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Institute of Sport Sciences and Physiotherapy, Faculty of Medicine, University of Tartu, Estonia.

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CONTENTS

ABBREVIATIONS

AWT	accelerometer wear time
BF%	body fat percentage
BMI	body mass index
CRF	cardiorespiratory fitness
DEXA	dual-energy X-ray absorptiometry
FFM	fat-free mass
FM	fat mass
FMI	fat mass index
LPA	light physical activity
MET	metabolic equivalent
MF	muscular fitness
MPA	moderate physical activity
MVPA	moderate-to-vigorous physical activity
PA	physical activity
PF	physical fitness
RPM	Raven's progressive matrices test
SLJ	standing long jump
ST	sedentary time
TPA	total physical activity
$\dot{V}O_{2peak}$	peak oxygen consumption
VPA	vigorous physical activity

LIST OF ORIGINAL PUBLICATIONS

I. **Reisberg K**, Riso EM, Animägi L, Jürimäe, J. Longitudinal relationships of physical activity, sedentary time, cardiorespiratory fitness, and muscular fitness with body fatness in preschoolers. *Sports*. 2024;12(9): 237.

II. **Reisberg K**, Riso EM, Animägi L, Jürimäe, J. Longitudinal associations between physical activity and sedentary time and cardiorespiratory and muscular fitness in preschoolers. *Journal of Functional Morphology and Kinesiology.* 2024; 9(4):199.

III. **Reisberg K,** Riso EM, Animägi L, Jürimäe, J. Longitudinal associations of body fatness and physical fitness with cognitive skills in preschoolers. *Children*. 2024;11(5):526.

In all papers, Kirkke Reisberg had primary responsibility for leading the design of the studies, coordinating and implementing data collection, performing data analysis, and writing the manuscripts.

1. INTRODUCTION

The prevalence of overweight and obesity among children and adolescents aged 5–19 years has dramatically increased over the last decades, similarly among both boys and girls (Obesity and overweight, 2024). Therewith, one fifth of preschool-aged children are overweight or obese (Coe, 2018). Adiposity is related to cardiovascular, endocrinologic, gastrointestinal, orthopaedic and psychological complications (Grant-Guimaraes et al., 2016) with an increased economic burden (Ling et al., 2023). It is not well understood whether extensive sedentary time (ST) at preschool age has a detrimental association with later body fatness measures or whether physical activity (PA) and physical fitness (PF) have longitudinal beneficial associations in preschool aged children (Leppänen et al., 2017). The preschool years are crucial for studying the determinants of childhood obesity, as it is the time when PA habits are becoming founded (Telama et al., 2014). If children begin school with excessive weight, they start their education on a negative trajectory (Puhl and King, 2013; Seyedamini et al., 2012), and once established, obesity can be extremely difficult and expensive to reverse (Lanigan and Sauven, 2020). Greater awareness about the associations between body fatness, PA, ST and PF will support the development of interventions to encourage healthy lifestyles in preschool-aged children.

There is a global concern about children being extensively sedentary and insufficiently physically active at all ages (Pizarro et al., 2022; WHO, 2020). A steady decline of PA from early childhood into middle childhood (Pereira et al., 2022) and further to adolescence (Sember et al., 2020) has been demonstrated. Research also shows that already in preschool, children spend a very long time engaging in sedentary behaviours, and only a small part of the day is spent performing different physical activities (Barbosa et al., 2016; Pagels et al., 2011), therewith, male preschoolers are more physically active than female preschoolers (Tucker, 2008). Correspondingly, the overall PF level of preschool children, among both boys and girls aged five, six and seven has been shown to be unsatisfactory (Mrozkowiak and Kaiser, 2021). Excessive ST has been linked with a number of health concerns in children and adolescents (Barnett et al., 2018; Mitchell and Byun, 2014). On the opposite, there is a wide range of physical and mental health benefits related to being physically active and fit in both boys and girls (Ortega et al., 2008; Rodriguez-Ayllon et al., 2019; Veldman et al., 2021).

Previous studies have rarely accounted for the gender differences in body fat accumulation and distribution (Karlsson et al., 2013; Taylor et al., 1997), time being engaged in physical activities (Tanaka et al., 2012) and PF levels (Latorre Román et al., 2017; Mrozkowiak and Kaiser, 2021) that are evident already at early age, thus restricting our understanding of whether the findings are generalizable to both genders or whether they are gender-specific. Recognizing gender-specific associations could contribute to the development of more specific intervention strategies for preschoolers aimed at obesity prevention during the period of transition from preschool to school.

Early childhood is a phase of rapid development in cognitive domains (Wallin et al., 2018), and trajectory of success is founded by improving cognitive skills at early age (Diamond, 2016; Józsa et al., 2022). The importance of cognitive health for academic success is well-recognized (Cadenas-Sánchez et al., 2020). The transition from preschool to elementary school marks a significant and crucial period in a child's education and personal development as school readiness typically sets standards for several developmental domains, including cognitive development (Scott-Little et al., 2006). Since the prevalence of overweight and obesity among children has globally taken dramatic dimensions (Obesity and overweight, 2024), it raises concerns over the impact of adiposity not only on children's physical health (Grant-Guimaraes et al., 2016; Weber et al., 2012) but potentially also on their cognitive performance (Brooks et al., 2023; Sadler et al., 2023). Furthermore, given that overall PF of preschool children is inadequate (Mrozkowiak and Kaiser, 2021), but specific associations between PF components and certain brain structures exist in children (Chaddock et al., 2010; Ortega et al., 2019), which suggest potential links between PF components and cognitive competence. Subsequently, the associations of PF and cognitive skills should also be elucidated in young boys and girls. It is necessary to consider the potential impact of gender, since there are gender differences in body fat content (Taylor et al., 1997), PA (Tanaka et al., 2012) and PF (Latorre Román et al., 2017; Mrozkowiak and Kaiser, 2021). Furthermore, boys and girls present also differences in specific cognitive outcomes (Drozdowska et al., 2021; Latorre-Román et al., 2016), as well as gender-specific effects of PA on cognitive outcomes have been reported (Barha et al., 2017; Pindus et al., 2023).

To sum up, it is likely that already preschool environment influences the further development of a child at school and understanding these factors might be helpful in promoting children's development and reducing the subsequent health problems later in childhood (Magnussen et al., 2013). Accordingly, the general aim of this dissertation was to investigate the longitudinal associations between body fatness, physical fitness, physical activity, sedentary time, and cognitive skills among preschool-aged boys and girls from Tartu County.

2. REVIEW OF THE LITERATURE

2.1 Body composition in children

Body composition can be regarded as an indicator of health and well-being already at young age (Müller et al., 2012). Excessive fat mass (FM) in childhood is accompanied by accelerated growth and pubertal development (Chung, 2017), and obesity has been related to various short- and long-term metabolic and cardiovascular complications, including impaired glucose metabolism, hypertension, dyslipidemia, fatty-liver disease and systemic low-grade inflammation (Wang and Lobstein, 2006). In contrast, there is a strong evidence for the positive impact of FFM compartment on health during growth and maturation (Farr and Dimitri, 2017; Mera et al., 2016).

Body mass index (BMI) is currently the most widely used parameter to identify children and adolescents with excess adiposity and related risk for the development of metabolic disease (Weber et al., 2012) as rapid weight gain in children can be attributed to FM rather than lean mass (Wells, 2003). In addition to BMI (Basterfield et al., 2012; España-Romero et al., 2013), several other adiposity measures such as waist circumference (Collings et al., 2017; España-Romero et al., 2013), waist-to-hip ratio (Turcotte et al., 2019) and waist-to-height ratio (Brambilla et al., 2013; Lo et al., 2016) have been used in the studies to explore the development of body fatness in children and adolescents.

While BMI is a rough estimate of body FM, body fat percent (BF%) is more precise for characterizing body fatness than BMI (Nuttall, 2015) as the relative contribution of FFM and FM to body mass cannot be differentiated by BMI (Butte et al., 2000; Nuttall, 2015). Therewith, gender differences in body fat accumulation (Taylor et al., 1997) and distribution (Karlsson et al., 2013) are already present for preschool-aged children. It has been shown that young boys have lower BF%, lower FM and higher bone-free lean tissue mass than girls (Taylor et al., 1997). Measurement of skinfold (subcutaneous adipose tissue) thicknesses at the specific sites of the body using a skinfold caliper is another method to estimate body fatness and has widely been used in children, including preschool-aged children (Collings et al., 2017; Kakebeeke et al., 2017; Moore et al., 1995). The sum of skinfold thicknesses for determining body FM is more precise than BMI (Cicek et al., 2014) and it correlates well with reference methods in children (Hussain et al., 2014).

In conclusion, overweight and obesity are not just cosmetic concerns, but medical problems that increase the risk of many diseases during growth and maturation, and as obtaining an epidemic proportions already among very young children, lifestyle interventions towards healthier body composition are of great importance.

2.2 Cardiorespiratory and muscular fitness in children

Physical fitness is the capacity to perform PA, and it makes reference to a full range of physiological and psychological qualities in children and adolescents (Ortega et al., 2008). Therefore, cardiorespiratory fitness (CRF) represents the overall capacity of the cardiovascular and respiratory systems, and the ability to perform prolonged strenuous exercise (Ortega et al., 2008). Peak oxygen consumption ($\dot{V}O_2$peak), the highest rate at which oxygen can be consumed during exercise, is widely recognized as the best single measure of young people's cardiorespiratory condition (Herdy et al., 2016). In epidemiological studies involving children and adolescents, CRF is most commonly assessed by 20 m shuttle run test, or modified versions of that (Leppänen et al., 2017; Ortega et al., 2008). Cadenas-Sánchez et al. (2016) confirmed the feasibility and high reliability of 20 m shuttle run test among children aged 3–5 years. Accordingly, it has been suggested that 20 m shuttle run test is an acceptable and feasible estimate of CRF and functional/exercise capacity, providing moderate criterion validity against objectively measured $\dot{V}O_2$peak with high to very high reliability (Tomkinson et al., 2019). It has been proposed that 20 m shuttle run test expresses fatness rather than CRF and the validity between 20 m shuttle run test and $\dot{V}O_2$peak is poor in boys aged 11–14 years (Welsman and Armstrong, õ2019). Yet, a systematic review stated that adiposity alone does not explain 20 m shuttle run performance in boys and girls (Lang et al., 2018). Similarly, it was reported that adiposity explained 40–60% of the longitudinal declines seen in 1.6 km running speed in 10- to 12-year-old children between 1985 and 1997 (Olds and Dollman, 2004). Furthermore, although referencing the CRF values from cycle ergometry to lean body mass lessened the discrepancies in PF between normal-weight and overweight groups, the data suggested that the child or adolescent with a BMI > 95 percentile has a substantial risk of reduced fitness (Cooper et al., 2016). While performance on 20 m shuttle run is associated with multiple health indicators among children (Lang et al., 2018), low levels of CRF at young age have been attributed to a higher risk of developing cardiovascular disease in adulthood (Ruiz et al., 2009).

Muscular fitness (MF) is the ability to perform work against a resistance (Ortega et al., 2008). The handgrip test is one of the most frequently applied tests for investigating MF in epidemiological studies with children (Cadenas-Sánchez et al., 2020; Ortega et al., 2008; Ramírez-Vélez et al., 2016). Therefore, the feasibility and high reliability of handgrip test among preschool age children has been identified (Cadenas-Sánchez et al., 2016). In order to account for developmental and body size differences the normalization of handgrip strength for body mass is indicated (Castro-Piñero et al., 2019; Gómez-Bruton et al., 2020; Xu et al., 2023). High relative upper-limb strength expresses general fitness of a young person (Manzano-Carrasco et al., 2023). Relative handgrip strength was inversely associated with future cardiovascular disease risk among children and adolescents(Castro-Piñero et al., 2019). Higher relative handgrip was associated with better bone structure and strength among preschoolers (Gómez-Bruton et al., 2020).

Among jump tests, SLJ has been widely used in young population for assessing explosive strength (Cadenas-Sánchez et al., 2020; Ortega et al., 2008). Standing long jump test has high reliability and criterion-related validity among children aged 6–12 years (Fernandez-Santos et al., 2015). Higher SLJ result predicted lower cardiovascular disease risk for children and adolescents (Castro-Piñero et al., 2019) and was determinant of healthier bone structure and higher strength at preschool age (Gómez-Bruton et al., 2020).

Muscular fitness compound measures have also been used in studies to express overall MF (Gil-Cosano et al., 2019; 2020; Kao et al., 2017). Research shows that MF has beneficial impact on bone health in children and adolescents with overweight and obesity (Gil-Cosano et al., 2019; 2020). Also positive association of MF with cognitive abilities among preadolescents was found (Kao et al., 2017).

