DISSERTATIONES
KINESIOLOGIAE
UNIVERSITATIS
TARTUENSIS
42

TRIIN RÄÄSK

Subjectively and objectively measured physical activity and its relationships with overweight and obesity in adolescent boys

DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS
42

DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS
42

TRIIN RÄÄSK

Subjectively and objectively measured physical activity and its relationships with overweight and obesity in adolescent boys

UNIVERSITY OF TARTU
Press

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

Dissertation was accepted for the commencement of the Degree of Doctor of Philosophy in Exercise and Sport Sciences on 16 June, 2016 by the Council of the Institute of Sport Sciences and Physiotherapy, University of Tartu, Estonia.

Supervisors: Associate professor Jarek Mäestu, PhD

Researcher Kenn Konstabel, PhD

Professor Toivo Jürimäe, PhD

Opponent: Assistant professor Arunas Emeljanovas, PhD
Lithuanian Sports University

Commencement: 6th October, 2016, Tartu

Publication of this dissertation was granted by the IUT 20-58.

ISSN 1406-1058
ISBN 978-9949-77-223-0 (print)
ISBN 978-9949-77-224-7 (pdf)

University of Tartu Press
www.tyk.ee

CONTENTS

LIST OF ABBREVIATIONS

AUC	area under the curve
BMI	body mass index
CI	confidence intervals
DSI	Domain-Specific Impulsivity
IPAQ	International Physical Activity Questionnaire
IPAQ-SF	International Physical Activity Questionnaire-Short Form
LPA	light physical activity
MPA	moderate physical activity
MVPA	moderate to vigorous physical activity
NEAT	non-exercise activity thermogenesis
OR	odds ratios
PA	physical activity
REE	resting energy expenditure
ROC	receiver operating characteristic
T1	second wave of data collection
T2	third wave of data collection
T3	fourth wave of data collection
TEE	total energy expenditure
TOM	time of measurement index
TPAQ	Tartu Physical Activity Questionnaire
VPA	vigorous physical activity
WHO	World Health Organization

LIST OF ORIGINAL PUBLICATIONS

I. Rääsk T, Lätt E, Jürimäe T, Mäestu J, Jürimäe, Konstabel K. Association of subjective rating to objectively assessed physical activity in pubertal boys with different BMI. Perceptual and Motor Skills. 2015; 121 (1): 245–259.

II. Rääsk T, Konstabel K, Mäestu J, Lätt E, Jürimäe T, Jürimäe J. Tracking of physical activity in pubertal boys with different MBI over two-year period. Journal of Sport Sciences. 2015; 16: 1–9.

III. Lätt E, Mäestu J, Ortega FB, Rääsk T, Jürimäe T, Jürimäe J. Vigorous physical activity rather than sedentary behaviour predicts overweight and obesity in pubertal boys: A 2-year follow-up study. Scandinavian Journal of Public Health. 2015; 43 (3): 276–282.

IV. Rääsk T, Mäestu J, Lätt E, Jürimäe J, Jürimäe T, Vainik U, Konstabel K. Comparison of IPAQ-SF and two other physical activity questionnaires with accelerometer in adolescent boys. PloS One. 2016: (submitted).

Paper I, II and IV, Triin Rääsk had the primary responsibility for protocol development, subjects´ screening, performing measurements, data analysis, and writing the manuscripts.

Paper III, Triin Rääsk had the primary responsibility for subjets's screening, and performing the measurements. She also contributed in data analysis and writing the manuscript.

INTRODUCTION

Overweight and obesity during childhood and adolescence are global welfare problems and currently approximately 81% of adolescents aged 11–17 years are insufficiently physically active in the world (World Health Organization, 2010). The recommendations for physical activity state that children and adolescents aged 5–17 years should do at least 60 minutes of moderate to vigorous physical activity (MVPA) daily and physical activity (PA) amounts greater than 60 minutes daily will provide additional health benefits. However, the overall level of physical activity has decreased during the last decades in children and adolescents with the most evident decrease in PA during life time appears during the pubertal period, which is also a very sensitive period for significant changes and growth of the whole body. Physical activity on the other side is inversely related to several diseases and conditions like diabetes, hypertension, obesity etc. Low levels of physical activity in childhood and adolescents also contribute to lower motor control which makes it difficult to take part in different types of physical activity in the adulthood, and thus affect also negatively PA levels in adulthood. Therefore, studying different aspects of PA is relevant in public health perspective. However, it should be indicated that the relationship between the amount of PA and health is not fully understood. Body weight status may also be a significant contributor to the rate of change in PA during puberty. Due to the significant changes in PA during certain periods of life, cross-sectional measurement designs may provide less reliability therefore, the information how PA tracks throughout puberty taking the weight status into account is of importance.

It should also be considered that measuring PA is also complicated, especially in children. Although modern technologies like GPS and accelerometry have frequently been used in research, they also have limitations to certain activities and these measurements itself are relatively time-consuming. PA in adolescents is still nowadays frequently measured with subjective ratings, because these are relatively inexpensive and easy to use in larger samples. It should be considered, that subjective self-reports of PA may not be always accurate because the respondent cannot memories or quantify their previous PA. Furthermore, subjective ratings are not appropriate for children less than 10 years old due to cognitive limitations. The research methods to increase the validity of subjective reports are still of importance to describe certain aspects of physical activity and parental information might increase the reliability of subjective ratings and therefore, the validity of the PA questionnaire. The general aim of the present thesis was to investigate the associations and tracking of subjectively and objectively measured PA and its relationship to weight status in pubertal boys.

1. REVIEW OF THE LITERATURE

1.1. Assessment of physical activity in adolescents

Self-report questionnaires to measure PA have been commonly used to assess adolescents' subjective ratings of PA, because they are relatively inexpensive and easy to use in large sample studies (Boon et al., 2010; Corder et al., 2008). Self-report methods include retrospective questionnaires, interview-administered recall, activity diaries and mail surveys (Armstrong & Welsman, 2006). However, it has been found that adolescents's subjective self-report of PA may be invalid (Corder et al., 2008; Slootmaker et al., 2009; Trost, 2007). For example, it has been found that the use of self-report instruments is not appropriate for children less than 10 years old due to cognitive limitations; children cannot self-report exactly their PA (Corder et al., 2009; Trost, 2007). Because children's PA is difficult to assess, parental questionnaires are sometimes recommended, although the resulting estimate of the children's PA is less accurate than desirable (Telford et al., 2004).

Modern technologies like GPS and accelerometry have frequently been used in research, they also have limitations to certain activities and the measurements itself are relatively time-consuming. Accelerometers allow objective assessment of PA in humans by detecting vertical and horizontal forces that apply to the body during movements. It is usually attached to the hip and weared for several days in order to collect reliable data. The ActiGraph accelerometers have been previously validated in laboratory and free-living conditions in young people (Freedson et al. 2005). However, accelrometers can not be used in water-based activities and they are not very reliable during different types of movement like skiing, cycling, skating etc. Despite those limitations accelerometers are commonly used in research (Grydeland et al. 2014).

The criterion or "gold standard" approach to assess total energy expenditure (TEE) in a free-living context is the doubly labeled water technique. TEE is comprised of multiple components including physical activity energy expenditure, resting energy expenditure, and the thermic effect of food. Despite PA being a complex and multifaceted construct measured using many approaches, unlike for the measurement of TEE, there is no recognized "gold standard" technique (Hills et al., 2014).

Self-report questionnaires have been shown to have weak to modest correspondence to objectively measured PA (e.g., accelerometer) (Gwynn et al., 2010; Machado-Rodrigues et al., 2011; Trost, 2007). There are several measurement aspects that affect such comparisons, e.g., times of subjective and objective measurements may not match exactly (Ottavaere et al., 2011). Agreement between subjective and objective assessment of PA data may also be affected by the measurement period, season of the year and what model of accelerometer has been used. Season appears to have less influence on adolescents' than younger children's PA (Kolle et al., 2009). Despite such issues, accelerometers are a promising instruments for measuring PA in children and adolescents in replacement of self-report questionnaires (Ellery et al., 2014; Martinez-Gomez et al., 2009; Trost, 2007).

