lim et al. 2009). Bioelectrical impedance analysis (BIA) is also often used and as it is relatively simple, noninvasive and quick (Wang & Hui 2015), i.e. it is suitable for children. The body composition of children was measured in a non-fasting state. The body impedance analysis (BIA) methodology is highly susceptible to the hydration status of the subject. A higher fluid volume in the body in a non-fasting state than in a fasting state may have overestimated lean mass and underestimated fat mass in our sample. Another limitation is that we did not have a direct or more precise measure of body composition, such as dual X-ray absorptiometry or agreement of the BIA method with a more direct measure of body composition. The clinical evaluation of excess body fat depends markedly on the methods and criteria used (Tompuri et al. 2015), but BIA has previously been shown to be a practical method to estimate body fat percentage in children and adolescent (Chula de Castro et al. 2018; Talma et al. 2013).

### 6.6.5 Other measures

Information on parents' education was collected at the recruitment of the STEPS Study participants. Thus, at the children's age of 5–6 years the parents' educational status was based on the situation well before the birth. However, the mean age of parents at the delivery was 30.8 (SD 4.6) years in the STEPS Study (Lagström et al. 2013). Thus, parents' may already have completed their studies at that age, even though some changes may of course have occurred in their educational level. The STEPS Study participants differ from the cohort in some demographic characteristics. The participating mothers were slightly older and the participants were more likely married than the entire cohort. Their occupational status was also higher than in the cohort which may cause a bias in regard to the variable of parents' educational status and working status. The child was also most likely the first for the participants compared with the whole cohort and they lived more often in the urban area (Lagström et al. 2013).

## 6.7 Future research implications

This study showed that the amount of different objectively measured intensity levels of physical activity or sedentary time was unimportant in terms of motor skills. Playing outdoors however was associated with certain motor skills type, i.e. the versatility of physical activity taking place outdoors may be of importance but requires more research with different methods. Using only accelerometers as a physical activity measurement method may be insensible as the rates of physical activity at different intensity levels varies heavily depending on device and cut point used (O'Brien et al. 2018). Observation and accelerometers used simultaneously could provide more comprehensive understanding of the different aspects of physical activity. To measure the qualitative aspects of daily physical activity in young children has been implicated previously (Soini et al. 2013). Similar issues exist in motor competence assessment. Both process and product -oriented methods for measuring motor skills are strongly recommended in future studies (Logan et al. 2016; Ré et al. 2018).

The many measurements of physical activity used in previous research poses problems with comparison of the results. The variety of measurements proves that physical activity is extremely hard to measure accurately and consistently. The argument "Everything matters; everything changes" concerning the constraints of motor development in designing movement activities for ECEC from Gagen & Getchell (2006) could be shared with physical activity. That argument refers to the variety of constraints that need to be considered when teaching a physical education class (Gagen & Getchell 2006). Indeed, the constraints affect the movements and development of motor competence. To study the constraints in physical education and measuring physical activity and motor skills with different methods simultaneously might lead to even deeper understanding of the measurements' reliability as well as the constraints' role in motor competence and in physical activity. Longitudinal study designs would give perspective on the development of motor skills from early childhood to later childhood when measured from preschool to elementary school. The different settings should be considered, i.e. preschool settings versus home-based childcare, by reason of the results of this study at hand. Different, thus product- and process-oriented, and simultaneous assessment methods for motor competence in a longitudinal study design within different settings would provide stronger results on motor development over time. In addition to this suggestion, the modification of constraints of motor development would help deepen the knowledge on the constraints model in practice. The modification of environmental and task constraints has already proved to result in positive outcomes (Robinson & Goodway 2009; Ulrich et al. 1998). To add, individual constraints, thus body weight and body fat, appeared to exist according to the results of this study. However, this issue needs further research and preferably in a longitudinal study design.

The role of parents in the physical activity and sedentary behavior of their children should be further examined. The different mechanisms in parental support that has strongest influence on the physical activity and sedentary behavior of their children needs to be examined in detail. The parents' physical activity and sedentary behavior habits were well proven to associate with those of their children according to this study at hand. However, it remained unclear whether only the parents' being a role model in practicing physical activity is the main influence on that of their children, or if perhaps other ways such as rules in the family, being physically active together with their child, or just encouraging to physical activity is of the greatest importance. According to earlier reviews, parental physical activity and family support are consistently reported to associate with children's physical activity (Sallis et al. 2000; Van Der Horst et al. 2007; Hinkley et al. 2008; Craggs et al. 2011). These reviews do not include in-depth analysis on the mechanisms behind these associations, thus, those mechanisms are worth to study. In addition, parental education was associated with physical activity and some motor skills in this study. Better income may be associated with equipment provided by homes, which is one parental support type for physical activity of their children. Better possibilities to participate in sports may be more common in families with higher income which can be associated with parental education level.