As regards gender differences at preschool age, boys outperform girls in CRF (Cadenas-Sanchez etal., 2019; Mrozkowiak and Kaiser, 2021), strength, running speed (Cadenas-Sanchez et al., 2019; Latorre-Román et al., 2016; 2017; Mrozkowiak and Kaiser, 2021), agility (Cadenas-Sanchez et al., 2019; Mrozkowiak and Kaiser, 2021) and reaction time (Latorre-Román et al., 2017).

In conclusion, PF as assessed by CRF and MF tests is a significant indicator of health status already at early age in boys and girls, which can be assessed by feasible field tests in these children.

2.3 Physical activity and sedentary time in children

Physical activity is termed as any bodily movement produced by contractions of skeletal muscles resulting in energy expenditure (Caspersen et al., 1985). According to intensity levels, PA can be roughly categorized as light PA (LPA), moderate PA (MPA) and vigorous PA (VPA), altogether determined as total PA (TPA) (Lee et al., 2018). Light PA includes slow walking, bathing, or other minor activities that do not result in a substantial increase in heart rate or breathing rate (WHO, 2020). Moderate PA encompasses activities such as brisk walking, dancing, playing double tennis or social tennis, raking the yard, and slow swimming; while examples of VPA include jogging, running, cycling, aerobics, playing competitive tennis, carrying heavy groceries or other loads upstairs, shoveling snow, vigorous gardening, or participating in a strenuous fitness class, and fast swimming (Gebel et al., 2015; MacIntosh et al., 2021). Sedentary time (ST) is defined as spending the time in sedentary behaviours (Tremblay et al., 2017), where sedentary behaviour is any waking behaviour characterized by an energy expenditure of 1.5 metabolic equivalents (METs) or lower while sitting, reclining, or lying position (Sedentary Behaviour Research, 2012). Examples are most desk-based office work, driving a car, and watching television; addressing as well to those being unable to stand, such as wheelchair users (WHO, 2020). It is proposed that instead of being classified as sedentary or light-intensity activity, standing should be categorized into passive standing (e.g., standing in a line or having a discussion with an individual as upright behavior with an intensity of ≤1.5 METs) and active standing (e.g., standing while doing dishes and standing while on an assembly line) with an intensity of >1.5 METs in the category of light-intensity activity (Kowalsky et al., 2021).

The most commonly used motion sensors to assess PA are accelerometers, which measure acceleration and movement of the body (Strath et al., 2013). Accelerometers are widely applied and feasible objective tools for measuring children's PA and ST. Guidelines for young population from 1–4 years suggest TPA of 180 min/day at any intensity of which at least 60 min should include MVPA at 3–4 years; children and adolescents aged 5–17 years are suggested to participate in an average of 60 min/day of MVPA throughout the week. Sedentary time should be limited across all age groups (WHO, 2020). Differences in the attachment sites of accelerometers, raw data processing standards and intensity cut-point determination complicates the comparison of the outcomes obtained in different studies, as well identifying the prevalence of children meeting the PA guidelines (Migueles et al., 2019). A disadvantage of accelerometers is their inability to detect arm movements, when worn on a hip; they underestimate the energy cost of certain activities, such as rowing, cycling, skiing, climbing, using the stairs and weight lifting (Aittasalo et al., 2015; de Vries et al., 2006; Remmers et al., 2014). Besides, accelerometer-registered determination of LPA, MPA and VPA does not take into consideration the actual energy expenditure (Haapala et al., 2020).

Physical activity and especially MVPA have been associated with several health benefits in childhood on motor and cognitive development, musculoskeletal and cardiometabolic health indicators, as well with better psychosocial and cognitive health and less adiposity (Carson et al., 2017; Pate et al., 2019; Poitras et al., 2016). On the contrary, higher screen time/television viewing was associated with unhealthier body composition, poorer cardiometabolic health, lower self-esteem and lower PF (Carson et al., 2016). Furthermore, boys are more physically active than girls already during preschool years (Tanaka et al., 2012; Tucker, 2008), as well ST among boys is shorter (Tanaka et al., 2012).

In conclusion, despite the well-known positive impact of PA on children's health, there is a trend towards more sedentary lifestyle and many children do not comply daily the criteria for healthy PA. In spite of some limitations, accelerometers are nowadays the most commonly used tools that allow the objective measurement of children's PA.

2.4 Cognitive processes in children

Cognition is a summary term for thought processes used in interactions with other humans and the environment (Wallin et al., 2018), hence cognitive ability reflects the ability to reason, solve problems, think abstractly, and acquire knowledge (Gottfredson, 1997). The great importance of cognition regarding to competent social functioning of children is widely recognized (Calkins and Bell, 2009).

Cognitive competence predicts important educational, occupational and health outcomes (Plomin and von Stumm, 2018). Cognitive processes are aggregate in the newborn but during development differentiate into definite domains of cognitive functioning (Price et al., 2000). By 10 years of age, when the brain has started to reach its adult size, children have already undergone significant development in cognitive functions (Wallin et al., 2018).

Conceptual abilities involve the ability to detect an abstract notion or set and the flexibility to shift from one competitive notion to another (Welsh, 2002). Concept formation is rapidly developing during early childhood (Kaat et al., 2021). Basic-level concepts that consist of object concepts used in everyday language, like dog, chair, and car, are the first type of concepts formed (Mandler, 2007). During development and throughout the life course, perceptual/sensory cues (which things look most alike), others' actions on the world (how others group or use objects), and cues from language, make it possible to form concepts (Gelman, 2009). The ability to form and flexibly change concepts is of great importance for the development of academic skills (van der Sluis et al., 2007). Concept formation is a critical prerequisite skill within the categorization domain (Kaat et al., 2021; Mandler, 2007), while categorization in turn gives the ability to overlook differences for the sake of generality (Sloutsky, 2003).

Language development starts soon after birth with recognizing sounds, by listening to the language, babies gradually begin to sort out the speech sounds that compose the words of their language. Learning language implies to the ability of producing and understanding language appropriately (Conti-Ramsden and Durkin, 2012). Broadly, language is subdivided into receptive (ability to understand) and expressive (ability to produce) components (Feldman, 2019). Higher verbal skills (incl. both expressive and receptive verbal skills and verbal understanding) at 3–5 years were longitudinally related to improvement in executive functioning (Fuhs et al., 2011). Children with language deficit are exposed to less successful cognitive, social, emotional development and educational achievements (Conti-Ramsden and Durkin, 2012). Verbal comprehension is the ability to understand spoken language (McDuffie, 2013) and preschool period is crucial for development of language (Conti-Ramsden and Durkin, 2012). Verbal comprehension is the ability to understand spoken language (McDuffie, 2013). Better verbal comprehension at 9 years predicted improved reading comprehension through 9–15 years (Reynolds et al., 2012).

Executive functions (EFs) incorporate controlled mental processes such as inhibition (response inhibition and interference control), working memory, and cognitive flexibility (Diamond, 2013). Fluid intelligence, a higher level executive function (Diamond, 2013), is the ability to reason and solve problems in novel situations, without relying extensively on previously acquired knowledge (Carpenter et al., 1990). Consequently, it is synonymous with the reasoning and probleem-solving composites of EFs (Diamond, 2016). Fluid intelligence has strong impact on strategies children use to learn tasks that require complex spatial, numerical, or conceptual relations, and is related to several other cognitive skills (Ferrer et al., 2009). Emerging early in life and peaking in adolescence, further declining throughout adulthood (Cattell 1987; McArdle et al., 2002), it is highly predictive of academic success (Ren et al., 2015), but its benefits reach beyond academic, such as better health outcomes (Wrulich et al., 2014), lower physical violence, lower drug intake, higher-self esteem (Huepe et al., 2011), and a lower risk for mortality (Wrulich et al., 2015). Non-verbal reasoning tasks measuring abstract reasoning are regarded as a non-verbal estimates of fluid intelligence (Saar et al., 2023) and progressive matrices assumed to measure child's ability to understand perceptual relations and to reason by analogy were included into current work. These types of tests require ability to encode and analyze patterns and to conceptualize relations in a visual-perceptual context (Feis, 2010). Generally, EFs are present within children's first year of life and experience dramatic growth during the age of 3–7 years (Riggs et al., 2006), being related to the development of prefrontal cortical area and skills in using control for specific goals (Doebel, 2020), followed thereafter by stagnancy through early adulthood (Best et al., 2011).

Boys and girls display some differences in specific cognitive outcomes (Drozdowska et al., 2021; González-Fernández et al., 2023; Latorre-Román et al., 2016). In the early years of life, girls typically develop language skills more quickly than boys and tend to have a larger vocabulary. For instance, at 16 months, girls have an average vocabulary of 95 words, compared to 25 words for boys. This trend is observed across different languages, both in understanding and speaking, as well as in vocabulary and grammar development. Boys tend to start combining words about three months later than girls (Adani and Cepanec, 2019). Also, in the working memory and inhibitory control tasks girls at 10–12 years made fewer errors and had more correct events than boys (Drozdowska et al., 2021). Girls at the age of 9–15 years presented also better cognitive functioning scores on attention and concentration test than boys (González-Fernández et al., 2023). Preschool aged girls also showed better intellectual maturity than boys (Latorre-Román et al., 2016). Yet, girls aged 6–13 years were performing at a slower level compared to boys in a speed/arousal dimension (Brocki and Bohlin, 2004).

In conclusion, cognitive performance refers to the way how individuals process and interpret information involved in learning, memory, communication, and problem solving, being also a predictor of general academic success. Early years are regarded as the most formative period of cognitive development, and solid bases for definite domains of cognitive functioning is established.

2.5 Associations of physical fitness with body fatness in children

Cross-sectional studies among preschool children regarding the links between CRF, MF, and BMI shows mostly no associations, since no relationships regarding CRF (Henriksson et al., 2016; Latorre-Román et al., 2017) and lower-limb muscular strength (Henriksson et al., 2016; Latorre-Román et al., 2017) have been reported. However, a positive association between upper-limb muscular strength and BMI exists (Henriksson et al., 2016), while an inverse relationship between CRF (Reeves et al., 1999) and BMI among preschool aged children has been demonstrated. Some of the lacking and contradictory associations between PF and BMI in preschoolers might be attributable to the opposing associations of PF with body leanness and FM values (Henriksson et al., 2019).

Cross-sectional studies on the associations of CRF and lower-limb muscular strength with BF% or fat mass index (FMI) have demonstrated inverse (Agha-Alinejad et al., 2015; Henriksson et al., 2016; Reeves et al., 1999) or no (Agha-Alinejad et al., 2015) relationships. Upper-limb muscular strength was negatively (Agha-Alinejad et al., 2015) related to BF% and FMI among preschoolers (Agha-Alinejad et al., 2015), or no associations between upper-limb strength and BF% or FMI were found in preschoolers (Henriksson et al., 2016; Latorre-Román et al., 2017).

Similar results were obtained from a longitudinal study among preschoolers with a 1-year follow-up (Henriksson et al., 2019).

Additionally, Agha-Alinejad et al. (2015) found that higher upper-limb muscular strength was inversely associated with most body fatness characteristics including BF% both among 5–6-year-old boys and girls. At the same time, higher CRF was associated with lower BF% among boys, but not among girls (Agha-Alinejad et al., 2015).

A longitudinal study by Henriksson et al. (2019) found that at 4.5 years higher CRF and lower-limb strength were associated with lower FMI one year later, meanwhile CRF and lower-limb strength were not related to BF%. No associations between upper-limb strength and FMI or BF% existed.

In conclusion, there is a limited number of studies with contradictory relationships between CRF and MF in preschool with body fatness indicators in school. Moreover research on this field among boys and girls at preschool age is almost absent. Thus, those possible longitudinal associations in preschool boys and girls should be further explored, since beginning the school with overweight means to start the studies on a negative course that can be hard and costly to alter.

2.6 Associations of physical activity and sedentary time with body fatness in children

It has been suggested that PA at an early age may influence the physiologic mechanism of fat accumulation during growth, so that early PA may have a sustained effect on the fatness phenotype later in life (Janz et al., 2009). Children who are less physically active at young age may be more vulnerable to fat accumulation during later years (Janz et al., 2009). Research shows that children who do not meet the sedentary screen time guidelines (<1 h/day) in preschool are at higher risk being overweight and obesity at school (Guan et al., 2020).