The widely used self-report questionnaire in adolescents is the International Physical Activity Questionnaire (IPAQ) and the criterion validity of the IPAQ is usually assessed using accelerometers; both instruments measure PA intensity categories in minutes per day (Boon et al., 2010; Graig et al., 2003; Lee et al., 2011). The IPAQ instrument was developed for the use in adults from the age of approximately 18 years and above (Hagströmer et al., 2008). The purpose of the IPAQ is to provide a set of well-developed instruments that can be used internationally to obtain comparable estimates of PA. There are two versions of the questionnaire. The short form of IPAQ (IPAQ-SF) is suitable for use in national and regional surveillance systems and the long form of IPAQ (IPAQ-LF) provides more detailed information that is often required in research work or for evaluation purposes (International Physical Activity Questionnaire website).

The results of meta-analysis have shown small-to-medium correlations between IPAQ and objective measurement (Kim et al., 2011). However, in a few studies, very low or even no correlations have been found (Hagströmer et al., 2008; Wang et al., 2013). The low correlations found especially among in younger (12–14-years old) adolescents group may be explained by several factors. First, the concepts used in the questionnaire might not be as easily understood and interpreted by the younger adolescents. As well as providing less accurate information, younger adolescents may also be involved in different types of activities that could be responsible for the low validity scores. Older adolescents (15–17-years old) are more likely to either participate in structured activity (sports) or to be sedentary, whereas the younger adolescents and children are more often engaged in spontaneous activities. These types of activities are more difficult to assess with a questionnaire.

In general, comparisons between the results of subjective and objective PA activity data in adolescence have been controversial. First, subjective assessment is cheaper and easier to carry out, especially when one has to confine oneself with retrospective assessment. And second the validity of subjective assessments is unclear and may vary across populations (e.g. its validity may be different across age groups [children vs adolescents vs adults] and BMI groups (obese vs normal weight). For example, it has been shon that subjective ratings underestimate PA as compared to objective assessment in adolescents (Machado-Rodrigues et al., 2011; Telford et al., 2004). The difference between IPAQ and accelerometer measured moderate-to-vigorous physical activity (MVPA) has been found to increase with higher activity and intensity levels (Dyrstad et al., 2014; Kim et al., 2011; Hong et al., 2012). Several studies have found that adolescents tend to over report their PA using IPAQ, as compared to accelerometer measured PA data (Boon et al., 2010; Ottevaere et al., 2011; Benitez-Porres et al., 2013). Furthermore, it has been found that adolescents tend to overreport vigorous PA (VPA) and underreport their moderate PA (MPA) in IPAQ-SF (Armstrong & Welsman, 2006; Lee et al., 2011; Lachat et al., 2008). Therefore, MVPA correlations between subjective and objective methods in adolescents may be stronger than correlations separately for MPA and VPA. In addition, international PA recommendations for adolescents also focus on MVPA (World Health Organization, 2010).

It is also important to investigate the relationships between adolescents PA, sedentary activities, and body mass index (BMI). Lee et al. (2015) found that PA and screen time in adolescents were associated with BMI. Various lifestyle choices, like television viewing, were also associated with overweight and obesity among children (Jago et al., 2010; Lee et al., 2015). In contrast, Foley et al. (2011) found no relationships between time spent in sedentary activities and weight status in children. This may be because the association between TV viewing and time in PA in children is small (Nilsson et al., 2009). However, it is also possible that measures of PA are not accurate enough to reliably characterize these relationships. In addition, overweight and obese adolescents have been reported to provide even less accurate self-assessment of PA than normal weight adolescents (Slootmaker et al., 2009).

1.2. Tracking physical activity in adolescents

Tracking is usually defined as the tendency of individuals to maintain their rank or position of PA within a group over certain time period (Telama, 2009). Most tracking studies have used correlation analysis between two measurement occasions as a measure of tracking change (Dumith et al., 2011; Telama, 2009). Another common measure, PA change (expressed as percentage of change per year), is of obvious interest, but it is independent of tracking as defined above (rank-order stability): for example, an individual may retain his or her rank-order position when there is a mean-level change, and lack of mean-level change is by no means a guarantee of high rank-order stability. Commonly, the follow-up duration in tracking studies is longer than a year. However, it has been suggested that the decrease of PA can already be seen over one and two-year period and this may be a health promotion target (Baggett et al., 2008; Corder et al., 2010; Nyberg et al., 2009). Telama (2009) further pointed out that an attention has to be paid to the adjustment of tracking correlations for different error variations because this may influence tracking results.

Increasing PA, especially in young children and adolescents, is of great importance for the advancement of public health (Kjonniksen et al., 2008; Nyberg et al., 2009; Telama, 2009). It has been found that physically active lifestyle starts to develop very early in childhood and that the stability of PA is moderate or high along the life course from youth to adulthood (Telama et al., 2014). However, different periods of PA decline occur during the lifespan, with the greatest during the adolescent growth spurt (Corder et al., 2010; Dumith et al., 2011).

Most PA tracking studies have used questionnaires (Dumith et al., 2011), with only a few have used objective methods to measure PA (Corder et al., 2010; Kristensen et al., 2008; Nilsson et al., 2009). It is highly desirable that objective methods are used in tracking studies because of their better validity and reliability compared to the self-report methods (Telama, 2009; Corder et al., 2010). However, objective measurement of PA is not always feasible; comparing the stability of self-reports and objective methods would also be of interest. However, there is a lack of studies in this field, since only few studies have been conducted (Baggett et al., 2008; Cleland et al., 2012; Ham & Ainsworth, 2010). For example, Baggett et al. (2008) found that tracking of inactivity and PA by self-report and accelerometer in middle school girls was fair to moderate during two-year period. The five years tracking correlations in adolescents (age of 12–18-years old) between self-reported physical activity levels and accelerometry derived minutes of MVPA per day were found to be small (r = 0.27) to moderate (r = 0.34) and higher correlations were found in girls and older (12–18-years old) adolescents (Muryhy et al., 2015).

Decline in PA at ages 9–16 is a rather consistent finding in the literature (Dumith et al., 2011; Kolle et al., 2010; Kristensen et al., 2008; Kristensen et al., 2010). Different rates of decline have been found in children with different body fat proportions, with change in children with greater body fat (Corder et al., 2010). The studies are not entirely consistent as to whether the change is uniform over the whole period, or mostly concentrated to a part of it (Dumith et al., 2011; Duncan et al., 2007; Nyberg et al., 2009; Kwon et al., 2012). If it is true, as some studies suggest (Corder et al., 2010) that the decline of PA is especially marked in overweight children, and consequently, tracking of (in)activity is in this group is higher, which is problematic for behavioural interventions as this is exactly the group where a change is the most desirable. Increases in inactivity are especially noticeable during childhood and adolescence, both in boys and girls (Janz et al., 2005; Kwon et al., 2012; Ortega et al., 2013). This results in an unfavourable activity profile predictive of obesity as well as other health concerns (Kjonniksen et al., 2008; Nyberg et al., 2009; Telama, 2009).

1.3. Physical activity as predictor of overweight and obesity in adolescents

Overweight and obesity during childhood and adolescence are global welfare problems. Being overweight or obese is one the most important risk factors for later cardiovascular disease and type 2 diabetes (Andersen et al., 2006; Steele et al., 2008). Puberty can be characterized as one of the most sensitive periods because there is a decrease in PA, and usually this is accompanied by weight gain (Riddoch et al., 2009). Lots of studies have investigated the relationship between PA, body composition (overweight and obesity), and in general have concluded that children younger than 17 years should participate in at least 60 minutes of MVPA a day (Martinez-Gomez et al., 2010; Laguna et al., 2013) to gain health benefits from PA. However, it has also been recommended that at least 90 minutes of MVPA a day for children and adolescents is needed in order to be healthy (Governmental of Canada, 2002). Despite the fact overweight and obesity among children and adolescents is increasing all the time, it could also be suggested that current PA recommendations may not be enough. There are studies in the literature that have shown that VPA (Martinez-Gomez et al., 2010; Ortega et al., 2007; Moliner-Urdiales et al., 2009; Gutin et al., 2005), rather than MPA (Gutin et al., 2005; Ruiz et al., 2006), plays a key role in decreasing the risk of being overweight or obese. The relationship between physical activity and overweight in children and adolescents is also moderated by blood pressure (Torrance et al., 2007), maximal oxygen uptake (Ottevaere et al., 2011) cardiovascular factors (Aires et al., 2010; Wedderkopp et al., 2003).