To support the work of practitioners working with children, the gender differences in both physical activity and motor skills are suggested to be further examined. In this study it was shown, with the support of earlier studies, that boys are more active physically than girls. Surprisingly, girls were superior to boys in most motor skills tasks at the age of 5 years. The better performance in certain motor skills by girls was not explained with physically active play outdoors. Studying the differences in motor skills and physical activity association by gender would help designing effective interventions strategies in health promotion (Logan et al. 2015). In addition to that, it might be valuable to study the constraints that environment poses to girls and to boys. For example, as stated earlier, different environments may support stereotyped activities for boys and girls (Morley et al 2015). In addition, different types of activities or hobbies children participate in, compared with different types of motor skills (e.g. object control, fine motor skills, body coordination, strength, and agility) might help channel the early childhood education programs in terms of the results obtained from such study. For instance, in this study at hand, association was found between drawing/handicrafts and fine manual control, no matter what gender. This type of study might be worth to replicate in the future, thus, comparing the daily activities with motor competence measured with both product- (e.g. the amount of hits to the target) and process- (e.g. the developmental level of striking) oriented measures.

Finally, as the body weight and body fat were in a significant role in some motor skills in this study, the anthropometrics should be taken into account when assessing the motor competence of children at early childhood and also in later childhood. Stodden's (2008) model about positive and negative spirals toward the risk of overweight/obesity also needs further investigation. Body weight and body fat might act as a constraint for motor development. Whether the excessive body fat or unhealthy body weight is a disruptive factor for motor competence or a consequence of low physical activity levels, would be worth to examine further. The variety of motor skills should be included in the assessments, and both individual, environmental, and task constraints examined in future studies. The results should be applied concretely to the early childhood education, for practitioners, caregivers, and parents.

# 7 Conclusions

Of 5 years old children, 65% play physically actively outdoors 60 minutes or more daily, reported by their parents. At the age of 5.6 years, less than 50% of children exceeded the WHO recommendation of 60 minutes of moderate-to-vigorous physical activity daily, measured objectively with accelerometers. However, children spent on average 50% of their day being physically active at any intensity level (light, moderate, vigorous), measured objectively with accelerometers. Mothers and fathers of these children spent on average 40% and 39% of their days being physically active at any intensity level. Mother's and child's moderate-to-vigorous physical activity were positively associated, higher educated fathers' moderate-to-vigorous physical activity was also associated with child's moderate-to-vigorous physical activity, and attendance in day care was associated with child's moderate-to-vigorous physical activity as well.

Children's mean screen time change from 13 months to 3 years was an increase of 55 minutes. Attending day care, father's higher sitting time, mother's lower screen time, mothers' higher education, mothers' younger age, mothers not working full-time, and child's lower BMI at the age of 13 months were associated with lower screen time change of children. At 5 years of age, 31% of children watched TV/DVD 60 minutes or more per day. More boys played computer/console games for more than 60 minutes per day (19%) than girls (7%), and more often girls (19%) did 60 minutes or more per day drawing/handicrafts than boys (5%) at the age of 5 years. At children's average age of 5.6 years, boys and girls spent on average 50% of their day being sedentary. Mother's sedentary time was associated with child's sedentary time, as was sedentary time of fathers with higher education.

At the age of 5.1 years, girls outperformed boys in motor skills. At the age of 5.6 years, healthy weight children had better scores in almost all motor skills than their overweight/obese peers. Children who did more drawing/handicrafts, had better fine manual skills, and children who played outdoors physically actively 60 minutes or more per day had better strength and agility scores. Attendance in day care was associated with strength and agility, and children whose fathers had higher education had better body coordination scores. At the age of 5.6 years measured with objective measures, moderate-to-vigorous physical activity or sedentary time were unassociated with motor skills. Instead, body fat percentage and attending day care were associated with some types of motor skills, namely body coordination and strength and agility.

Parents' physical activity and sedentary behavior habits are influential for their child's physical activity and sedentary behavior habits in early childhood. Higher parental education and children's attendance in day care seems to positively affect the child's physical activity and sedentary behavior habits throughout early childhood. Attendance in day care seems beneficial for the competence in motor skills. Significant association between physical activity and motor skills was missing in 5–6-year-old children, instead, higher body fat among girls and overweight/obesity in all children seems to be negatively associated with most types of motor skills. Doing handicrafts or drawing was associated with better fine manual control skills and playing outdoors physically actively over 60 minutes per day was associated with better strength and agility skills.