Overall, studies on the associations between ST and adiposity during early childhood demonstrate positive (España-Romero et al., 2013; Guan et al., 2020;

Moore et al., 1995) as well as no (Basterfield et al., 2012; Butte et al., 2016; Collings et al., 2013; 2017; España-Romero et al., 2013; Leppänen et al., 2016; 2017) associations. A cross-sectional study showed that ST was not associated with BMI and waist circumference among boys and girls aged 3–5 years, though higher ST was associated with higher waist circumference among girls at the 90th percentile (España-Romero et al., 2013). A longitudinal study found that ST at the age of 4.5 years was unrelated to FMI and BF% at 5.5 years (Leppänen et al., 2017). Another longitudinal study also found no association between ST at 3–5 years with a change in BF% during 1-year follow-up (Butte et al., 2016). Yet, inactive children at the age of 3–5 years had 3.8 times greater likelihood to have an increased triceps skinfold thickness than active children before entering first grade at school (Moore et al., 1995). In addition, the measured skinfold thickness increased more among active girls compared to inactive ones during the period from preschool to school. While among active boys the measured skinfold thickness decreased, among inactive boys it increased (Moore et al., 1995).

Studies with objectively measured MVPA and body fatness indicators in early childhood report either negative (Butte et al., 2016; Basterfield et al., 2012; Collings et al., 2013; 2017; Leppänen et al., 2017) or no (Basterfield et al., 2012; Butte et al., 2016; Bürgi et al., 2011; Collings et al., 2017; Leppänen et al., 2017) associations. Not many studies have looked separately the associations between PA and body fatness among boys and girls, with some studies reporting gender differences for the outcomes. Accordingly, Basterfield et al. (2012) demonstrated that a reduced MVPA at 6–7 years was associated with an increase in FMI only among boys during the 2-year-follow-up period (Basterfield et al., 2012). In a study of children aged 5–6 years, who were observed till the age of 12 years, high baseline MVPA but not low/medium MVPA, predicted a lower FM gain among girls and not among boys (Jáuregui et al., 2012). MVPA at 5 years was a predictor of lower FM at 8 years and 11 years both among boys and girls.Yet, in girls, the effect of MVPA was not evident when FM at the age 5 years was included into analysis (Janz et al., 2009).

So, there is some inconsistency in the findings on the relationships between objectively measured ST and PA levels and body fatness in preschool-aged children. Furthermore, only a few cross-sectional (España-Romero et al., 2013) and longitudinal (Janz et al., 2009; Moore et al., 1995) studies have investigated preschool-aged boys and girls separately, leaving it unclear whether sedentary behaviour and PA have different impacts on adiposity in boys compared to girls.

In conclusion, there is a shortage of studies with mixed results on the associations between PA, ST and adiposity during early childhood. The preschool years are important for exploring the factors that play role in the development of childhood obesity, as PA behaviours are established early.

2.7 Associations of physical activity and sedentary time with physical fitness in children

Physical activity is a major modifiable determinant for increasing PF (Bürgi et al., 2011). Cross-sectional studies among preschool aged children demonstrate that a higher VPA (Bürgi et al., 2011; Leppänen et al., 2016), MVPA (Leppänen et al., 2016; Riso et al., 2019b), and TPA (Bürgi et al., 2011) were beneficial for CRF, and higher VPA and MVPA were associated with a higher lower-limb strength (Leppänen et al., 2016; Riso et al., 2019b). At the same time, while Leppänen et al. (2016) showed that VPA and MVPA were related to a higher upper-limb strength, another study detected no associations with upper-limb strength (Riso et al., 2019b). Accordingly, those few cross-sectional studies that have been conducted mostly support beneficial associations between PA and PF among preschoolers.

Regarding longitudinal associations among preschoolers, it has been shown that a higher VPA and MVPA at 4.5 years were associated with a higher CRF at 5.5 years (Leppänen et al., 2017), yet only VPA, but not MPA or TPA at 4–6 years were related to the improvement in CRF during the 9-months follow-up period in another study (Bürgi et al., 2011). With respect to muscular strength, a higher VPA and MVPA at the age of 4.5 years were longitudinally associated with a higher lower-limb strength, but not with upper-limb muscular strength one year later (Leppänen et al., 2017). Subsequently, two longitudinal studies that have been conducted among preschool aged children predominantly show favourable associations between PA and PF, with the exception for upper-limb strength.

Research about cross-sectional (Leppänen et al., 2016; Riso et al., 2019b) and longitudinal (Leppänen et al., 2017) associations of ST with CRF and muscular strength during preschool years is scarce and findings are mixed, showing either that higher ST relates to lower PF or no associations is found . In one study, a higher ST among children aged 6–7 years was related to a lower CRF (Riso et al., 2019b), while no associations among children aged 4 years were found in another study (Leppänen et al., 2016). A study among 4-year-old children showed that ST was negatively associated with upper-limb strength after adjustment for gender and age, maternal BMI and educational attainment, paternal BMI and educational attainment, and accelerometer wear time (AWT) but after adjusting also for VPA, the association disappeared (Leppänen et al., 2016). In another study, ST among preschool children aged 6–7 years was not associated with upper-limb strength (Riso et al., 2019b). Regarding lower-limb strength, it has been found that a higher ST was related to lower lower-limb strength after adjustment for age and gender, but the associations disappeared when the data were additionally adjusted for organized sport participation and parents' education level in 6–7 year old children (Riso et al., 2019b). Leppänen et al. (2016) found that ST and lower-limb strength were unrelated in children aged 4 years. Longitudinally, ST at the age of 4.5 years did not predict CRF or upper- and lower-limb muscular strength one year later (Leppänen et al., 2017).

In conclusion, there is a lack of studies investigating the associations between PA and PF among preschool aged children. Considering that PA is the major determinant of PF the relationships between PA and PF during preschool years need to be explored in order to understand and potentially improve healthy lifestyle solutions. In terms of studies about the associations between PA and PF, there is not much research for the associations between ST and PF among preschool-aged children. As boys and girls spend different amounts of time conducting PA, as well their PF is different, it is important to investigate the relationships between PA, ST, and PF among both genders separately.

2.8 Associations of body fatness with cognitive performance in children

There are studies to suggest inverse relationships between body fatness and cognitive skills in early childhood (Davis and Cooper, 2011; Haapala et al., 2019; Martin et al., 2016), while other investigations have not detected associations between body fatness and cognition (Haapala et al., 2018; Flores et al., 2023; Martin et al., 2016). A negative relationship between BF% and reading fluency and reading comprehension in 6–8-year-old boys but not among girls has been found (Haapala et al., 2018). Higher BMI in 3–year-old boys was associated with worse visuospatial skills, yet not with expressive language skills or reasoning skills at 5 years (Martin et al., 2016), while obesity was not associated with arithmetical performance among 3–6-year-old children (Flores et al., 2023). These studies together demonstrate that body fatness at young age might be associated with specific cognitive skills with some indications for gender specific associations.

Studies disagree on whether higher regional or whole-body fat content predicts worse cognitive performance (Davis and Cooper, 2011; Khan et al., 2015; Raine et al., 2017). Higher abdominal fat deposition was associated with worse relational memory but not with item memory in children with overweight or obesity at 7–9 years (Khan et al., 2015). Whole-body FM was not associated with relational or item memory (Khan et al., 2015). In addition, no associations between body fatness parameters and memory tasks existed in normal weight children (Khan et al., 2015). Likewise, Raine et al. (2017) found that especially in 8–9-year-old children with obesity, a reduction in visceral adipose tissue only over the course of 9 months was associated with increased inhibitory control. However, higher whole-body and abdominal body fatness predicted inferior executive function, resistance to distraction, and gestalt processing among 7–11-year-old children with overweight (Davis and Cooper, 2011). Accordingly, based on the small amount of studies with contradicting results, it is difficult to draw conclusions about the exact role of regional body fat deposition on cognitive skills among children of younger schoolage.

Very few observational studies have explored the gender-specificity of the associations between body fatness indicators and cognition at young age. A negative association between body fatness and cognition among preschool-aged (Martin et al., 2016) and first-grade boys (Haapala et al., 2018) but not in girls has been demonstrated. But, a decrease in obesity status had positive associations with some cognitive skills in preschool-aged girls, yet not in boys (Martin et al., 2016).

In conclusion, considering the increasing global prevalence of childhood obesity, and as evidence continues to show adverse effects of adiposity on brain health during neurodevelopmentally vulnerable period (Brooks et al., 2023), it is essential to consider the effects which childhood adiposity may have on children's cognitive abilities. In a view of the mixed results and the paucity of longitudinal studies at early childhood, and as there are gender differences in body fat accumulation and distribution already at young age with potential differential impact on cognitive abilities in boys and girls, it is important to elucidate the possible longitudinal associations between body fatness in preschool-aged boys and girls with their cognitive skills in school.

2.9 Associations of physical fitness with cognitive performance in children

Research on the relations between PF and brain structures mediating cognitive functions in childhood is scarce and the meaning of the results is somewhat difficult to explain. A larger hippocampus has been demonstrated among children aged 9–10 years with higher CRF; they also performed better in a hippocampal-dependent relational memory task, whereas associations between CRF, nucleus accumbens volume, and memory were missing (Chaddock et al., 2010). In addition, no association between CRF and whole-brain size was found (Chaddock et al., 2010). A shape analysis of subcortical brain nuclei among children at 9.7 years revealed that CRF and upper-limb strength were mostly associated with enlargements and contractions of the nuclei, respectively, while only a few positive or negative associations between lower-limb strength and the shape of subcortical brain nuclei were present (Ortega et al., 2019)

In accordance with the research on brain structures, there is a lack of uniformity in findings on the associations between PF and cognition in children. Cardiorespiratory fitness and MF seem to be associated with some cognitive skills, but not with others. For example, in 4–6–year-old children, CRF at baseline was related to improvements in attention and not to working memory during a 9-month period (Niederer et al., 2011). Higher CRF was related to better performance in preschoolers on Goodenough–Harris drawing test (Latorre-Román et al., 2016). In addition, 9-year-old children with higher CRF had better visual discrimination (Hillman et al., 2005), but not better reaction time compared to children with lower CRF (Hillman et al., 2009). Moreover, CRF at 6–9 years did not predict non-verbal cognitive performance two years later in boys or girls (Haapala et al., 2019). Regarding MF, SLJ was related to better cognition among 3–6-year-old children in a cross-sectional study (Latorre-Román et al., 2016), yet, neither SLJ nor handgrip strength at 7–9 years old children predicted non-verbal cognitive performance further in childhood and adolescence (Lima et al., 2022). Meanwhile, it has been reported that higher MF was indirectly associated with higher math outcomes through visuospatial working memory only among adolescent girls but not among boys (Syväoja et al., 2021). In addition to the contrasting findings described above, the number of longitudinal studies on the associations of CRF, SLJ, or handgrip strength with cognitive skills in preschoolers (Niederer et al., 2011) and primary schoolers (Chaddock et al., 2012; Haapala et al., 2019; Lima et al., 2022) is small.

In conclusion, little is known about the relationship between PF and cognitive competence in preschool children. Therewith, these associations among boys and girls separately have been rarely investigated. Acknowledging that there are differences in PF level among boys and girls which is already evident at an early age, it is important to study the associations of preschool CRF and MF with cognitive skills in boys and girls at school, as cognitive skills are important predictors of educational, occupational and health outcomes.

3. OBJECTIVES OF THE STUDY

The general aim of this dissertation was to investigate the longitudinal associations between body fatness, physical fitness, physical activity, sedentary time, and cognitive skills among Estonian preschoolers.

The specific purposes of the study were to:

1. investigate whether physical activity, sedentary time, cardiorespiratory fitness and muscular fitness in preschool are associated with body fatness in the first grade of school among boys and girls (Paper I);
2. investigate whether physical activity and sedentary time in preschool are associated with cardiorespiratory fitness and muscular fitness in the first grade of school among boys and girls (Paper II);
3. investigate whether body fatness, cardiorespiratory fitness and muscular fitness in preschool are associated with cognitive skills in the first grade of school among boys and girls (Paper III).

4. METHODS

4.1 Participants and study design

This longitudinal two-phased study was conducted in Tartu County in South Estonia. Altogether, 400 children aged 6–7 years from thirteen kindergartens, and their parents, were invited to participate in 2016 in the first wave, 284 families accepted the invitation and of these 256 provided valid accelerometer data. Families were again asked to participate in 2017 (second wave), when the children were in the first grade of school. Two hundred families gave their consent and assent to participate. From those 200 participants, participants who did not complete measures, were excluded from analyses. Specifically, in Paper I complete data on variables used in the analyses on the associations of MVPA and ST in preschool with BF% in school were available for 48 boys and 40 girls. Complete data on variables used in the analyses on the associations of CRF and MF in preschool with BF% in school were available for 56 boys/54 girls and 58 boys/55 girls, respectively. In paper II, complete data on the associations of VPA, MVPA, TPA and ST in preschool with CRF and MF in school were applicable for 41 boys and 36 girls. In Paper III, complete data on the associations of BF%, CRF and MF in preschool with conceptual, perceptual and verbal skills in school were available for 67 boys/66 girls, 67 boys/66 girls and 66 boys/66 girls, respectively. Baseline characteristics of children from paper I, II and III are presented in Table 1.