Ortega et al. (2007) found that those children with low levels of VPA were more likely to be overweight compared to those who had high levels of VPA. Martinez-Gomes et al. (2010) suggested in their cross-sectional study that approximately 20 minutes of VPA discriminated more accurately between normal weight, overweight and obese categories compared to 60 minutes of MVPA. However, longitudinal data on the relationship between PA and overweight at the beginning of puberty are still inconsistent, as demonstrated by different levels of objectively measured PA with different relationships to overweight (for a review, see Rauner et al. (2000). In recent years, several studies have focused on sedentary time and low PA as factors of overweight and obesity, but with controversial results. For example, in a cross-sectional study, Maher et al. (2012) found that sedentary time, not MVPA, was associated with overweight and obesity in 9- to 16-year-old subjects. Mitchell et al. (2013) found that sedentary time was associated with an increase in BMI independent of MVPA, while Kwon et al. (2013) found that MVPA had a strong relation with adiposity independent of sedentary time. It is still under debate how PA levels at the beginning of puberty predict health outcomes throughout puberty and in later adulthood. For example, Ekelund et al. (2012) were not able to confirm that baseline time in MVPA or sedentary time predicted cardiometabolic outcomes in adolescents at follow-up. Studies have shown negative associations between MVPA and fat mass (Ness et al., 2007; Riddoch et al., 2009), but whether these associations exist longitudinally throughout puberty is not fully understood (Jáuregui et al., 2012). One factor that might limit the cross-sectional analysis could be the decrease in PA during the period of growth spurt (Ortega et al., 2013), as it might not characterise the previous PA level. There are also very few studies that have investigated how baseline PA predicts body fatness changes longitudinally. Riddoch et al. (2009) demonstrated in a large and well-characterized group of children at the beginning of puberty that MVPA levels at the age of 12 are strongly and inversely associated with fat mass two year later.

The studies have not always shown an effect of PA on obesity (Foley et al., 2011; Nilsson et al., 2009). In interpreting these results one should take into account that while TEE of PA by definition has an effect on acute energy balance, the effects on obesity are not always simple or straightforward. For example, excess energy may be used in non-exercise activity thermogenesis

(NEAT) such as fidgeting or simply standing; in the same ways, increases in exercise physical activity may bring about decreases in NEAT (Villablanca et al., 2015). Similarly, it has been hypothesized that PA interventions may bring about a compensatory mechanism (sometimes called “activityStat”) whereby PA in other time segments is reduced (see Gomersall et al. 2013 for a recent review). PA may boost appetite and thereby increase energy intake (Dhurandhar et al., 2015). Other factors affecting energy balance such as eating (Blundell et al., 2003), sleep and stress (Razzoli & Bartolomucci, 2016) should also be considered.

1.4. Conclusions

In general, physical activity declines during the lifespan and increases in inactivity are especially noticeable during childhood and adolescence, with the most significant decreases occurring during pubertal growth spurt. Self-report questionnaires to measure PA have been commonly used to assess adolescents’ subjective ratings of PA (Boon et al., 2010; Corder et al., 2008). However, it has been found that adolescents’s subjective self-report of PA may be invalid with both over- and underreporting having been indicated (Corder et al., 2008; Slootmaker et al., 2009; Trost, 2007). Accelerometers however, have been found to be a promising objective instruments for measuring physical activity in children and adolescents in replacement of self-report questionnaires. It is important to investigate the associations and tracking of subjectively and objectively measured PA in adolescents boys with different weight status, to understand what is the contribution of weight status to physical activity change during puberty. It must also be considered that for body composition changes, the amount of physical activity and the contribution of the PA intensity and sedentary behavior are of the greatest importance and should be the target for public health perspective.

To conclude, we aim to focus on subjective and objective ratings of physical activity during the puberty and weight status and how physical activity tracks during pubertal period.

AIM AND PURPOSE OF THE THESIS

The general aim of the present thesis was to investigate the association of subjectively and objectively measured PA and PA relationship with weight status in pubertal boys.

According to the general aim, the specific aims of present thesis were to:

1. compare different self-report PA questionnaires with accelerometer measured PA data;
2. compare the ratings of children and parent Tartu Physical Activity Questionnaire (TPAQ) with accelerometer based PA data in normal, overweight and obese boys;
3. examine the tracking of PA between accelerometer and children and parental TPAQ in normal weight and overweight and obese pubertal boys over two-year period;
4. examine how the fulfilment of different PA recommendations, different PA cut-offs and sedentary time associate with the risk of being overweight or obese during the puberty over the two-year period.

2. MATERIALS AND METHODS

2.1. Participants and study design

This thesis was a part of the project “Risk factors for metabolic syndrome in boys during pubertal development: A longitudinal study with special attention to PA and fitness”. This project started in 2009 when boys from 3th and 4th grades from Tartu and its surroundings schools were invited to participate. The project invitation was given to each boy of particular classes in those schools who agreed to participate and approximately 84% of boys agreed to take part (Lätt et al., 2013; Utsal et al., 2012). The initial exclusion criteria to participate were different health problems that did not allow the potential subjects to participate in physical education classes. All participants were thoroughly informed of the purposes and contents of the project and the written informed consent was obtained from the parents before participation in the project. The participants gave verbal assent. All participants or parents had the right to stop participating at any time-point of the project. This project was approved by the Medical Ethics Committee of the University of Tartu.

This project had for four waves of data collection. After the first testing in the laboratory the participants were called back in the following three years. All four waves of data collections took place at approximately same time of the year: the first wave of data collection was from November 2009 until April 2010, the second wave of data collection was from November 2010 until April 2011; the third wave of data collection was from November 2011 until April 2012 and the fourth wave of data collection was from November 2012 until April 2013.

During a research day, all participants completed self-report PA questionnaires: IPAQ-SF, TPAQ for children and parents, and DSI scale. The TPAQ for children and their parents contained identical questions. Additionally, participants were asked to wear an accelerometer for seven consecutive days.

The current thesis uses data from the second, third and fourth data collection waves as in those testings we had accelerometer based PA data and questionnaires. The number of the participants in second year was 313. For paper I, 191 13–14-years old boys had complete data for fourth wave on accelerometer, IPAQ-SF, TPAQ and SDI. For paper II, 224 11–12-year old boys had the complete second wave data on accelerometer, children and parental TPAQ. For paper III, 156 12–14-year old boys had complete data for three waves (second, third, and fourth) of data collections on accelerometer and children and parental TPAQ. And for paper IV, 136 12–14-year old boys had complete data for three waves (second, third, and fourth) of data collections on accelerometer.

2.2. Anthropometric characteristics of the subjects

All anthropometrical characteristics were conducted by trained researchers. Participants' body height and body mass were obtained on the first day of the measurements. Body height was measured in standing position to the nearest 0.1 cm using Martin metal anthropometer. Body mass was measured with minimal clothing with medical balance scale (A&D Instruments, UK) to the nearest 0.05 kg. BMI was calculated as the body mass divided by the square of body height (kg/m^2). On the basis of BMI, the participants were grouped as normal weight, overweight and obese according to BMI cut-offs by Cole et al. (2000) that has been used in previous studies (Gwynn et al., 2010; Slootmaker et al., 2009). BMI rather than body fat percentage was used to form the weight categories because age-graded reference values are available for BMI. Body fat percent (%) was measured using the DPX-IQ densitometer (Lunar Corp., Madison, WI, USA), with the participants in light clothing and arms at both sides. The devise was calibrated accordingly to the suggestions of the manufacturer and was run in medium scan mode. The biological age of the participants was assessed according to self-assessment using an illustrated questionnaire of the pubertal stage according to the Tanner classification method which has been validated and used previously. The evalution of public hair was used (Ruiz et al., 2006; Tanner, 1962).