Overall, physical activity and motor skills were not associated in early childhood and neither were sedentary time and motor skills. Playing physically actively outdoors was however associated with strength and agility. Parental role modeling in terms of physical activity and sedentary behavior habits was associated with those of their children in early childhood. Parents' high education status and children attending day care outside the home seemed influential to better motor skills and higher physical activity levels. Boys underperforming girls in motor skills was impossible to explain with lower physical activity levels or playing outdoors less because boys were physically more active than girls.

It seems that despite the fact that boys are physically more active than girls at the age of 5 to 6 years (measured with both questionnaires and objective measures), girls are better in their motor skills (measured with a variety of different types of motor skills). Thus, other factors than physical activity exist that effects the development of motor skills. For instance, body weight among all participants and body fat among girls were associated with motor skills in this study. This may well indicate that children with overweight or obesity may already in early childhood be slipping into the negative spiral of engagement based on Stodden and colleagues' model. In addition, the parental role model in physical activity and sedentary behavior seems fairly important as children and parent's moderate-to-vigorous physical activity, sedentary times, and screen times were significantly associated in this study.

The implications for practice include providing more knowledge on variables associated with motor skills. How and to whom this knowledge is provided are questions that involve more concrete work which cannot be addressed with this study at hand. However, recommendations can be made. Thus, it is highly recommended to forward the information to parents, caregivers, practitioners, and politicians dealing with physical activity challenges. It is of importance, that early childhood educators understand more deeply the constraints of motor skills in the development of motor competence, as Gagen and Getchell have suggested. Practical and theoretical education concerning the individual, environment, and task constraints may help early childhood educators to tailor their physical education programs into even more effective ones through making educators more aware of motor development of preschool-aged children. It is of importance to provide such education for caregivers as the effects of low motor competence in fundamental motor skills may have negative consequences on competence in more advanced sport skills. In the worst case, low motor competence may lead to low physical activity levels and overweight or obesity in later childhood.

# Acknowledgements

This doctoral thesis was conducted in University of Turku, faculty of Medicine, clinical department and in Turku Child and Youth Research Institute during years 2013-2020. The work has been financially supported by the Academy of Finland (grant number 121569), the Juho Vainio Foundation, the Yrjö Jahnsson Foundation, the C.G. Sundells Foundation, and the Turku University Foundation.

I wish to thank my supervisors Professor Pasi Koski and Adjunct Professor Hanna Lagström for their guidance during this project. I owe my gratitude for Pasi Koski for sharing his expertise, making valuable remarks, and also for offering me interesting work opportunities outside the thesis and thus widening the research field, namely to the field of sports clubs and physical activity interventions. I thank Hanna Lagström especially for her guidance in the first steps of this project. Most of all, I am grateful for providing the equipment for conducting the research.

I owe my gratitude for reviewers Greet Cardon, professor at the Gent University, Department of Movement and Sports Sciences, and Timo Jaakkola, Adjunct Professor at the University of Jyväskylä, Faculty of Sport and Health Sciences. Both reviewers' valuable remarks and insights improved the manuscript and made it more relevant.

I thank the follow-up group: Katja Pahkala, Adjunct Professor, Päivi Rautava, Professor, Chief Physician of Research, and Helena Viholainen, Adjunct Professor, for valuable support and answering to my queries quickly and precisely. Special thanks to Helena for expertise related to motor skills and Katja for MET and PA issues.

I am grateful for Anne Kaljonen, data manager, for formulating all the data sets for analyses used and especially for the persistence in getting the motor skills scores profoundly coded. I am also grateful for biostatisticians and co-authors Eliisa Löyttyniemi, MSc, (study I and III) and Saija Hurme, MSc, (study II and IV), for conducting the analyses with me and helping me to conquer at least some parts of the diverse world of the statistics.

I wish to thank my other co-authors, Lisa Barnett, Associate Professor in Deakin University, Tuija Tammelin, PhD, research director at LIKES Research Centre for Physical Activity and Health, and Janne Kulmala, MSc, activity monitoring specialist at LIKES. I am grateful for having Lisa Barnett to be part of the sub study IV. The comments and remarks from Lisa clearly improved the manuscript and challenged me as a researcher. I wish to thank another specialist, Tuija Tammelin, for kind encouragement to follow my own choices within the articles but at the same time pushing me to the right direction and helping with choosing a reasonable focus for each paper. I thank Janne Kulmala for patiently explaining the functions of the accelerometers and providing relevant research of objective measures at the time.

I want to thank Pia Salmela, for language revision of the thesis in prior to reviewing process. I also want to thank Mirva Virtanen for, literally, the last-minute help with the language in the crucial parts of the thesis. I thank Erika Salmela, MEd, and Heidi Varjo, MEd, for their valuable contribution in data collection regarding the study visits with complete BOT-2 tests. I also thank Anne-Mari Pieniniemi, a study nurse for conducting hundreds of BOT-2 tests for 5-year old children.