Additionally, each parent completed a short questionnaire reporting their educational levels that were graded as basic, general secondary/vocational, or higher. The educational level of parent who had highest education was included in the analysis. The Research Ethics Committee of the University of Tartu (references 254/T-13 and 266T-8) approved this study.

4.2 Assessment of body composition

Body height was measured using a Seca 213 portable stadiometer (Hamburg, Germany) to the nearest 0.1 cm. Body weight was measured using a digital medical scale (A&D Instruments, Abington, UK) to the nearest 0.05 kg. Body mass index was calculated as body weight (kg)/body height $(m)^2$. Children with overweight and obesity were identified by age- and gender-specific BMI cutoff values (Cole et al., 2000). Skinfold thicknesses (triceps and subscapular) were measured to the nearest 0.2 mm in triplicate with a Holtain caliper (Crymych, UK) according to a standardized protocol (Olds et al., 2006). Body fat percentage (BF%) was calculated using the formula developed by Slaughter et al. (1988). The following equations were applied. For boys BF% =1.21 (triceps + subscapular) – 0.008 $(\text{triceps + subscapular})^2$ – 1.7 and for girls BF%= 1.33 (triceps + subscapular) – 0.013 $(\text{triceps + subscapular})^2$ – 2.5. For a sum of triceps and subscapular greater than 35 mm, the BF% = 0.783 (triceps + subscapular) + 1.6

for boys, and BF% = 0.546 (triceps + subscapular) + 9.7 for girls were applied (Slaughter et al., 1988).

4.3 Assessment of physical fitness

To measure CRF, a 20 m shuttle run test was applied (Léger et al., 1988) based on a standardized protocol (Welk and Meredith, 2008). Children were told to run back and forth over a distance of 20 m marked with two lines. The test commenced at a speed of 8.5 km/h, and the running speed was increased after every minute by 0.5 km/h. The test ended when the children could not follow the set pace of the test. The number of laps completed was recorded (Welk and Meredith, 2008).

Upper-limb muscular strength was assessed by a digital dynamometer (Digital TKK 5401, Grip D, Takei, Tokyo, Japan) in a standing position, with the shoulder being tested slightly apart from the body and the elbow extended. A child was asked to squeeze the dynamometer continuously for 2–3 s. Two attempts with each hand was performed, and the best result was taken into account. The mean of left and right handgrip strength (kg) was calculated (Kolimechkov et al., 2020), and expressed relative to body mass (in kg/kg) (Gil-Cosano et al., 2019).

Lower-limb muscular strength was assessed by a standing long jump (SLJ) test (cm). A child stood on a line, with the feet slightly apart, and then performed two-footed takeoffs, landing as far as possible (European Council, 1988). The best of two attempts was taken into account (Henriksson et al., 2019).

As in important indicator of children's overall physical development, a muscular fitness z-score was computed from the combination of gender-specific standardized measures of relative upper-limb strength (kg/kg) and lower-limb strength (cm). The MF z-score was computed as the mean of the two z-scores (relative upper-limb MF and lower-limb MF), where z-score = (value-mean)/standard deviation (Gil-Cosano et al., 2019).

4.4 Assessment of physical activity

The hip-mounted Actigraph GT3X accelerometer (ActiGraph LLC, Pensacola, FL, USA) was used to estimate PA and ST. Children were instructed to wear the accelerometer for seven days and to remove it only when performing water-based activities (e.g., bathing, swimming) and during sleeping (Fossdal et al., 2018). The data were collected in intervals of 15 s. Participants with at least three days (including one weekend day) of ≥10 h daily AWT were included in the analysis (Migueles et al., 2017). Non-wearing time was characterized as ≥20 min periods of consecutive readings of zero counts and was excluded from the analysis (Esliger et al., 2005). The acceleration cut-off points for classifying ST, LPA, MPA, and VPA were as follows: 0–100, 101–2295, 2296–4011, and ≥4012 counts per minute, respectively (Evenson et al., 2008). The average time per day spent in each intensity zone was calculated as follows: (weekdays x 5 + weekends x 2)/7 (Migueles et al., 2020). Moderate-to-vigorous PA was calculated by summing the time spent in MPA and VPA (Kettner et al., 2013; Martinez-Gomez et al., 2010). Total PA was determined by summing up LPA, MPA and VPA (Lee et al., 2018). Accelerometer wear time was obtained by summing ST, LPA, MPA, and VPA (Leppänen et al., 2017).

4.5 Assessment of cognitive skills

Estonian version (Männamaa and Kikas, 2011) of Modified Boehm Test of Basic Concepts – Third Edition (Boehm-3) was applied to measure cognitive skills (Boehm, 2004). The test was made up of three parts, covering assessment of conceptual, verbal and perceptual skills. A progressive matrix test was applied to test the children's perception; accordingly, a child had to select the right picture to complete a regular arrangement of pictures. Conceptual skills described child's ability to understand the concepts of adverbs and position of objects. Child's ability to comprehend Estonian language demonstrated his/her verbal skills. A child had to listen to the researcher's instructions and mark the picture that matched the sentence that was given by the investigator during both tests. A child was scored one point for every right answer, and the scores were presented for each of the three categories (Männamaa and Kikas, 2011).

4.6 Statistical analysis

Statistical analysis was conducted with SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA) and a p value of less than 0.05 was considered statistically significant. The data from boys and girls were analysed separately. Continuous variables that were normally distributed were compared by Student's *t*-test, while the Mann–Whitney U test was used for other continuous variables, and the chi-square test was applied for categorical variables. Multiple linear regression analysis was applied to examine the associations between exposures and outcomes. Unadjusted and adjusted models are presented. In the unadjusted model, the relationship between the two variables, independent and dependent, is shown. The adjusted model reflects interaction between multiple independent factors. In Paper I, the associations between MVPA, ST, CRF, and MF z-score in preschool with BF% in school were examined. Baseline values of exposures (MVPA, ST, CRF, MF z-score) and baseline values of the outcome (BF%) (Haapala et al., 2019) were included in the adjusted model, and PA data were additionally adjusted for baseline AWT (Aggio et al., 2016; Leppänen et al., 2017; Wickel et al., 2017), to account for differences in how long the accelerometer was worn. In Paper II, the associations between VPA, MVPA, TPA and ST in preschool and CRF and MF z-score in school were explored. Baseline values of exposures (VPA, MVPA, TPA and ST) and baseline value of outcome (CRF or MF z-score)

(Haapala et al., 2019) were included in the adjusted model. Additionally, AWT (Aggio et al., 2016; Leppänen et al., 2017; Wickel et al., 2017) at baseline was added in the adjusted model. In Paper III, the associations between BF%, CRF, and MF z-score in preschool with verbal, conceptual, and perceptual skills in school were examined. Baseline values of exposures (BF%, CRF, MF z-score) and baseline outcomes (verbal, conceptual, and perceptual skills) (Haapala et al., 2019; Niederer et al., 2011; Riso et al., 2019a; Syväoja et al., 2014) were included in the adjusted model. Additionally, in all papres, child's age was included to control age-related variability (Booth et al., 2013; Haapala et al., 2019; Leppänen et al., 2017), as well parental education as an sociodemographic factor (España-Romero et al., 2013; Haapala et al., 2019; Syväoja et al., 2014) at baseline were included in the adjusted model. Multicollinearity was not a problem, as the values of the variance inflation factor between variables were less than 5.

5. RESULTS

5.1 Baseline characteristics of children

Boys were taller ($p < 0.001$), heavier ($p = 0.010$), and had greater handgrip strength ($p = 0.007$) than girls (Table 1). Boys also had a lower BF% than girls ($p < 0.001$). Boys had higher VPA ($p = 0.042$), MVPA ($p = 0.003$) and TPA ($p = 0.001$) compared to girls. The rest baseline characteristics and parental educational level were similar between boys and girls (Table 1).

Table 1. Baseline characteristics.

Variable	Boys	Girls	*p*
Anthropometric measures (*n* = 67 boys, 66 girls)			
Age (years)[1]	7 (1)	6 (1)	0.240
Height (cm)	127 (5.4)	124 (5.7)	**<0.001**
Weight (kg)[1]	26 (6.5)	23.5 (5.6)	**0.010**
BMI (kg/m^2)[1]	16.1 (2.5)	15.4 (2)	0.323
BF%	19.8 (6.3)	21.4 (5.9)	**<0.001**
Prevalence of overweight and obese (%)	17.9	9.9	0.170
Parental education (%)			0.765
Lower secondary	1.4	3	
Post-secondary or vocational	15.7	17.9	
University degree	82.9	79.1	
Physical activity (*n* = 41 boys, 36 girls)			
VPA (min/day)[1]	18 (12.7)	13.5 (12.3)	**0.042**
MVPA (min/day)[1]	62.9 (29.4)	57.6 (29.2)	**0.003**
TPA (min/day)	382 (59.2)	359 (41.5)	**0.001**
ST (min/day)[1]	382 (71.9)	400 (77.4)	0.237
AWT (min/day)[1]	774 (93.1)	752 (96)	0.151
Physical fitness tests (*n* = 40 boys, 37 girls)			
20 m shuttle run (laps)[1]	18 (19.3)	18.5 (8.5)	0.383
Handgrip strength (kg)[1]	11.5 (3)	9.9 (2.6)	**0.007**
Handgrip strength/weight (kg/kg)	0.4 (0.1)	0.4 (0.1)	0.299
Standing long jump (cm)	125 (18)	119 (18)	0.061
Muscular fitness z-score	0.01 (0.5)	−0.01 (0.5)	0.797
Modified Boehm-3 test			
Perceptual skills (max score 10)[1] (*n* = 67 boys, 66 girls)	8 (3)	7 (5)	0.201
Conceptual skills (max score 17)[1] (*n* = 67 boys, 66 girls)	14.5 (2)	14 (2.8)	0.418
Verbal skills (max score 9)[1] (*n* = 66 boys, 66 girls)	5.5 (1)	6 (1)	0.650

Data are from Student's *t*-test or the Mann–Whitney U-test, or the chi-square test for categorical variables, and are presented as means (standard deviations), medians (interquartile ranges[1]), or percentages (%). BMI – body mass index; BF% – body fat percentage; VPA – vigorous physical activity; MVPA – moderate-to-vigorous physical activity; TPA – total physical activity; ST – sedentary time; AWT – accelerometer wear time. Bold values denote $p < 0.05$.

5.2 Associations of MVPA ST, CRF and MF in preschool with BF% in school (Paper I)

Among boys, MVPA in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.601$, $p < 0.001$), MVPA in preschool was not associated with BF% in school, while BF% in preschool had a positive relationship with BF% in school ($p < 0.001$). In girls, MVPA in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.703$, $p < 0.001$), MVPA in preschool was not significantly associated with BF% in school, at the same time, BF% in preschool was positively associated with BF% in school ($p < 0.001$).

Among boys, ST in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.627$, $p < 0.001$), ST in preschool was not associated with BF% in school, but BF% in preschool was positively associated with BF% in school ($p < 0.001$). In girls, ST in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.726$, $p < 0.001$), higher ST ($p = 0.021$), higher BF% ($p < 0.001$), and lower AWT ($p = 0.021$) in preschool were associated with higher BF% in school.

Among boys, CRF in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.656$, $p < 0.001$), CRF in preschool was not associated with BF% in school, while BF% ($p < 0.001$) and age ($p = 0.027$) in preschool were positively associated with BF% in school. In girls, CRF in preschool was not associated with BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.650$, $p < 0.001$), CRF in preschool was not associated with BF% in school, while BF% in preschool was positively associated with BF% in school ($p < 0.001$).

Among boys, higher MF ($R^2 = 0.069$, $p = 0.042$) in preschool was associated with lower BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.641$, $p < 0.001$), MF in preschool was not associated with BF% in school, but BF% ($p < 0.001$) in preschool was positively associated with BF% in school. In girls, lower MF ($R^2 = 0.122$, $p = 0.006$) in preschool was associated with higher BF% in school (Table 2, unadjusted model). In the adjusted model ($R^2 = 0.698$, $p < 0.001$), lower MF ($p = 0.009$), higher age ($p = 0.011$), and higher BF% ($p < 0.001$) in preschool were associated with higher BF% in school.

Table 2. Multiple regression analysis demonstrating the associations of physical activity, sedentary time, and physical fitness in preschool with body fatness in school.