2.3. Objective measurement of physical activity

Participants' objectively measured PA was assessed by accelerometer (GT1M ActiGraph, Monrovia, CA, USA). The accelerometer has been previously validated in laboratory and free-living conditions in young people (Freedson et al., 2005; Martinez-Gomez et al., 2010; Martinez-Gomez et al., 2012). The accelerometer is compact, small (3.8 x 3.7 x 1.8cm) and light-weight (27g) uniaxial monitor designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00 G's with a frequency of 0.25–2.50 Hz and converts the signal to numeric values known as activity counts (Boon et al., 2010; Freedson et al., 2005). We used the same intensity categories as previously used in other similar studies (Martinez-Gomez et al., 2010; Martinez-Gomez et al., 2012; Nilsson et al., 2009): sedentary time (< 100 counts per min), light PA (LPA) (> 100 counts per min), MPA (> 2000 counts per min) and VPA (> 4000 counts per min). Additionally, MVPA was calculated by summing the highest two intensity categories. The participants were asked to wear the accelerometer always on the right hip with adjustable elastic belt for seven consecutive days during waking hours, except during water and bathing activities. The participants received the accelerometer together with written and verbal instructions and practical demonstration on how to wear accelerometer. The accelerometer was programmed to record activity counts in 15-s epochs and non-wearing time was defined as ≥ 20 consecutive minutes of 0 counts and this time was not included in the analysis. PA data were included for further analyses if the participants had accumulated a minimum of 8-h of activity data per day for at least 3 valid days (Martinez-Gomez et al., 2010). Raw seven-day accelerometer data were downloaded into the ActiLife (light version 5.3.0) computer software for determination of activity counts and was then imported to R, statistical programme (R Core Team, 2010) for analysis. In the following analyses, the variables referring to time in activity categories were transformed to "adjusted minutes" (Konstabel et al., 2014) by dividing the raw minutes by wearing time and multiplying the resulting fraction by the average wearing time. This was done to avoid confounding by wearing time. Different PA thresholds (5 and 20 minutes per day in VPA, 60 and 90 minutes per day in MVPA) were selected according to the literature (Laguna et al., 2013; Martinez-Gomez et al., 2010; Public Health Canada, 2002) as the thresholds that have been most frequently been proposed to affect overweight and obesity.

2.4. Subjective assessment of physical activity

2.4.1 Tartu Physical Activity Questionnaire

TPAQ is a short self-report questionnaire that consists of 26 questions about the last week PA and has been used in previous studies (Harro et al., 2009; Wedderkopp et al., 2003). The TPAQ for children and their parents contained identical questions. The only difference was that the parents' version was rephrased so that the ratings were for the child's behavior.

In our thesis we only used those TPAQ questions that were directly related to sedentary time, walking/cycling and MVPA. Nineteen of the TPAQ questions were not directly about PA level (e.g., costs of attending the sports club; reasons for missing the physical education classes; does the respondent's best friend attend to a sports club, etc). In some cases, information from two or more questions was combined to make up a single variable: (Q1) walking and cycling (minutes per week were computed by multiplying two answers: how many days in a typical week did the child go to school by foot or by bike, and how many minutes did it take; after this, weekly minutes of going to school and going home from school were added); (Q2) Sport club minutes per week (computed analogously to Q1); (Q3) Frequency of PA (how many days in the previous week was the child at least moderately active for at least 30 minutes); the score ranged from 0 to 7; (Q4) Frequency of PA yes vs. no (at least 30 minutes 5 times a week was the child moderately active); (Q5) Screen time (how many hours a day watching TV or using computer), coded as no time = "1"; less than 1 h = "2"; 2 - 3 h = "3"; 4–5 h = "4"; more than 6 h = "5".

2.4.2 International Physical Activity Questionnaire-Short Form

The purpose of the IPAQ is to provide a set of well-developed instruments that can be used internationally to obtain comparable estimates of PA. There are two versions of the questionnaire. The IPAQ-SF is suitable for use in national and regional surveillance systems and the IPAQ-LF provide more detailed information often required in research work or for evaluation purposes (International Physical Activity Questionnaire website). We used IPAQ-SF that assesses PA of the previous 7 days (Graig et al., 2003; Lee et al., 2011). Data obtained from the IPAQ-SF was coded and analyzed using the IPAQ recommended guidelines (International Physical Activity Questionnaire website). Using the IPAQ-SF scoring system, the total number of days and minutes of PA were calculated for each participant. The IPAQ-SF records the activity of four intensity levels: sitting (sedentary time), walking/cycling, moderate intensity (MPA) and vigorous intensity such as aerobics (VPA).

2.4.3 Domain-Specific Impulsivity

As a measure of self-reported inactivity, we used a subscale from DSI, translated with the permission of the authors (Tsukayama et al., 2012). That scale was developed to assess tendencies for short-term gratification at the expense of long-term goals and standards across six impulsivity domains, including exercise. The respondents were asked to rate how often they did each of the activities, on a scale from 0 = "Never" to 4 = "Very often". Sample items from the exercise subscale include "Avoiding working out (e.g., jogging, going to the gym, etc.)" and "Being sedentary". To the four original questions, we added "I prefer to move as little as possible". As the content of these as well as the other items in this subscale refer to being inactive or avoiding activity, we refer henceforth to this subscale as inactivity scale; the remaining subscales from the Domain Specific Impulsivity Scale were not used in the present thesis. The theoretical maximum of inactivity score was thus 20, however in reality, the options “often” and “very often” were seldom used, and almost half of the sample (47%) indicated a complete disagreement with all 5 items receiving thus a score of zero. 37% of the sample received a score between 1 and 5, and 16% had a score of 6 or higher.

2.5. Statistical analyses

All analyses for paper I, II and III were made using R-statistics (R Core Team, 2012; R Core Team, 2014) and all analyses for paper IV were made using the SPSS version 17.0 for Windows (SPSS, Inc., Chicago, IL).

Descriptive statistics of the participants were presented as means ± SD. All variables were checked for normality of distribution before the analysis. The differences in mean values were assessed by ANOVA and t-test where appropriate. Pearson’s correlation and partial correlation (controlling for age and Tanner stage) coefficients were conducted to describe the relationships between variables. All variables where measurement unit were minutes (i.e., accelerometer measured time in intensity categories; subjective estimates of sedentary time, MVP and VPA from IPAQ, as well as MVPA index from TPAQ) were log transformed before regression analyses (i.e., log transformation was used for correlations and multiple regression; the means and SDs were calculated with untransformed data and expressed in minutes).

TPAQ MVPA indexes were created based on children's and parents’ responses as follows. The adjusted daily minutes of MVPA were regressed on the questionnaires variables. The rationale behind using the MVPA index is twofold. First, for comparing objective and subjective assessments of PA, we need to express both in a comparable way; that is, items from the TPAQ need to be combined into a single index. Secondly, the TPAQ questionnaire variables had different units (minutes per week, yes/no scale, number of days per week) which could not be combined by just adding all items. Using regression weights, we combined the information from all items in an economic way, and at the same time made the unit of the resulting index comparable with the objective assessment of MVPA. The adjusted daily minutes of MVPA were regressed on the questionnaires variables. The rationale behind using the MVPA index is twofold. First, for comparing objective and subjective assessments of PA, we need to express both in a comparable way; that is, items from the TPAQ need to be combined into a single index. Secondly, the TPAQ questionnaire variables had different units (minutes per week, yes/no scale, number of days per week) which could not be combined by just adding all items. Using regression weights, we combined the information from all items in an economic way, and at the same time made the unit of the resulting index comparable with the objective assessment of MVPA.

The differences between dependent correlations were assessed using a method developed by Steiger (1980) and implemented by Revelle (2013) and agreement between the questionnaires and accelerometer were assessed using the Bland and Altman method (Bland & Altman, 1986) as implemented in R package MethComp version 1.22 (Carstensen et al., 2013).

In the paper IV, the receiver operating characteristic (ROC) curves (Hajian-Tilaki, 2013) were used to calculate the optimal PA cut-off points for MPA, VPA, MVPA and sedentary time at baseline that best discriminate between normal weight and overweight categories. Additional analyses were performed to discriminate between normal weight and obese using both classifications.

A ROC curve provides the whole spectrum of specificity/sensitivity values for all possible cut-offs. Sensitivity is the probability of identifying overweight or obese correctly. Specificity is the probability of identifying normal-weight children correctly. The false-positive proportions were those normal-weight boys who were incorrectly identified as being overweight or obese. To identify the best threshold, the distance between the perfect test and each sensitivity and one-specificity pair was calculated.

The area under the ROC curve (AUC) and 95% confidence intervals (CI) were calculated. The AUC represents the ability of the test to classify children correctly according to their weight/body-fat category. The values of AUC range from 0.5 (non-informative test) to 1.0 (ideal test). Finally, using logistic regression, odds ratios (OR) and the CIs for being overweight or obese at baseline were calculated using different PA thresholds as independent variables (5 and 20 minutes per day of VPA, 60 and 90 minutes per day of MVPA, and the threshold obtained in this study from the ROC analysis). Additionally, the sedentary time threshold obtained in paper IV from the ROC analysis was used. The OR CIs for being overweight or obese at follow-up were calculated using same baseline PA and sedentary time thresholds.