I owe thanks to STEPS Study families for participation, as well as the participants in the Motor skills and physical activity study. Without your participation, the thesis would have been impossible to conduct as such.

I want to express my thanks to all previous colleagues at the Turku Child and Youth Research Institute. I especially want to thank Leena Haanpää, adjunct professor, Piia af Ursin, PhD, and Jenni Vaarno, PhD, for their valuable comments, as well as discussions during the coffee breaks and lunches. I also thank other CYRI co-workers Johanna, Anne-Mari, Anne, Maija, Sanna, Hanna Lau, and Marko for sharing the world of research with me. I thank all the ex-colleagues at Turku Sport Services, especially Kristina, Eeva, Merja and Terhi for encouragement regarding my dissertation project. I thank the current co-workers at the university of Applied Sciences, especially Milja, Markus, Oskar, Mathias, and Johanna, for willingly or not being forced to share my anxiousness and worries prior to the dissertation. But mostly, for the laughter and positive atmosphere.

I want to express my loving thanks to my family and friends. Special thanks to Jaana, Tatu, Mira, and Kalle for many years of friendship now. I want to thank all hippomaniacs at Yli-Lemo stables for sharing the enthusiasm for horses almost every single day, and sailing and skiing mates for the time spent in snow and in the “skärgården". I express my gratitude to my mother, father, and sister, for providing support and encouragement during all these years. Loving thanks to Pessi, for the love, laughter, and humor we share every day. Our kids, Alli and Joona, for making us a whole family and reminding what is important.

Kaarina, March 2020
*Tanja Matarma*

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# Appendices

**Table 19.** Children's physical activity determinants and correlates that were studied at least in three studies/review.

| Children’s physical activity determinants and correlates | Sallis et al. 2000 | Van der Horst et al. 2007 | Hinkley et al. 2008 | Craggs et al. 2011 | De Craemer et al. 2012 | Bingham et al. 2016 | Tonge et al. 2016 * | Hesketh et al. 2017** |
|---|---|---|---|---|---|---|---|---|
| Age group | 3–12 years | 4–12 years | 2–5 years | 4–9 years | 4–6 years TPA/MVPA | 0–6 years TPA/MVPA | 0–5 years | 0–6 years |
| **Demographic, biological** | | | | | | | | |
| Sex (male) | Co | Co | Co | De | Nc/Co | Co/Co | Co | Co |
| Ethnicity | | Nc | | | | -/Nc | | |
| Body weight/BMI/adiposity | In | Nc | Nc | | | In/Nc | In | |
| Parental overweight | Co | | | | | | | |
| Parental education | | In | | | | In/Nc | | |
| Parental working status | | | | | | In/- | | |
| Socio-economic status | Nc | | | In | Nc/Nc | | | |
| **Psychological, cognitive, emotional** | | | | | | | | |
| Perceived barriers NEGATIVE | Co | Nc | | | | | | |
| Intention/preference for PA | Co | | | | | | | |
| Body image/self-esteem | Nc | | | | | | | |
| Perceived benefits/attitudes | Nc | | | | | | | |
| Self-efficacy | In | Co | | | | | | |
| Perceived competence | In | | | In | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Behavioral** | | | | | | | | |
| Healthy diet | Co | | | | | | | |
| Previous physical activity | Co | | | | | | | |
| Motor coordination | | | | | | In/In | Co | |
| Child’s time in sedentary activities | In | Nc | In | | | In/- | | |
| **Social, cultural** | | | | | | | | |
| Parental physical activity | In | Co | Co | | In/- | In/- | | |
| Parent participation in child PA | In | | | | | | | |
| Parental interaction | | | Co | | | In/- | | |
| Parents lack of time and resources | | | | | | | | Co |
| Parental support/encouragement | | Co | Nc | | Nc/- | | | |
| Transport to PA places | Nc | | | | | | | |
| **Physical environment** | | | | | | | | |
| Access to facilities | Co | | | | | | | |
| Season or weather | In | | In | | | In/In | | Co |
| Neighborhood safety | Nc | | | | | | | |
| Time spent in places for play/outdoors | Co | | Co | | | -/Nc | Co | |
| Preschool attended/location | | | Co | | | Co/- | Nc | |
| Educator qualification/presence | | | | | | | In | Co |
| Active opportunities/equipment | | | | | Nc/- | | Co | |

* in early child education services, ** a qualitative review, PA = physical activity, TPA = total physical activity, MVPA = moderate-to-vigorous physical activity, De = Determinant, Co = Correlate, Nc = Not correlate, In = Inconclusive/inconsistent/indeterminate, BMI = body mass index (kg/$m^2$)

UNIVERSITY OF TURKU

Painosalama Oy, Turku, Finland 2020

ISBN 978-951-29-7986-8 (PRINT)
ISBN 978-951-29-7987-5 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)