	BF% in School			
	Boys		Girls	
Variables in Preschool	β	*p*	β	*p*
Unadjusted (*n* = 48 boys, 40 girls)				
MVPA	0.054	0.702	−0.174	0.254
Adjusted (*n* = 48 boys, 40 girls)				
MVPA	0.094	0.365	−0.160	0.101
Age	0.118	0.232	0.129	0.193
BF%	0.791	**<0.001**	0.808	**<0.001**
Education	−0.004	0.968	−0.117	0.216
AWT	−0.052	0.634	−0.081	0.413
Unadjusted (*n* = 48 boys, 40 girls)				
ST	−0.189	0.180	−0.008	0.960
Adjusted (*n* = 48 boys, 40 girls)				
ST	−0.302	0.058	0.587	**0.021**
Age	0.153	0.118	0.128	0.175
BF%	0.771	**<0.001**	0.833	**<0.001**
Education	−0.001	0.990	−0.073	0.436
AWT	0.218	0.161	−0.578	**0.021**
Unadjusted (*n* = 56 boys, 54 girls)				
CRF	−0.248	0.058	−0.098	0.456
Adjusted (*n* = 56 boys, 54 girls)				
CRF	−0.059	0.496	−0.014	0.875
Age	0.186	**0.027**	0.144	0.100
BF%	0.766	**<0.001**	0.828	**<0.001**
Education	−0.048	0.591	−0.053	0.558
Unadjusted (*n* = 58 boys, 55 girls)				
MF	−0.263	**0.042**	−0.349	**0.006**
Adjusted (*n* = 58 boys, 55 girls)				
MF	0.032	0.716	−0.231	**0.009**
Age	0.139	0.100	0.222	**0.011**
BF%	0.818	**<0.001**	0.789	**<0.001**
Education	−0.006	0.944	−0.054	0.497

BF% – body fat percentage; β – standardized regression coefficient; MVPA – moderate-to-vigorous physical activity; AWT – accelerometer wear time; ST – sedentary time; CRF – cardiorespiratory fitness; MF – muscular fitness. Bold values denote $p < 0.05$.

5.3 Associations of VPA, MVPA, TPA, and ST in preschool with CRF and MF in school (Paper II)

Among boys, VPA in preschool was not associated with CRF in school (Table 3, unadjusted model). VPA in preschool was not associated with CRF in school, but CRF in preschool was positively associated with CFR in school (p <0.001) after adjusting for the confounding factors (R^2 = 0.402, p = 0.003). Among girls, a higher VPA (R^2 = 0.106, p = 0.038) in preschool was associated with a higher CRF in school (Table 3, unadjusted model). No associations after adjustment for the confounding factors were found.

Among boys, MVPA in preschool was not associated with CRF in school (Table 3, unadjusted model). MVPA in preschool was not associated with CRF in school, but CRF in preschool was positively associated with CFR in school (p < 0.001) after adjusting for the confounding factors (R^2 = 0.303, p = 0.003). Among girls, MVPA in preschool was not associated with CRF in school (Table 3, unadjusted model).. No associations in the adjusted model were found.

Among boys, TPA in preschool was not associated with CRF in school (Table 3, unadjusted model). TPA in preschool was not associated with CRF in school, yet CRF in preschool was positively associated with CFR in school (p <0.001) after adjusting for the confounding factors (R^2 = 0.315, p = 0.003). Among girls, TPA in preschool was not associated with CRF in school (Table 3, unadjusted model). No associations after adjustment for the confounding factors were found.

In boys, ST in preschool was not associated with CRF in school (Table 3, unadjusted model). CRF in preschool was positively associated with CRF in school (p < 0.001) after adjusting for the confounding factors (R^2 = 0.315, p = 0.003). In girls, ST in preschool was not associated with CRF in school (Table 3, unadjusted model). No associations after adjustment for the confounding factors were found.

In boys, a higher VPA (R^2 = 0.119, p = 0.015) in preschool was associated with a higher MF in school (Table 3, unadjusted model). VPA in preschool was not associated with MF in school, while MF in preschool was positively associated with MF in school (p <0.001) after adjusting for the confounding factors (R^2 = 0.457, p < 0.001). In girls, VPA in preschool was not associated with MF in school (Table 3, unadjusted model). VPA in preschool was not associated with MF in school, but MF in preschool was positively associated with MF in school (p = 0.001) after adjusting for the confounding factors (R^2 = 0.426, p = 0.001).

In boys, a higher MVPA (R^2 = 0.119, p = 0.015) in preschool was associated with higher MF in school (Table 3, unadjusted model). MVPA in preschool was not associated with MF in school, but MF in preschool was positively associated with MF in school (p < 0.001) after adjusting for the confounding factors (R^2 = 0.461, p < 0.001). In girls, MVPA in preschool was not associated with MF in school (Table 3, unadjusted model). MVPA in preschool was not associated with MF in school, while MF in preschool was positively associated with MF in school (p = 0.001) after adjusting for the confounding factors (R^2 = 0.430, p = 0.001).

Table 3. Multiple regression analysis demonstrating the associations of physical activity and sedentary time in preschool with physical fitness in school.

Variables in Preschool	**Physical Fitness in School**							
	CRF				**MF**			
	Boys (*n* = 41)		**Girls (*n* = 36)**		**Boys (*n* = 41)**		**Girls (*n* = 36)**	
	β	***p***	**β**	***p***	**β**	***p***	**β**	***p***
Unadjusted								
VPA	0.250	0.084	0.325	**0.038**	0.345	**0.015**	0.295	0.061
Adjusted								
VPA	0.130	0.367	0.139	0.449	-0.044	0.731	-0.011	0.947
Age	-0.136	0.349	-0.159	0.390	-0.209	0.104	0.140	0.357
Physical fitness *	0.560	**<0.001**	0.240	0.237	0.618	**<0.001**	0.642	**0.001**
Education	0.044	0.757	0.202	0.293	0.194	0.132	0.096	0.528
AWT	0.110	0.472	0.024	0.899	0.124	0.374	-0.091	0.569
Unadjusted								
MVPA	0.186	0.200	0.307	0.051	0.346	**0.015**	0.230	0.148
Adjusted								
MVPA	0.075	0.608	0.175	0.336	-0.078	0.547	-0.071	0.664
Age	-0.146	0.324	-0.164	0.371	-0.217	0.093	0.135	0.369
Physical fitness *	0.570	**<0.001**	0.245	0.214	0.628	**<0.001**	0.677	**0.001**
Education	0.057	0.692	0.197	0.301	0.198	0.121	0.088	0.566
AWT	0.119	0.443	0.045	0.810	0.132	0.346	-0.120	0.473
Unadjusted								
TPA	0.130	0.373	0.169	0.290	0.336	**0.018**	0.252	0.112
Adjusted								
TPA	0.139	0.352	0.134	0.451	-0.159	0.246	-0.063	0.694
Age	-0.131	0.372	-0.171	0.353	-0.242	0.064	0.133	0.376
Physical fitness *	0.586	**<0.001**	0.292	0.136	0.649	**<0.001**	0.674	**0.001**
Education	0.060	0.670	0.156	0.436	0.191	0.124	0.099	0.512
AWT	0.073	0.655	-0.018	0.921	0.173	0.231	-0.092	0.539
Unadjusted								
ST	0.111	0.448	-0.171	0.286	0.126	0.390	-0.038	0.812
Adjusted								
ST	-0.217	0.352	-0.378	0.451	0.246	0.246	0.182	0.694
Age	-0.131	0.372	-0.171	0.353	-0.242	0.064	0.133	0.376
Physical fitness *	0.586	**<0.001**	0.292	0.136	0.649	**<0.001**	0.674	**0.001**
Education	0.060	0.670	0.156	0.436	0.191	0.124	0.099	0.512
AWT	0.299	0.190	0.341	0.490	-0.082	0.707	-0.264	0.578

* Baseline physical fitness item (cardiorespiratory fitness or muscular fitness z-score) was entered in the model with respective physical fitness item at follow-up. β – standardized regression coefficient; CRF – cardiorespiratory fitness; MF – muscular fitness; VPA – vigorous physical activity; AWT – accelerometer wear time; MVPA – moderate-to-vigorous physical activity; TPA – total physical activity; ST – sedentary time. Bold values denote $p < 0.05$.

In boys, a higher TPA ($R^2 = 0.113$, $p = 0.018$) in preschool was associated with a higher MF in school (Table 3, unadjusted model). TPA in preschool was not assoocitaed with MF school, but MF in preschool was positively associated with MF in school ($p < 0.001$) after adjusting for the confounding factors ($R^2 = 0.476$, $p < 0.001$). In girls, TPA in preschool was not associated with MF in school (Table 3, unadjusted model). TPA in preschool was not associated with MF in school, while MF in preschool was positively associated with MF in school ($p = 0.001$) after adjusting for the confounding factors ($R^2 = 0.429$, $p = 0.001$).

In boys, ST in preschool was not associated with MF in school. ST in preschool was not associated with MF in school, but MF in preschool was positively associated with MF in school ($p <0.001$) after adjusting for the confounding factors ($R^2 = 0.476$, $p < 0.001$). In girls, ST in preschool was not associated with MF in school (Table 3, unadjusted model). ST in preschool was not associated with MF in school, yet MF in preschool was positively associated with MF in school ($p = 0.001$) after adjusting for the confounding factors ($R^2 = 0.429$, $p = 0.001$).

5.4 Associations of BF%, CRF and MF in preschool with conceptual skills, verbal skills and perceptual skills in school (Paper III)

In boys, BF% in preschool was not associated with cognitive skills in school (Table 4, unadjusted model). In the adjusted model, BF% in preschool was not associated with cognitive skills in school, but verbal ($R^2 = 0.217$, $p = 0.002$) and perceptual ($R^2 = 0.300$, $p < 0.001$) skills in preschool were positively associated with verbal and perceptual skills (both $p < 0.001$) in school, respectively.

In girls, BF% in preschool was negatively associated with perceptual skills ($R^2 = 0.070$, $p = 0.036$) in school (Table 4, unadjusted model). In the adjusted model, BF% in preschool was not associated with cognitive skills in school, while conceptual ($R^2 = 0.195$, $p = 0.004$) and verbal ($R^2 = 0.206$, $p = 0.003$) skills in preschool were positively associated with conceptual ($p = 0.002$) and verbal ($p = 0.001$) skills in school, respectively. Additionally, age in preschool was negatively associated with verbal skills ($p = 0.024$) in school. Also, higher parental educational attainment in preschool ($R^2 = 0.292$, $p < 0.001$) was associated with higher perceptual skills ($p < 0.001$) in school.

In boys, CRF in preschool was positively associated with perceptual skills ($R^2 = 0.081$, $p = 0.033$) in school (Table 4, unadjusted model). In the adjusted model, CRF in preschool was not associated with cognitive skills in school, but verbal ($R^2 = 0.151$, $p = 0.018$) and perceptual ($R^2 = 0.259$, $p < 0.001$) skills in preschool were positively associated with verbal ($p = 0.003$) and perceptual skills ($p < 0.001$) in school, respectively.

In girls, CRF in preschool was positively associated with conceptual skills (R^2 = 0.073, p = 0.039) in school (Table 4, unadjusted model). In the adjusted model, CRF in preschool was not associated with cognitive skills in school, but conceptual (R^2 = 0.220, p = 0.004) and verbal (R^2 = 0.166, p = 0.014) skills and parental education (R^2 = 0.278, p = 0.001) in preschool were positively associated with conceptual (p < 0.001), verbal (p = 0.013), and perceptual skills (p < 0.001) in school, respectively. In addition, older age in preschool was associated with lower verbal (p = 0.023) and perceptual (p = 0.022) skills in school.

In boys, MF in preschool was positively associated with verbal skills (R^2 = 0.074, p = 0.024) in school (Table 4, unadjusted model). In the adjusted model, the association between MF in preschool and verbal skills in school remained positive (p = 0.021). Additionally, conceptual (R^2 = 0.095, p = 0.066), verbal (R^2 = 0.236, p = 0.002), and perceptual (R^2 = 0.248, p = 0.001) skills in preschool were positively associated with conceptual (p = 0.048), verbal (p = 0.004), and perceptual skills (p < 0.001) in school, respectively.

In girls, MF in preschool was not associated with cognitive skills in school (Table 4, unadjusted model). In the adjusted model, MF in preschool was not associated with cognitive skills in school, but higher conceptual (R^2 = 0.208, p = 0.005) and verbal (R^2 = 0.214, p = 0.004) skills and parental education (R^2 = 0.298, p < 0.001) in preschool were associated with higher conceptual (p = 0.001), verbal (p = 0.008), and perceptual skills (p < 0.001), respectively. In addition, older age in preschool was associated with lower perceptual (p = 0.009) skills in school.

Table 4. Multiple regression analysis demonstrating the associations of body fatness and physical fitness in preschool with cognitive skills in school.