Statistical significance was set at $p < 0.05$ for all analysis.

3. RESULTS

3.1. Associations between self-reported questionnaires and accelerometer measured physical activity in adolecsent boys

The main characteristics of the subjects are shown in Table 1. The IPAQ-SF MVPA showed less time as compared to accelerometer derived MVPA (respective averages 43 and 56 minutes). IPAQ-SF sedentary time also showed less time compared to accelerometer derived sedentary time (respective averages 519 and 545 minutes).

Correlations between self-reported PA questionnaires and accelerometer measured PA are shown in Table 2. All questionnaires were correlated with accelerometer measured PA; significant correlations ranged from 0.07–0.36 for IPAQ-SF, from 0.02 – 0.35 for children TPAQ, and from 0.13 - 0.29 for the DSI (inactivity scale). To investigate whether questionnaires under- or overestimate PA as compared to accelerometer data, paired t-test was used.

Table 1. Descriptive statistics of subjects (N = 191).

	Mean ± SD
Age (y)	13.99 ± 0.69
Body height (cm)	169.19 ± 9.11
Body mass (kg)	60.49 ± 17.05
BMI (kg/m²)	20.92 ± 4.66
Accelerometer measured PA	
Sedentary time (min/d)	545.2 ± 56.08
LPA (min/d)	167.68 ± 39.58
MPA (min/d)	37.39 ± 15.66
VPA (min/d)	18.98 ± 14.71
MVPA (min/d)	56.37 ± 25.03
Steps (counts/min)	8021.95 ± 3010.04
Valid time (min/d)	769.25 ± 108.86
IPAQ-SF	
Sedentary time (min/d)	519.22 ± 107.74
Walking (min/d)	21.25 ± 28
MPA (min/d)	15.51 ± 15.42
VPA (min/d)	27.60 ± 23.73
MVPA (min/d)	43.02 ± 28.99
Child TPAQ	
TPAQ MVPA index (min/d)	59.71 ± 9.14
Walking/cycling (min/d)	43.14 ± 40.40
Screen time (1–5)	3.29 ± 0.81
DSI	
Inactivity scale (0–20)	2.47 ± 3.11

Body mass index (BMI); Domain-Specific Impulsivity (DSI); International Physical Activity Questionnaire-Short Form (IPAQ-SF); light physical activity (LPA); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); physical activity (PA); Tartu Physical Activity Questionnaire (TPAQ); vigorous physical activity (VPA); standard deviation (SD).

Table 2. Pearson correlations between accelerometer and self-report PA questionnaires in pubertal boys.

	Accelerometer measured PA (min/d)									
	MVPA		VPA		MPA		LPA		Sedentary time	
TPAQ MVPA index (min/d)	0.35	***	0.34	***	0.27	***	0.13		-0.22	**
TPAQ screen time (min/d)	-0.31	***	-0.24	***	-0.28	***	-0.28	***	0.31	***
TPAQ walking/cycling (min/d)	0.21	**	0.21	**	0.16	*	-0.02		-0.09	
IPAQ-SF MPA (min/d)	0.16	*	0.16	*	0.11		0.07		-0.10	
IPAQ-SF VPA (min/d)	0.31	***	0.24	***	0.29	***	0.15	*	-0.18	*
IPAQ-SF MVPA (min/d)	0.31	***	0.29	***	0.25	***	0.13		-0.16	*
IPAQ-SF walking (min/d)	0.36	***	0.34	***	0.27	***	0.07		-0.22	**
IPAQ-SF sedentary (min/d)	-0.23	**	-0.19	*	-0.18	*	-0.12		0.16	*
DSI Inactivity scale (0–20)	-0.29	**	-0.29	***	-0.22	*	-0.13		0.17	*

Domain-Specific Impulsivity (DSI); International Physical Activity Questionnaire-Short Form (IPAQ-SF); light physical activity (LPA); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); physical activity (PA); Tartu Physical Activity Questionnaire (TPAQ); vigorous physical activity (VPA). Sample size for inactivity questionnaire was 129, and ranged from 183 to 190 for other questionnaires; * $p<0.05$ **; $p<0.01$; *** $p<0.001$.

We found that IPAQ-SF underestimates MVPA compared to accelerometer derived MVPA (mean difference - 13.44; t (186) = -5.46, $p < 0.0001$). This underreporting was more marked in active boys, whose daily MVPA was at least 60 minutes (mean difference - 31,5; t (72) = 8.3, $p < 0.0001$), and was not significant in less active boys (mean difference - 1.9; t (113) = 0.68, p = 0.50). The TPAQ MVPA index slightly overestimates MVPA compared to accelerometer derived MVPA (mean difference 3.11; t (183) = 1.81, p = 0.072).

Agreement between the PA questionnaires and objective PA was also assessed using the Bland and Altman method (Bland & Altman, 1986). In Figure 1, the Bland and Altman plots for MVPA indicate that higher physical activity resulted in less accurate estimation of IPAQ-SF derived MVPA compared to accelerometer derived MVPA (r = - 0.14, $p < 0.05$). Furthermore, in Figure 2 the Bland and Altman plots for MVPA indicate that higher physical activity also resulted in smaller underestimation of TPAQ derived MVPA compared to accelerometer derived MVPA (r = 0.78, $p < 0.0001$). Sedentary time prediction did not depend on activity categories (R = - 0.06, p = 0.4) (Figure 3).

The best regression model using TPAQ items as predictors of MVPA included TPAQ screen time and TPAQ walking/cycling ($R^2 = 0.16$, N = 187, $p < 0.0001$). Time spent in sport clubs was not predictive of MVPA when controlled for screen time, even though there was a correlation between MVPA and time spent in sport clubs. Adding DSI inactivity scale to the model including TPAQ screen time and walking/cycling as predictors, increased the R^2 to 0.19 ($p < 0.0001$).

TPAQ screen time was the only significant predictor of accelerometer measured LPA. The best model for predicting sedentary time included two predictors: TPAQ screen time and IPAQ walking ($R^2 = 0.135$). IPAQ sedentary time was not significant in the model after controlling for screen time and walking.

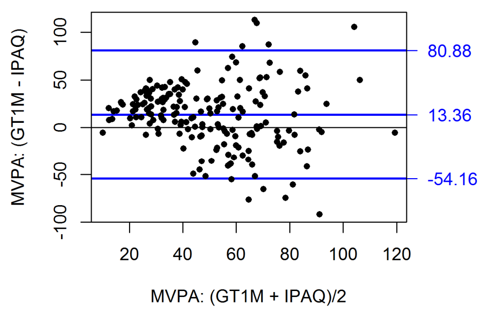

Figure 1. Bland and Altman plot with difference in mean time spent in MVPA for the IPAQ-SF and accelerometer.
Accelerometer (GT1M=Actigraph model with that name); International Physical Activity Questionnaire (IPAQ); moderate to vigorous physical activity (MVPA); In the Bland and Altman plot, difference between two measurements is plotted against their mean. Mean and 95% confidence intervals of the difference are shown with blue lines. If there is no bias (in this case, over- or underestimating), then mean error should be close to zero. In addition, most measurement points should ideally be within the 95% confidence limits of the mean error (that is, within the lower and the upper blue line).

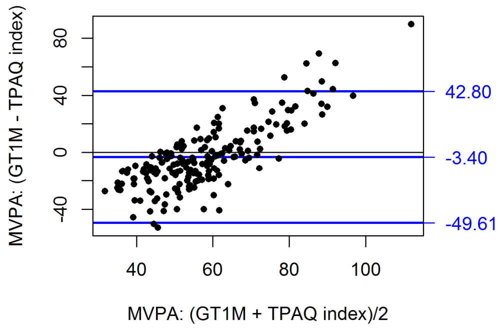

Figure 2. Bland and Altman plot with difference in mean time spent in MVPA for the TPAQ and accelerometer.
Accelerometer (GT1M=Actigraph model with that name); moderate to vigorous physical activity (MVPA); Tartu Physical Activity Questionnaire (TPAQ). In the Bland and Altman plot, difference between two measurements is plotted against their mean. Mean and 95% confidence intervals of the difference are shown with blue lines. If there is no bias (in this case, over- or underestimating), then mean error should be close to zero. In addition, most measurement points should ideally be within the 95% confidence limits of the mean error (that is, within the lower and the upper blue line).