	Cognitive Skills in School											
	Conceptual Skills				**Verbal Skills**				**Perceptual Skills**			
	Boys (*n* = 66)		**Girls (*n* = 67)**		**Boys (*n* = 66)**		**Girls (*n* = 66)**		**Boys (*n* = 66)**		**Girls (*n* = 67)**	
Variables in Preschool	**β**	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	***p***
Unadjusted												
BF%	−0.075	0.599	0.221	0.082	−0.155	0.227	−0.016	0.901	−0.079	0.539	−0.265	**0.036**
Adjusted												
BF%	0.033	0.801	0.190	0.130	−0.082	0.500	−0.040	0.746	−0.172	0.139	−0.184	0.119
Age	0.168	0.199	−0.092	0.449	0.064	0.592	−0.284	**0.024**	−0.151	0.186	−0.203	0.081
Cognitive skills *	0.177	0.195	0.396	**0.002**	0.467	**<0.001**	0.416	**0.001**	0.574	**<0.001**	0.189	0.103
Education	0.254	0.073	0.149	0.238	0.113	0.358	0.069	0.579	−0.166	0.153	0.493	**<0.001**
Unadjusted												
CRF	−0.070	0.607	0.270	**0.039**	0.033	0.807	0.164	0.213	0.285	**0.033**	0.067	0.617
Adjusted												
CRF	−0.123	0.367	0.065	0.637	0.034	0.791	−0.039	0.786	0.227	0.059	−0.052	0.696
Age	0.182	0.190	−0.131	0.307	0.091	0.500	−0.306	**0.023**	−0.129	0.290	−0.288	**0.022**
Cognitive skills *	0.291	0.061	0.450	**<0.001**	0.419	**0.003**	0.341	**0.013**	0.535	**<0.001**	0.201	0.109
Education	0.037	0.805	0.140	0.329	0.073	0.574	0.084	0.564	−0.085	0.471	0.510	**<0.001**
Unadjusted												
MF	−0.150	0.270	0.056	0.674	0.302	**0.024**	−0.207	0.116	0.182	0.180	0.152	0.252
Adjusted												
MF	−0.142	0.289	0.021	0.875	0.293	**0.021**	−0.223	0.102	0.097	0.432	0.255	0.051
Age	0.155	0.255	−0.110	0.419	0.127	0.319	−0.229	0.095	−0.090	0.467	−0.347	**0.009**
Cognitive skills *	0.303	**0.048**	0.460	**0.001**	0.380	**0.004**	0.349	**0.008**	0.531	**<0.001**	0.219	0.072
Education	0.042	0.776	0.140	0.294	0.081	0.515	0.084	0.512	−0.073	0.551	0.448	**<0.001**

* Baseline cognitive skill (conceptual, verbal, or perceptual skill) score was entered in the model with respective cognitive skill at follow-up. β – standardized regression coefficient; BF% – body fat percentage; CRF – cardiorespiratory fitness; MF – muscular fitness. Bold values denote $p < 0.05$.

6. DISCUSSION

6.1 Longitudinal associations of physical activity, sedentary time, cardiorespiratory fitness, and muscular fitness with body fatness in preschoolers (Paper I)

We aimed to investigate whether MVPA, ST, CRF, and MF in preschool age are associated with BF% in the first school year among boys and girls. The first main finding was that ST at preschool age was positively associated with body fatness in the first grade of school once controlled for baseline age, BF%, AWT, and parental education in girls, but not in boys. While our finding is supported by a study among adolescent boys and girls (De Bourdeaudhuij et al., 2012), previous research has shown limited and mixed findings on the relationships between ST and body fatness among preschool-aged children (Basterfield et al., 2012; Butte et al., 2016; Collings et al., 2013; 2017; España-Romero et al., 2013; Guan et al., 2020; Leppänen et al., 2016; 2017; Moore et al., 1995). For example, España-Romero et al. (2013) reported no associations between ST and BMI z-score and waist circumference in young boys and girls, although higher ST was associated with higher waist circumference among girls at the 90th percentile. However, BMI is not the most accurate method for predicting FM in young children (Vanderwall et al., 2017) since it does not distinguish between FM and lean mass (Messner et al., 2024). Butte et al. (2016) investigated the association between ST and change in BF% and found that objectively measured ST at 3–5 years was not associated with a change in BF% at 1-year follow-up after adjusting for several child and maternal characteristics and household factors (Butte et al., 2016). Similarly, another longitudinal study found no relations of objectively registered ST at 4.5 years with FMI and BF% a year later after adjusting for gender, age, AWT, and VPA (Leppänen et al., 2017). These results align with the lack of associations between ST and BF% in the current study before controlling for confounders. However, after adjustment, the associations between ST in preschool and BF% in school became positive among girls. Partially in line with the current study's results among girls, inactive children aged 3–5 years were 3.8 times more likely than active peers to have an increasing triceps skinfold incline gradient before starting first grade after controlling for age, TV viewing, energy consumption, triceps skinfold thickness, parental BMI, perceived competence, and social acceptance score (Moore et al., 1995). Also, in active girls, skinfold thickness increased by 1 mm during the period from preschool to school, while the skinfold thickness among inactive girls increased by 1.75 mm. The skinfold thickness among active boys decreased by 0.75 mm but increased by 0.25 mm among inactive boys (Moore et al., 1995). Earlier cross-sectional studies among Estonian schoolchildren at 7–9 years (Riso et al., 2016) and 10–12 years (Riso et al., 2018) have also found an association between ST and BF% comparable to that found in the present study among Estonian preschool-aged girls. One reason, why specifically body composition of girls and not boys was affected by ST, could be possibly explained by higher resting (Goran et al., 1994) and daily energy expenditure (Freedson et al., 1981) of boys compared to girls. Girls body composition may also be more influenced by sedentary behaviour like TV viewing leading to poor dietary habits (Trofholz et al., 2019), while boys are more likely to engage in activities like gaming (Yalçın et al., 2022) related to less energy intake from food than TV watching (Marsh et al., 2014). As boys were more active than girls, PA practice might serve to certain degree protective effect against higher BF (Ramires et al., 2015).

In addition, we found that MVPA in preschool was unrelated to body fatness in the first grade of school after adjustment for confounding factors in boys and girls. It is proposed that PA, the largest modifiable component of energy expenditure, may assist in attaining a healthy weight by encouraging energy balance (Collings et al., 2013). The sparse number of studies on objectively measured MVPA and body fat indices among preschoolers report contradictory results (Basterfield et al., 2012; Butte et al., 2016; Bürgi et al., 2011; Collings et al., 2013; 2017; Leppänen et al., 2016; 2017). Collings et al. (2013) specifically emphasized the importance of VPA (3368 counts per minute in their work), since MPA was unrelated to body fatness and MVPA gave an inverse association with body fatness due to VPA among 4–year-old children (Collings et al., 2013). In a later study, Collings et al. (2017) reported that more than 3500 counts per minute (corresponding to the high end of MPA and VPA in our study) among children aged 11 months–5 years was negatively related to the sum of skinfolds after adjustment for age, gender, ethnicity, deprivation in an area, AWT, and season. The strength of the relationship was greater with higher PA intensity, peaking for activity with more than 6000 counts/min (Collings et al., 2017). Despite that, no associations of different PA intensity zones and TPA with the sum of skinfolds, BMI, or waist circumference were found in a group of children aged 11 months to 5 years (Collings et al., 2017). Corresponding to the missing associations between MVPA and BF% in unadjusted and adjusted analyses in the present study, Bürgi et al. (2011) identified that TPA, MPA, and VPA were not associated with BF% cross-sectionally among 4–6-year-old children after adjustment for sociocultural factors. Also, no longitudinal relationship was found between baseline PA and changes in BF% during the 9-month follow-up (Bürgi et al., 2011). While higher MVPA was associated with lower BF% at 4.5 years after controlling for gender, age, AWT, ST, maternal and paternal BMI, and educational level (Leppänen et al., 2016), those associations disappeared longitudinally (Leppänen et al., 2017). Additionally, Butte et al. (2016) obtained concurrent results in a cross-sectional and longitudinal study among preschool-aged children. Unlike the current study, Basterfield et al. (2012) demonstrated gender-specific associations among schoolchildren at 7–9 years – a reduction in MVPA was linked to an increase in FMI only among boys (Basterfield et al., 2012). Additionally, a study among children aged 9 to 10 years, originating from different countries, including Estonia, demonstrated that, after controlling for gender, birth weight, study place, puberty, and parents' BMI, MVPA had a significant but weak relationship with adiposity, explaining $<1\%$ of the variation (Ekelund et al., 2004).

There are several possible reasons for the discrepancies observed in the results of previous studies. First, investigators have applied different body fatness measurements such as skinfold thickness (Collings et al., 2017; Moore et al., 1995), bioelectric impedance (Basterfield et al., 2012; Bürgi et al., 2011), dual-energy X-ray absorptiometry (Butte et al., 2016; Collings et al., 2013), air-displacement plethysmography (Leppänen et al., 2016; 2017), BMI (Basterfield et al., 2012; España-Romero et al., 2013), and waist circumference (Collings et al., 2017; España-Romero et al., 2013). Second, study design (cross-sectional vs. longitudinal) might affect the associations found in studies. Third, the findings are influenced by the confounders applied. To account for baseline differences in the outcome of interest, we adjusted for the baseline value of the outcome, as did Bürgi et al. (2011), Basterfield et al. (2012), Moore et al. (1995), and Haapala et al. (2019), while the other longitudinal studies did not (Butte et al., 2016; Leppänen et al., 2017). Additionally, unlike the current study, others have adjusted for birth weight (Collings et al., 2013), sleep duration (Collings et al., 2013), height (Collings et al., 2013; 2017), energy intake (Moore et al., 1995), race/ethnicity (Butte et al., 2016; Collings et al., 2013; España-Romero et al., 2013), weekly daycare hours (Butte et al., 2016), TV viewing (Moore et al., 1995), perceived competence and social acceptance score (Moore et al., 1995), socioeconomic deprivation (Basterfield et al., 2012; Collings et al., 2017), season of assessment (Collings et al., 2017), VPA or MVPA in the models with ST and vice versa (Basterfield et al., 2012; Butte et al., 2016; Collings et al., 2013; Leppänen et al., 2017), parental migrant status (Bürgi et al., 2011), smoking during pregnancy (Collings et al., 2013), maternal age (Butte et al., 2016), duration of breastfeeding (Collings et al., 2013), maternal BMI (Butte et al., 2016; Collings et al., 2013; Leppänen et al., 2016), paternal BMI (Leppänen et al., 2016) or parents' BMI (Moore et al., 1995), maternal (Butte et al., 2016; Collings et al., 2013; Leppänen et al., 2016) and paternal education (Leppänen et al., 2016), family income, and size (Butte et al., 2016). Most studies also controlled for gender and did not study boys and girls separately (Basterfield et al., 2012; Butte et al., 2016; Bürgi et al., 2011; Collings et al., 2013; 2017; Leppänen et al., 2016; 2017).

The second goal of our study was to explore whether CRF and MF at preschool age are associated with BF% in the first school year among boys and girls. The second main finding was that higher MF in preschool was associated with lower body fatness in the first school year among girls but not in boys when adjusted for potential confounding variables. More precisely, while the unadjusted analysis revealed that higher MF in preschool was related to lower body fatness in school both among boys and girls, those associations remained significant only among girls after controlling for age, BF%, and parental education at baseline.

Only a few cross-sectional (Agha-Alinejad et al., 2015; Henriksson et al., 2016; Latorre-Román et al., 2017) and longitudinal studies (Henriksson et al., 2019) have investigated the associations of CRF and upper- and lower-limb muscular strength with body fatness among preschool children. Correspondingly to the current study, Latorre-Román et al. (2017) found that CRF was unrelated to BMI after adjustment for age among children at 3–6 years. They also found that SLJ test results were not associated with BMI (LatorreRomán et al., 2017). On the contrary, in another cross-sectional study among preschoolers aged 4.5 years, CRF and lower-limb muscular strength were inversely associated with BF% and FMI once adjusted for age, gender, FMI, and fat-free mass index. At the same time, upper-limb muscular strength was unrelated to body fatness parameters (Henriksson et al., 2016). Those findings were confirmed by a longitudinal study among children aged 4.5 years with a 1-year follow-up (Henriksson et al., 2019). Among primary school children aged 6 years, CRF, upper-limb muscular strength (flexed arm hanging), and lower-limb muscular strength predicted decreased body fat growth over the following 9 years after controlling for gender (Rodrigues et al., 2013).

While the previously described studies did not identify associations specifically among boys and girls, Agha-Alinejad et al. (2015) studied 5–6-year-old boys and girls separately. The authors reported that upper-limb muscular strength (modified pull-ups) was inversely correlated with most adiposity parameters including BF% in both genders. This corresponds to our results in boys and girls regarding the inverse association between MF and BF% from unadjusted analysis. As Agha-Alinejad et al. (2015) adjusted only for weight and did not precisely report those results, we cannot compare the results from the adjusted analysis. Also, higher CRF correlated with lower BF% among boys, but not among girls (Agha-Alinejad et al., 2015). Additional analysis with baseline data in current study revealed an agreement with those findings, as we found inverse relation between CRF and BF% ($\beta = -0.287$ $p = 0.032$) among preschool-aged boys in the present sample of children, as well as with missing relations among girls (data not shown). However, our longitudinal findings indicate that CRF in preschool is unrelated to BF% in school among both genders. Again, there are many reasons for nonuniformities in the results between studies, including regression adjustment and body fatness measurement, which was assessed by skinfolds in the present and some other (Agha-Alinejad et al., 2015; Reeves et al., 1999; Rodrigues et al., 2013) studies, air-displacement plethysmography in some studies (Henriksson et al., 2016; 2019), and BMI (Latorre-Román et al., 2017; Reeves et al., 1999) in other studies. There were also some differences in tests applied to measure children's PF. While most investigators used the 20 m shuttle run test to measure participants' CRF, one study applied half-mile time (Reeves et al., 1999); a hand dynamometer was most widely used to test upper-limb muscular strength, yet flexed arm hang (Rodrigues et al., 2013) and modified pull-ups (Agha-Alinejad et al., 2015) were also used. Finally, unlike comparative research, the mean of the relative upper- and lower-limb muscular strength z-score was used in our study to represent MF (Gil-Cosano et al., 2019). In future studies, we suggest to include also upper-limb and lower-limb muscular strength measures together with their compound score in order to allow more comprehensive analysis, as also there is some cross-sectional data to support different associations between upper-limb versus lower-limb strength with the shape of subcortical brain nuclei in preadolescent children (Ortega et al., 2019).

In conclusion, lower ST and higher MF at preschool age are related to lower body fatness in first grade among girls, but not among boys, implicating that as the prevention of childhood obesity has great impact on public health (Grant-Guimaraes et al., 2016), there is necessity to focus on reducing ST and promotion of MF especially among girls during preschool period in order to further build up healthier body composition. MVPA and CRF at preschool age are not related to body fatness in school in boys and girls.

6.2 Longitudinal associations of physical activity and sedentary time with cardiorespiratory and muscular fitness in preschoolers (Paper II)

PA is a major modifiable determinant for increasing PF during growth in children (Bürgi et al., 2011), and there is a particularly paucity of longitudinal research. Hence, this study aimed to investigate whether VPA, MVPA, TPA, and ST at preschool age are associated with CRF and MF in the first grade of school among boys and girls. The main finding in the present study was that VPA, MVPA, TPA, and ST in preschool were unrelated to CRF and MF among boys and girls after adjustment for potential confounding factors, although in the unadjusted analysis, we found that, in boys, a higher VPA, MVPA, and TPA in preschool were associated with a higher MF in school, and a higher VPA in preschool was linked to a higher CRF in school among girls. Once adjusted for confounding factors, such as age, AWT, the corresponding PF item, and the highest parental education level at baseline, the observed associations between VPA, MVPA, and TPA in preschool and fitness later in school disappeared. We found, additionally, that a higher CRF and MF in preschool were associated with a higher CRF and MF, respectively, in school among boys in all adjusted models. Among girls, a higher MF in preschool was related to a higher MF in school. Preschool CRF might associate with school CRF among boys but not girls as boys may prefer other type of physical activities than girls.

The comparison of our results with previous findings shows some similarities (Bürgi et al., 2011; Leppänen et al., 2016; 2017; Migueles et al., 2023; Potter et al., 2018; Riso et al., 2019b) and some discrepancies (Bürgi et al., 2011; Leppänen et al., 2016; 2017; Riso et al., 2019b; Potter et al., 2018). Regarding the associations between PA and CRF, we found that, longitudinally, VPA, MVPA, and TPA were not associated with CRF after controlling for confounders, but earlier cross-sectional research showed that a higher MPA, VPA, and MVPA were correlated with a better CRF (Bürgi et al., 2011; Leppänen et al., 2016; Riso et al., 2019b). Specifically, a higher VPA and MVPA at 4–5 years of age were associated with better results in the 20 m shuttle run test after adjustment for gender, age, AWT, ST, and parental BMI and education level. While the results for MVPA were primarily due to VPA (Leppänen et al., 2016), Bürgi et al. (2011) found that a higher MPA, VPA, and TPA were related to a higher CRF at 4–6-years of age after controlling for parental migrant status and education. Riso et al. (2019b) reported that MVPA, and particularly VPA, at 6–7 years of age were related to more laps in the 20 m shuttle run test after adjustment for age and gender (model 1) and for age, gender, organized sport participation, and parental education (model 2).

Regarding longitudinal research on this topic, Leppänen et al. (2017) found that VPA and MVPA at the age of 4–5 years of age predicted a higher CRF one year later (Leppänen et al., 2017), which corresponded to their cross-sectional findings (Leppänen et al., 2016) and findings from our study before controlling for confounders among girls. In a longitudinal analysis, Bürgi et al. (2011) demonstrated that VPA at the age of 4–6 years of age was related to the improvement in the 20 m shuttle run test during the 9-month follow-up after adjustment for baseline outcome parameters and parental sociocultural factors. Similar to results from the adjusted analysis of current study, they found no associations between TPA and CRF (Bürgi et al., 2011). Additionally, Migueles et al. (2023) reported that none of the movement behaviours (e.g., VPA, MPA, and ST) among 4-year-old children were associated with CRF and MF at 9 years of age directly after adjustment for gender, age, mother's education, and group allocation. The compositional analysis found that more VPA relative to all the other behaviours at the age of 4 years was indirectly (via VPA at 9 years of age) associated with a better CRF at 9 years of age. While Potter et al. (2018) demonstrated that a higher parent-reported PA (h/week) at 4.5 years of age predicted a better fitness composite score (incl. the 20 m shuttle run test performance, grip strength, vertical jump, sit-and-reach, and the inverse of waist circumference) at 3-year follow-up after adjustment for gender, follow-up age, and household income, the associations between PA and every single PF measure were insignificant (Potter et al., 2018). To summarize, while some studies seem to relate PA with a greater CRF (Bürgi et al., 2011; Leppänen et al., 2016; Riso et al., 2019b), the findings from the present and some other studies do not uniformly confirm this association (Bürgi et al., 2011; Migueles et al., 2023; Potter et al., 2018). Whether the analysis was conducted with a sample consisting both genders or separately among boys and girls could influence the results. Also, the age of the participants, the amount and content of PA they were engaged in, and as well the confounding factors included in the analysis could have played a role in the discrepancies.

Concerning the associations between PA and muscular strength among preschool-aged children, we found that a higher VPA, MVPA, and TPA in the last preschool year were related to a higher MF among boys a year later in school before adjusting for confounding factors, although after adjustment, those associations disappeared. Among girls, PA was not related to MF neither in the unadjusted nor adjusted model. An earlier cross-sectional study showed that a higher VPA and MVPA among children aged 4–5 years were related to higher handgrip dynamometer and SLJ test results after adjustment for gender, age, AWT, ST, and parents' BMI and education level (Leppänen et al., 2016). At 6–7 years of age, a higher VPA and MVPA were related to a higher lower-limb strength, but not to upper-limb strength in either adjustment model (Riso et al., 2019b). Longitudinally, a higher VPA and MVPA at 4–5 years of age were associated with a higher lower-limb muscular strength at the one-year follow-up. A higher VPA was associated with a better handgrip strength before adjusting for confounding factors. However, after adjustments, the association disappeared (Leppänen et al., 2017).

To sum up, there is a paucity of studies that investigated the associations between PA and muscular strength in preschoolers, and the findings support a positive association with lower-limb strength, but the relationship with upper-limb strength is controversial, and the associations with compound MF have not been studied to date, which makes a direct comparison of our results with other studies more complicated. Perhaps, to achieve more pronounced and longer lasting effects from PA on PF, the intensity and total amount of PA should be increased in preschool institutions. Ek et al. (2019) reported that preschool teachers perceived children's VPA as low in their daily work and acknowledged that a PA of higher intensity (e.g., climbing, running) should be provided more often. The largest barriers for not offering more VPA were suboptimal facilities or time constraints (Ek et al., 2019). Targeting such barriers could be important for future interventions to promote VPA in preschool-aged children (Migueles et al., 2023). Additionally, integrating daily and longer sessions of exercises that specifically target multiple aspects of fitness into the kindergarten schedule could be considered, as they have been shown to be effective in improving PF, especially among boys (Mačak et al., 2022).

There is a negligible amount of research with mixed results on the associations between sedentary behaviours and CRF or muscular strength among preschool-aged children. Questionnaire-based ST at the age of 4.5 years was inversely associated with upper-limb strength, but not with vertical jump performance after controlling for gender, follow-up age, BMI, and household income (Potter et al., 2018). Riso et al. (2019b) reported that, among 6–7-year-old children, a higher ST was related to a lower CRF in all adjusted models, and ST was inversely related to lower-limb strength after adjustment for age and gender, but not when an adjustment was made for age, gender, organized sport participation, and parental education. No association between time spent sedentary and grip strength was observed (Riso et al., 2019b) that matched our longitudinal outcomes regarding MF. There were no associations between ST in preschool with CRF and MF in school among boys and girls in the current study. Leppänen et al. (2016) found that ST at 4–5 years of age was associated with lower upper-limb strength, when PA was not adjusted, but after adjusting also for VPA, the association disappeared. No relations between ST with CRF and lower-limb strength were found (Leppänen et al., 2016), similar to the current study. Corresponding with our results, ST at 4–5 years of age was not associated either with CRF and upper- or lower-limb strength a year later after controlling for several confounding factors (Leppänen et al., 2017).

The results of present investigation demonstrate no associations between PA measurements in preschool and PF measurements in the first grade of school after adjustments for confounding variables in boys and girls. However, preschool PF was frequently associated with PF in school, showing that, among boys, both CRF and MF values and, among girls, MF values track well from kindergarten to the first grade of school. Our results are similar to those of other studies that have found a fairly stable tracking of PF from childhood and/or adolescence to adulthood (García-Hermoso et al., 2022). Thus, the CRF and MF parameters at preschool age can be used to characterize PF longitudinally at school in boys and MF parameters in girls, suggesting that building up higher PF levels should be targeted already from early childhood, as poor fitness is related with multiple chronic diseases (Castro-Piñero et al., 2019; Rasmussen et al., 2000; Ruiz et al., 2009).

In conclusion, while VPA, MVPA, TPA, and ST in preschool were not independently associated with CRF and MF among boys and girls in the first grade of school, a higher PF level in the last preschool year was often associated with a higher corresponding PF component in the first grade of school among boys and girls, suggesting that integrating exercises specifically designed to improve fitness into the daily PA schedule of preschoolers could be useful in order to enhance their PF.

6.3 Longitudinal associations of body fatness and physical fitness with cognitive skills in preschoolers (Paper III)

The transition from preschool to school is a crucial turning point in children's lives. School readiness typically sets standards for several developmental domains, including children's nutritional status, overall PF level, and motor and cognitive development (Akçinar, 2013; Scott-Little et al., 2006). The preschool period should prepare children for successful adaptation to school entry in order to fulfil school requirements (Scott-Little et al., 2006). Therefore, this study aimed to investigate whether body fatness, CRF, and MF in preschool are associated with cognitive skills in the first grade of school. The main findings were as follows: (1) BF% in preschool was not associated with conceptual, verbal, and perceptual skills in the first grade of school in boys and girls after adjustment for potential confounding factors; (2) CRF in preschool was not associated with conceptual, verbal, and perceptual skills in school in boys and girls when adjusted for possible confounding factors; (3) higher MF in preschool was associated with higher verbal skills in school only in boys after adjustment for potential confounding factors. It was also observed that cognitive skills in preschool were frequently positively associated with cognitive performance at follow-up in the first grade of school both in boys and girls, although there were some gender differences. For example, in adjusted models, baseline perceptual skills predicted perceptual skills a year later among girls, and not boys reflecting hypothetically the differences in the trajectory of cognitive development boys and girls were going through as the trajectory of cognitive development during childhood and adolescence is characterized by periods of sharp increases and periods of relative stability (Tikhomirova et al., 2020). Additionally, higher parental educational attainment at baseline was associated with higher perceptual skills at follow-up in girls. Correspondingly, Riso et al. (2019a) concluded that preschoolers from more highly educated families had higher conceptual and verbal skills. Interestingly, younger age in preschool was occasionally associated with higher verbal or perceptual skills in school only among girls.