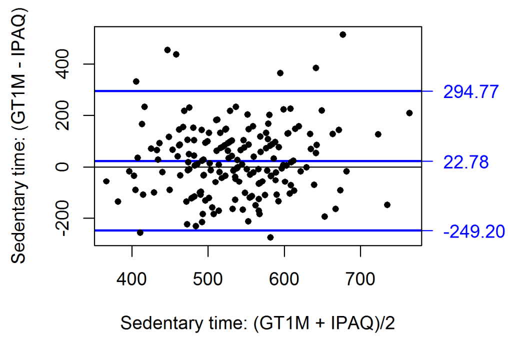

Figure 3. Bland and Altman plot with difference in mean time spent in sedentary time for the IPAQ-SF and accelerometer.
Accelerometer (GT1M=Actigraph model with that name); International Physical Activity Questionnaire (IPAQ). In the Bland and Altman plot, difference between two measurements is plotted against their mean. Mean and 95% confidence intervals of the difference are shown with blue lines. If there is no bias (in this case, over- or underestimating), then mean error should be close to zero. In addition, most measurement points should ideally be within the 95% confidence limits of the mean error (that is, within the lower and the upper blue line).

For finding an optimal prediction model of PA, we used multiple regressions. First, we regressed accelerometer MVPA on all variables derived from IPAQ. The results are shown in Table 3. IPAQ self-reported VPA and MPA, as well as walking and sedentary time predicted objective MVPA (all regression coefficients were statistically significant), even though the R-square was modest (0.26). Adding TPAQ screen time to the prediction increased R-square to 0.29; in that model, TPAQ screen time was a significant predictor, while IPAQ sedentary time was not significant at 0.05 levels. Adding any other items from TPAQ, or the TPAQ MVPA index, or inactivity scale did not improve the prediction.

Table 3. Multiple regression models for predicting MVPA from IPAQ-SF variable.

	b	SE(b)	t	p
(Intercept)	5.81	1.00	5.83	< 0.0001
IPAQ-SF VPA (min/d)	0.09	0.03	3.39	0.0009
IPAQ-SF MPA (min/d)	0.06	0.03	2.08	0.0386
IPAQ-SF walking (min/d)	0.13	0.03	4.91	< 0.0001
IPAQ-SF sedentary time (min/d)	-0.41	0.16	-2.66	0.0086

International Physical Activity Questionnaire-Short Form (IPAQ-SF); moderate physical activity (MPA); probability level (p); regression weight (b); standard error of the regression weight [SE(b)]; value of the t-statistic (t); vigorous physical activity (VPA). All variables were log transformed before analysis. Model coefficient of determination (R^2) was 0.26, N = 181, $p < 0.0001$. R^2 for the model including only VPA and MPA as predictors was 0.11.

3.2. Associations between TPAQ and accelerometer measured physical activity in adolecsent boys with different BMI

The main characteristics of the subjects of different weight categories and their parents' ratings on PA are shown in Table 4.

Table 4. Descriptive statistics for all measurments of subjects (mean ± SD).

	Total Sample (n = 224)	Normal Weight (n = 171)	Overweight/Obese (n = 53)
Age (y)	12.17 ± 0.75	12.16 ± 0.74	12.19 ± 0.78
Body height (cm)	154.17 ± 8.18	153.04 ± 7.93	157.83 ± 7.97
Body mass (kg)	47.36 ± 13.62	41.73 ± 6.88	65.52 ± 14.15
BMI (kg/m²)	19.7 ± 4.29	17.72 ± 1.74	26.09 ± 3.8
Tanner stage (*N*s for each category)			
1/2 /3 /4 /5 /6	6 /82 /111/24/1/0	5/62/ 86/ 17/ 1/ 0	1/ 20/ 25/ 7/ 0/ 0
Accelerometer measured PA			
Sedentary time (min/d)	524 ± 56	520 ± 56	538 ± 52
LPA (min/d)	225 ± 42	226 ±43	221 ± 40
MPA (min/d)	49 ± 17	50 ± 17	45 ± 16
VPA (min/d)	17 ± 13	19 ± 13	11 ± 7
MVPA (min/d)	66 ± 25	69 ± 26	57 ± 21
Total PA (counts/min)	469 ± 142	486 ± 147	413 ± 111
Valid time (min/d)	816 ± 78	819 ± 79	806 ± 77
Child TPAQ			
TPAQ MVPA index (min/d)	67 ± 8	67 ± 8	64 ± 8
Sport club (min/wk) (quartiles)*	98/240/360	120/240/360	0/180/270
Walking/cycling (min/wk)*	0/250/500	0/250/500	25/350/500
Frequency of PA (0–7)	3.97 ± 1.39	4.11 ± 1.36	3.55 ± 1.39
PA ≥ 5 times a week (% yes)	73	71	77
Sport club (% yes)	79	82	70
Screen time (1–5)	3.15 ± 0.82	3.15 ± 0.81	3.17 ± 0.85
Parental TPAQ			
TPAQ MVPA index (min/d)	66 ± 7	67 ± 7	65 ± 7
Sport club (min/wk) (quartiles)*	60/180/270	90/180/330	0/120/270
Walking/cycling (min/wk)*	124/295/500	70/250/500	200/375/750
Frequency of PA (0–7)	4.03 ± 1.25	4.08 ± 1.27	3.87 ± 1.18
PA ≥ 5 times a week (% yes)	63	68	45
Sport club (% yes)	76	79	68
Screen time (1–5)	3.04 ± 0.7	2.99 ± 0.7	3.2 ± 0.69

Body mass index (BMI); light physical activity (LPA); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); physical activity (PA); Tartu Physical Activity Questionnaire (TPAQ); vigorous physical activity (VPA); standard deviation (SD). For variables grossly deviating from normality, indicated with asterisk (*), median and quartiles (i.e., 25th, 50th, and 75th percentile) are shown instead of mean and standard deviation.

The children's TPAQ MVPA index was higher in normal weight group: the means were 67.3 and 64.2, respectively for normal, overweight and obese groups ($t = 2.4$, $p = 0.02$, Cohen's $d = 0.37$). For parental TPAQ MVPA index, the means were 66.6 minutes per day (normal weight group) and 65.0 minutes per day (overweight/obese group) ($t = 1.4$, $p = 0.15$, $d = 0.23$). The respective means for accelerometer-measured MVPA were 69.5 minutes per day (normal weight) and 56.6 minutes per day (overweight and obese group), and the difference was significant ($t = 3.7$, $p < 0.0001$, $d = 0.51$). A Welch correction was used in the above t-tests but the results using the classical t-test led to identical conclusions. Correlations between TPAQ MVPA indexes and accelerometer measured MVPA are listed in Table 5.

Table 5. Pearson correlations between TPAQ MVPA index and acceleromerer measured MVPA.

	r	95% CI	p	df
Child TPAQ MVPA index (min/d) **vs**				
MVPA (min/d)	0.28	0.16; 0.40	0.0000	222
Normal weight group	0.18	0.03; 0.32	0.0189	169
Overweight/obese group	0.59	0.38; 0.74	0.0000	51
(Difference between groups)		*z = 3.07, p<0.001*		
Parental TPAQ MVPA index (min/day) **vs**				
MVPA (min/d)	0.30	0.18; 0.42	0.0000	222
Normal weight group	0.27	0.12; 0.40	0.0004	169
Overweight/obese group	0.40	0.14; 0.60	0.0032	51
(Difference between groups)		*z = 0.92, p=0.36*		
Child TPAQ MVPA index (min/d) **vs**				
parental TPAQ MVPA index (min/d)	0.54	0.44; 0.62	0.0000	222
Normal weight group	0.52	0.40; 0.62	0.0000	169
Overweight/obese group	0.56	0.34; 0.72	0.0000	51
(Difference between groups)		*z = 0.33, p=0.74*		

Confidence intervals (CI); correlation coefficient (r); degree of freedom (*df*); (moderate to vigorous physical activity (MVPA); probability level (p); Tartu Physical Activity Questionnaire (TPAQ). In each block, the first line indicates the correlation in the total sample, followed by correlations in subgroups, and a test comparing the correlations within subgroups.

Children's and parental TPAQ MVPA indexes were compared by means of a Bland-Altman plot (Fig. 4). The mean difference between the two indexes was 0.33 minutes, with standard error of the difference being 7.6, and 95% limits of agreement ranging from – 14.8 to 15.4 minutes.