In the unadjusted analysis, we found that skinfold thickness-derived BF% in preschool was negatively associated with perceptual skills in school among girls. However, once adjusted for confounding factors, such as age, parental education, and cognitive skills at baseline, no associations between BF% in preschool and conceptual, verbal, or perceptual skills in the first grade of school existed in boys or girls. Prior studies in children show rather mixed results in terms of correlations between BF% or obesity and cognitive measures (Bisset et al., 2013; Davis and Cooper, 2011; Haapala et al., 2018; 2019; Raine et al., 2017). Haapala et al. (2018) reported a weak inverse association between DEXA-measured BF% and the ability to read with proper speed and accuracy, as well as the ability to understand the text that was read, among 6–8-year-old boys after controlling for age and parents' education. Variation in motor performance between boys with lower and higher BF% explained these gender-specific associations to a high degree (Haapala et al., 2018). In a longitudinal study, in 3–year-old boys, obesity predicted inferior pattern recognition, but not naming vocabulary or reasoning skills at 5 years after controlling for several confounding factors. "Growing out" of obesity between the ages of 3 and 5 years was positively correlated with reasoning skills in 5–year-old girls (Martin et al., 2016). In children at 8–9 years of age, only the extent of reduction in visceral FM over the course of 9 months was associated with increased inhibitory control. These associations were particularly obvious among obese children (Raine et al., 2017). However, Davis and Cooper (2011) showed that both whole-body and abdominal body fatness were negatively associated with executive function, resistance to distraction, and gestalt processing in children with overweight aged 7–11 years after adjustment for gender, race, and parental educational attainment (Davis and Cooper, 2011). Consistent with the present study, Haapala et al. (2018) demonstrated that bioelectrical impedance method-detected BF% at 6–9 years did not predict non-verbal reasoning skills after two years in either gender after controlling for cognitive skills at baseline. Meanwhile, one study even suggested that not overweight but underweight at an early age predicted worse cognitive and academic performance once adjusted for early behavior, cognitive skills, and socioeconomic status (Bisset et al., 2013). The variability in the results of these studies might come from differences in the weight status of the studied children, different methods applied to investigate body composition, different cognitive tasks involved in the studies, sociodemographic differences across countries, and differences in adjustments for confounders. In current study, body fatness in preschool was not independently associated with cognitive skills in grade one in boys or girls.

Studies by Chaddock et al. (2010) and Ortega et al. (2019) in preadolescent children demonstrate that the associations between PF items and brain structures might be specific, where certain brain structures seem to react to a certain PF item either by enlargement or contraction, the exact impact of which on the functions of the brain, including on cognitive performance, needs to be further explored (Ortega et al., 2019). Accordingly, there seems to be a variability in associations between PF and cognition in children and adolescents across studies.

In our study, higher CRF in preschool was associated with higher conceptual skills in girls and higher perceptual skills in boys a year later. However, these associations disappeared after controlling for confounding variables like age, parental education, and cognitive skill at baseline. In general, there seems to be a lack of consistency in the studies exploring the associations between CRF and cognition at a young age. A cross-sectional study showed that CRF was linked to better working memory performance in boys but not in girls aged 8–11 years (Drollette et al., 2016). Children at 9 years of age with high CRF levels estimated using a 20 m shuttle run test displayed better outcomes in a visual discrimination task (Hillman et al., 2005) and demonstrated higher accuracy in inhibitory control tasks than children who had lower CFR levels, although reaction times were not different between the groups (Hillman et al., 2009). Longitudinal research has also demonstrated mixed findings on the relationships between CRF and cognitive skills. Specifically, Chaddock et al. (2012) showed that children with higher $\dot{V}O_{2peak}$ at 9–10 years had superior response accuracy in compatibility conditions, yet not in incompatibility conditions on a flanker test at baseline and follow-up testing one year later, compared with less fit children. In addition, a shorter compatible and incompatible reaction time for children with higher levels of fitness was observed (Chaddock et al., 2012). Niederer et al. (2011) reported that baseline 20 m shuttle run test results were associated with improvements in attention but not with working memory during a 9-month period among children aged 4–6 years after controlling for several confounding factors (Niederer et al., 2011). To explore the association between CRF and cognition, Haapala et al. (2019) applied a Raven's progressive matrices test (RPM), which has methodological similarities to the non-verbal perceptual reasoning skills testing applied in our study. Comparably to our results, cycle ergometer-assessed exercise capacity at 6–9 years was not associated with RPM scores after two years, nor with changes in RPM scores during a two-year period in boys or girls after controlling for baseline RPM score, age, and study group. In accordance with the current study, baseline cognition strongly predicted cognitive functioning at two-year follow-up among both genders (Haapala et al., 2019).

Differences in CRF and cognition testing methodology and the confounding variables included may modify the associations between CRF and cognitive performance, and hence clear up the diversity observed in the results of the studies. However, longitudinal research on the relationships between fitness items other than CRF and cognitive functioning is limited. The current study demonstrated that higher MF in preschool was associated with higher verbal skills in school independent of confounders in boys, with no such association observed for females. We know from findings in cognitively unimpaired adults that PA has partly sex-dependent associations with brain integrity (Gonneaud et al., 2022). Therefore, current data indicate that higher MF in preschool period affects brain regions responsible for language development specifically among boys, who might especially benefit from that as research shows that the functional organization of the female brain confers an innate advantage in the acquisition of communication and language systems, including language comprehension relative to men, that is evident already at early age (Adani and Cepanec, 2019). Syväoja et al. (2021) detected that higher MF, calculated as the sum of upper-limb and abdominal strength, was indirectly associated with higher outcomes in mathematics through visuospatial working memory in 12–17-year-old girls but not in boys. Additionally, an indirect path from compound fitness z-score (including the six-minute-run, SLJ, and the jumping sideways task) via executive functions among 5–7-year-old preschoolers to mathematical and reading achievement 1.5 years later in school has been reported (Oberer et al., 2018). After controlling for age, gender, pubescence, intervention group, menstrual age, mother's age, family earnings, and parity, Lima et al. (2022) found that at 7–9 years, out of all the PF components tested in children, only speed and agility, and manual dexterity were related to later cognitive skills on RPM at middle childhood and adolescence, respectively. However, 50 m dash and outcomes in a box and block test were not related to cognition after additionally controlling for prenatal, neonatal, and child fitness measures. Baseline SLJ or handgrip strength or sit-ups were not associated with later cognitive performance.

In conclusion, we extended previous research by demonstrating that in our model, in which several independent variables were simultaneously included, cognitive skills in preschool seemed to be frequently associated with cognitive skills in the first grade of school, and only a higher MF compound score in preschool was independently associated with higher verbal skills in school among boys. The positive association between MF and verbal skills observed in present study specifically among boys shows that engagement in activities that build muscle strength during preschool period could be helpful in assisting the development of language abilities among males who are most likely to benefit from it.

7. LIMITATIONS AND STRENGTHS OF THE STUDY

We acknowledge that there are certain limitations to the current study. Present study may be underpowered to detect the difference due to relatively small number of participants. Still, the sample size in present study is analogous to several similar studies in the given field (Drollette et al., 2016; Flores et al., 2023; Haapala et al., 2019; Oberer et al., 2018). Body fat content was measured indirectly by measuring skinfold thickness, and although Slaughter's equation has fairly high validity with DEXA for calculating BF% in children, DEXA is still considered the gold standard in body composition assessment (Hussain et al., 2014). There are some accelerometer-related limitations, such as inability to capture activities performed in water and during cycling (Harrison et al., 2017; Herman Hansen et al., 2014); U-shaped reactivity, especially in young children (Dössegger et al., 2014); and the hip-mounted accelerometer underestimating sedentary behaviours and MVPA and overestimating LPA and breaks in sedentary activities (Montoye et al., 2016). All of these can lead to bias in the objective PA and ST estimates. Although we adjusted our statistical analysis for some confounding factors, we cannot exclude the possibility of residual confounders due to genetic, socioeconomic, or nutritional factors.

On the other hand, the strengths of this study are the objective monitoring of PA and the application of standardized PF and cognitive skills tests in a longitudinal design separately in boys and girls.

8. CONCLUSIONS

1. Lower sedentary time and higher muscular fitness in preschool were associated with lower body fatness in first grade of school among girls, but not among boys. Moderate-to-vigorous physical activity and cardiorespiratory fitness in preschool were not associated with body fatness in first grade of school among boys and girls (Paper I).
2. Vigorous, moderate-to-vigorous and total physical activity, and sedentary time in preschool were not associated with cardiorespiratory fitness and muscular fitness in first grade of school among boys and girls (Paper II).
3. Higher muscular fitness in preschool was associated with higher verbal skills in school among boys, but not among girls. Body fatness and cardiorespiratory fitness in preschool were not associated with conceptual, verbal, and perceptual skills in first grade of school among boys and girls (Paper III).

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SUMMARY IN ESTONIAN

Keha rasvasisalduse, kehalise võimekuse, kehalise aktiivsuse ja kognitiivse võimekuse vahelised longitudinaalsed seosed eelkooliealistel lastel

Sissejuhatus

Kehakoostist peetakse tervise ja heaolu indikaatoriks juba noores eas, paraku on lapseea ülekaalulisus ja rasvumine ühes kaasneda võivate kardiorespiratoorsete ja psühholoogiliste komplikatsioonidega ülemaailmselt kasvav tervise- ja majanduslik probleem. Kirjeldatud on ka ülekaalulisuse ja rasvumise mittesoovitud mõjusid laste kognitiivsetele funktsioonidele ja akadeemilisele võimekusele. Rasvumise epideemia kõrval veedavad lapsed üleliia palju aega istuvatel tegevustel ning sageli ei järgita soovituslikke liikumisnorme. Ülemäärast istumisaega seostatakse mitmete terviseprobleemidega, kehalise aktiivsuse harrastamine ja hea kehaline võimekus varases eas toob kaasa aga positiivse mõju kehalisele, vaimsele ja kognitiivsele arengule. Samas ei ole üheselt selged pikaajalised seosed keha rasvasisalduse, kehalise võimekuse, kehalise aktiivsuse, istumisaja ja kognitiivse võimekuse vahel eelkooliealistel lastel.

Eesmärk ja ülesanded

Käesoleva uurimistöö peamiseks eesmärgiks oli uurida Eesti eelkoolieaiste laste seas longitudinaalseid seoseid keha rasvasisalduse, kehalise võimekuse, kehalise aktiivsuse, istumisaja ja kognitiivse võimekuse vahel.

Töös seati järgmised ülesanded:

1. uurida, kas kehaline aktiivsus, istumisaeg, kardiorespiratoorne võimekus ja lihasjõud eelkoolis seostuvad keha rasvasisaldusega esimeses klassis poistel ja tüdrukutel (I artikkel);
2. uurida, kas kehaline aktiivsus ja istumisaeg eelkoolis seostuvad kardiorespiratoorse võimekusega ja lihasjõuga esimeses klassis poistel ja tüdrukutel (II artikkel);
3. uurida, kas keha rasvasisaldus, kardiorespiratoorne võimekus ja lihasjõud eelkoolis seostuvad kognitiivse võimekusega esimeses klassis poistel ja tüdrukutel (III artikkel).

Metoodika

Käesolevas uuringus osalesid Tartu maakonna lapsed kahel korral – lasteaia viimasel aastal (6–7 a) ja olles asunud õppima 1. klassis (7–8 a) (kolmes artiklis n = 41–67 poissi ja 36–66 tüdrukut). Osalejate keha rasvasisaldus määrati nahavoltide paksuste määramise meetodiga. Laste kehalist võimekust hinnati standardiseeritud kehalise võimekuse testidega – kardiorespiratoorne võimekus määrati 20 m süstikjooksu testiga, ülajäsemete jõudu mõõdeti käe dünamomeetriga ja alajäsemete jõudu paigalt kaugushüppe testiga. Laste kehalist aktiivsust ja istumisaja pikkust mõõdeti aktseleromeetriga. Kognitiivne võimekus (kontseptuaalne, pertseptiivne ja verbaalne võimekus) mõõdeti modifitseeritud Boehm-3 testiga.

Järeldused

1. Väiksem istumisaeg ja suurem lihasjõud eelkoolis olid seotud väiksema keha rasvasisaldusega esimeses klassis tüdrukutel, aga mitte poistel. Mõõdukas-tugev kehaline aktiivsus ja kardiorespiratoorne võimekus lasteaias ei olnud seotud keha rasvasisaldusega esimeses klassis ei poistel ega tüdrukutel (I artikkel).
2. Tugev, mõõdukas-tugev ja kogu kehaline aktiivsus ning istumisaeg eelkoolis ei olnud seotud kardiorespiratoorse võimekusega ja lihasjõuga esimeses klassis ei poistel ega tüdrukutel (II artikkel).
3. Suurem lihasjõud eelkoolis oli seotud parema verbaalse võimekusega esimeses klassis poistel, aga mitte tüdrukutel. Keha rasvasisaldus ja kardiorespiratoorne võimekus eelkoolis ei olnud seotud kontseptuaalse, verbaalse ega pertseptiivse võimekusega esimeses klassis ei poistel ega tüdrukutel (III artikkel).

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- all data collecting team.

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