To investigate the possible seasonal effects in MVPA, a "time of measurement" (TOM) index was calculated as the absolute difference in days between the first day of accelerometer recording and the winter solstice. The TOM index was not significantly correlated with TPAQ MVPA indexes and was weakly correlated with accelerometer derived MVPA ($r = 0.19$, $p < 0.003$, 95% CI: 0.06, 0.31). The data were divided into two categories based on the time of measurement: "winter" (measurement within less than 60 days from the winter solstice, that is, the TOM index < 60), and "spring/autumn" (TOM index ≥ 60). In both BMI groups, as well as in the total sample, the correlation between accelerometer measured MVPA and the children's TPAQ MVPA indexes was slightly lower in winter (Fig. 5) however the differences were not statistically significant. Furthermore, the correlation between accelerometer measured MVPA and the parents TPAQ MVPA indexes was slightly lower in winter.

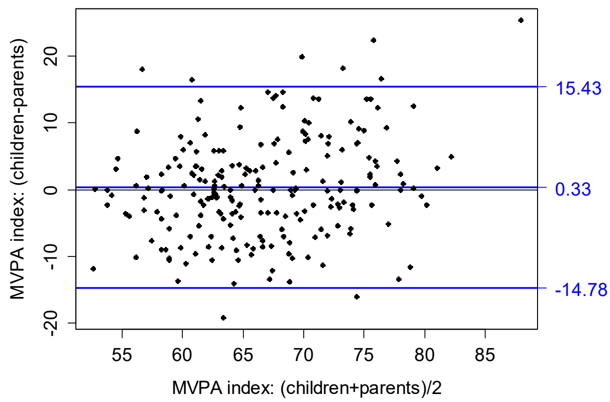

Figure 4. Bland-Altman plot comparing MVPA indexes computed from children's and parent TPAQ.

Moderate to vigorous physical activity (MVPA). In the Bland and Altman plot, difference between two measurements is plotted against their mean. Mean and 95% confidence intervals of the difference are shown with blue lines. If there is no bias (in this case, over- or underestimating), then mean error should be close to zero. In addition, most measurement points should ideally be within the 95% confidence limits of the mean error (that is, within the lower and the upper blue line).

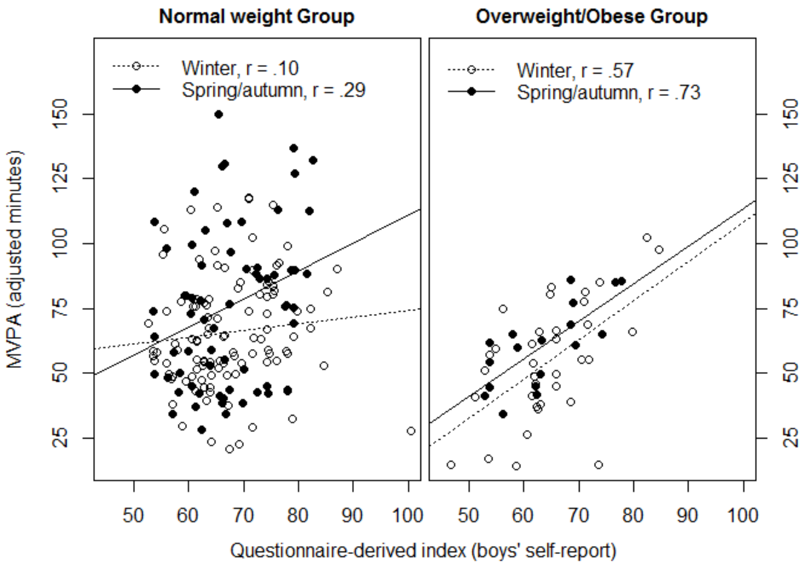

Figure 5. Pearson correlation between accelerometer measured MVPA and TPAQ MVPA index in pubertal boys with different BMI.

Correlation coefficient (r); moderate to vigorous physical activity (MVPA).

Sedentary time was different across weight groups: the means were 519.8 in the normal weight group and 538.3 in the overweight and obese group (t = - 2.2, p = 0.03, d = 0.33).

Sedentary time (as adjusted minutes) was predicted using two variables: the TPAQ MVPA index and an additional question from the TPAQ screen time. The results of multiple regressions are shown in Table 6, separately for children's and parental TPAQ MVPA index. Both screen time and TPAQ MVPA index were significant predictors of sedentary time for both children's and parental MVPA estimates. Sedentary time was better predicted by parental than children's TPAQ data: R_2 for the two models were 0.08 and 0.06. Sedentary time was better predicted in the overweight and obese than the normal weight group: R^2 of the models including both screen time and TPAQ MVPA index were 0.16 and 0.04 using children's TPAQ, and 0.13 versus 0.06 using parental TPAQ.

Table 6. Models predicting sedentary time (adjusted minutes) from TPAQ screen time and TPAQ MVPA index (unstandardized regression coefficient).

					Model Statistics		R^2 for models in subgroups	
	b	SE(b)	p	ΔR^2	R^2	p	Normal weight	Over-weight / Obese
Child TPAQ								
Intercept	566.3	35.1	< 0.001					
screen time (min/d)	10.34	4.51	0.022	0.04				
MVPA index (min/d)	-1.12	0.44	0.011	0.03	0.06	<0.001	0.04	0.16
Parental TPAQ								
Intercept	570.56	38.61	< 0.001					
Screen time (min/day)	16.28	5.11	0.007	0.05				
MVPA index (min/d)	-1.45	0.51	0.005	0.03	0.08	<0.001	0.06	0.13

Change in R^2 (ΔR^2); coefficient of determination (R^2); moderate to vigorous physical activity (MVPA); probability level (p); regression weight (b); standard error of the regression weight [SE(b)]; Tartu Physical Activity Questionnaire (TPAQ).

3.3. Tracking of physical activity between accelerometer and TPAQ in pubertal boys with different BMI

The main characteristics of the subjects over three testing points are shown in Table 7. Mean body height, body mass and BMI increased and body fat (%) decreased significantly ($p < 0.001$) over two-year period in total sample. Only in overweight and obese boys, there was no change in BMI over two years.

Table 7. Descriptive statistics for all measurments of subjects (mean ± SD).

	T1		T2		T3	
	Normal weight (n=117)	Overweight/obese (n=39)	Normal weight (n=117)	Overweight/obese (n=39)	Normal weight (n=117)	Overweight/obese (n=39)
Age (y)	11.56 ± 0.74	11.46 ± 0.85	12.59 ± 0.74[a]	12.48 ± 0.85[a]	13.96 ± 0.70[b,c]	13.89 ± 0.86[b,c]
Body height (cm)	152.88 ± 7.39	157.49 ± 8.50	160.85 ± 9.16[a]	165.09 ± 8.93[a]	167.76 ± 8.88[b,c]	171.37 ± 8.82[b,c]
Body mass (kg)	41.30 ± 6.96	66.18 ± 15.63	47.43 ± 8.65[a]	72.58 ± 19.44[a]	53.43 ± 9.02[b,c]	79.15 ± 20.94[b,c]
BMI(kg/m²)	17.53 ± 1.76	26.34 ± 4.02	18.23 ± 1.98[a]	26.34 ± 5.37	18.84 ± 2.06[b,c]	26.72 ± 5.52
Body fat (%)	18.20 ± 6.13	38.65 ± 9.55	18.13 ± 6.82	36.04 ± 10.69[a]	16.60 ± 7.05[b,c]	33.48 ± 11.27[b,c]
Tanner stage 1/2/3/4/5/6 (%)	3/35/55/8/0/0		0/15/47/29/9/0		0/3/20/43/33/1	
Accelerometer measured PA						
Sedentary time (min/d)	530 ± 73	541 ± 76	551 ± 88[a]	542 ± 75	547 ± 107	550 ± 78
LPA (min/d)	222 ± 48	219 ± 41	198 ± 40[a]	189 ± 48[a]	167 ± 44[b,c]	171 ± 50[b,c]
MPA (min/d)	48 ± 16	45 ± 14	43 ± 15[a]	42 ± 20	36 ± 15[b,c]	41 ± 16
VPA (min/d)	20 ± 15	12 ± 8	21 ± 15	16 ± 9[a]	20 ± 16	15 ± 10[b]
MVPA (min/d)	68 ± 26	57 ± 18	64 ± 25/	57 ± 25	56 ± 27[b,c]	55 ± 21
Total PA (counts/min)	476 ± 155	412 ± 97	452 ± 155	409 ± 133	416 ± 171[b,c]	392 ± 129
Valid time (min/d)	820 ± 75	817 ± 81	813 ± 89	788 ± 77	770 ± 113[b,c]	776 ± 86[b]
Child TPAQ						
MVPA index (% of time)	7.6 ± 1	7.5 ± 0.9	7.6 ± 1	7.6 ± 1	7.5 ± 1.5	7.4 ± 1.1
Sport club (min/week)	234 ± 148	187 ± 147	254 ± 185	167 ± 154	297 ± 447	187 ± 176
Walking/cycling (min/week)	297 ± 318	407 ± 331	299 ± 315	412 ± 338	285 ± 278	380 ± 306
Frequency of PA (0–7)	3.97 ± 1.37	3.38 ± 1.27	4.14 ± 1.37	3.87 ± 1.30	3.90 ± 1.58	3.58 ± 1.18
Frequency of PA (yes %)	69	69	74	72	60[c]	66
Screen time (1–5)	3.15 ± 0.84	3.13 ± 0.89	3.28 ± 0.82	3.31 ± 0.83	3.25 ± 0.77	3.44 ± 0.97
Parental TPAQ						
MVPA index (% of time)	7.7 ± 1	7.2 ± 1	7.5 ± 1.1	7 ± 1	7.4 ± 1.1 [b]	7. 1± 1.1
Sport club (min/week)	213 ± 153	162 ± 148	230 ± 179	153 ± 149	229 ± 194	164 ± 144
Walking/cycling (min/week)	349 ± 319	455 ± 330	348 ± 341	361 ± 293[a]	373 ± 322	441 ± 297
Frequency of PA (0–7)	4.03 ± 1.39	3.69 ± 1.28	3.86 ± 1.40	3.31 ± 1.51	3.71 ± 1.45[b]	3.41 ± 1.13
Frequency of PA (yes %)	68	45	61	44	54 [b]	40
Screen time (1–5)	2.95 ± 0.66	3.21 ± 0.73	3.04 ± 0.64	3.43 ± 0.90	3.15 ± 0.74 [b]	3.40 ± 0.85

Body mass index (BMI); light physical activity (LPA); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); physical activity (PA); Tartu Physical Activity Questionnaire (TPAQ); standard deviation (SD); second wave (T1); third wave (T2); fourth wave (T3); vigorous physical activity (VPA).

Over the two-year period, sedentary time (% of time) increased and LPA, MPA and MVPA decreased significantly ($p < 0.05$) in total sample as well as in both weight groups. There was an increase in VPA in overweight and obese group when comparing second wave (T1) and third wave (T2) (on the average, 12 and 16 minutes, respectively, $p = 0.04$), but it appears to have levelled off by T2 (mean = 15). In the overweight and obese group, there was an increase in VPA when comparing T1 with either T2, or fourth wave (T3). (The respective means were 12, 16, and 15 minutes per day; $p < 0.05$ using paired t-test.) The changes in objectively measured PA are shown in Figure 6.

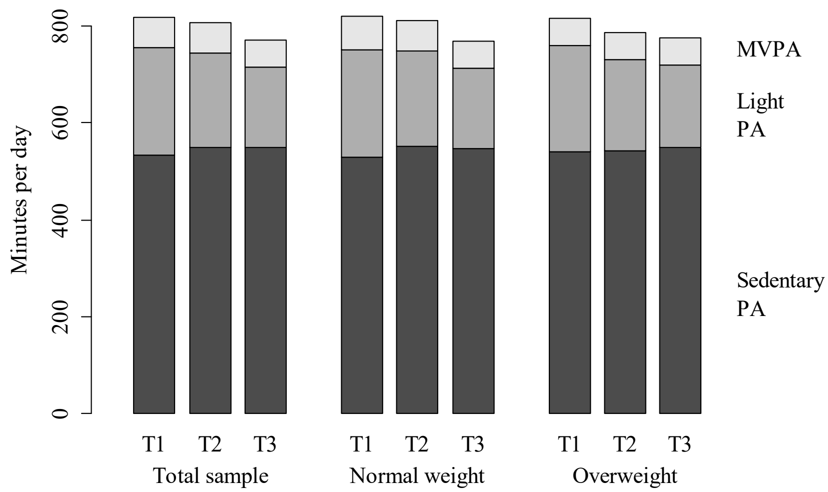

Figure 6. Objectively measured PA changes between sedentary PA, Light PA and MVPA.
Fourth wave (T3); moderate to vigorous physical activity (MVPA); physical activity (PA); second wave (T1); third wave (T2).

TPAQ MVPA indexes based on parental TPAQ decreased significantly ($p < 0.01$) over-two-year period; the corresponding indexes based on children's TPAQ were not significantly different.

Tracking correlations (T1-T3, T1-T2, and T2-T3) in total sample, normal weight and overweight and obese boys of objectively measured PA, TPAQ MVPA indexes and body parameters are given in Table 8. All tracking correlations were significant ($p < 0.05$) in both BMI boys groups, except for the following three correlations in the overweight and obese group: the T1-T2 correlations for untransformed sedentary time, and MVPA index, and the T2-T3 correlation for untransformed minutes of sedentary time. The correlations between proportions of sedentary time tracked better than untransformed minute correlations of sedentary time in both BMI groups (paralleled by a decrease in wearing time in two years).

T1-T3 tracking correlations of BMI and MVPA in both BMI groups are shown in Figure 7.

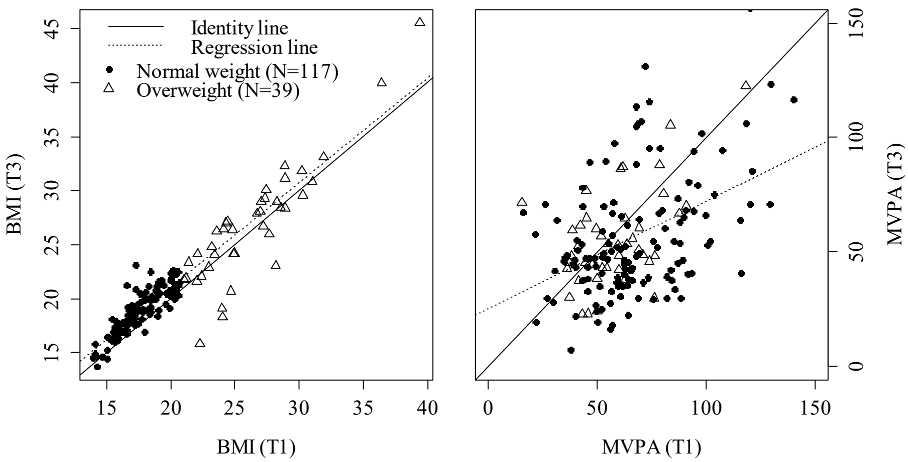

Figure 7. Tracking of BMI (left panel) and MVPA (right panel).
Body mass index (BMI); moderate to vigorous physical activity (MVPA); second wave (T1); fourth wave (T3).

The correlations between TPAQ MVPA indexes based on parent TPAQ were higher than those based on boys' TPAQ, in both BMI groups, and for all three intervals (T1-T3, T1-T2, and T2-T3). The two-year tracking correlation (T1-T3) was also higher for TPAQ MVPA parental index as compared to accelerometer derived MVPA (the respective r's were 0.58 and 0.47). The tracking correlations were, in general, not significantly different across BMI groups (Table 8).

Table 8. Tracking of PA and anthropometrical characteristics of the subjects during the three-year study period (Pearson correlations).

	T1-T3			T1-T2			T2-T3		
	Total Sample (n=156)	Normal weight (n=117)	Overweight/ obese (n=39)	Total Sample (n=156)	Normal weight (n=117)	Overweight/ obese (n=39)	Total Sample (n=156)	Normal weight (n=117)	Overweight/ obese (n=39)
Accelerometer measured phusical activity									
Sedentary time (min/d)	0.36	0.36	0.34	0.44	0.51	0.16 (n.s)*	0.52	0.57	0.22 (n.s)*
LPA (min/d)	0.51	0.51	0.44	0.48	0.46	0.51	0.60	0.54	0.72
MPA (min/d)	0.38	0.39	0.39	0.46	0.49	0.39	0.63	0.60	0.73
VPA (min/d)	0.62	0.60	0.64	0.64	0.63	0.54	0.73	0.76	0.41*
MVPA (min/d)	0.47	0.47	0.48	0.55	0.57	0.41	0.69	0.69	0.71
TPAQ									
Children MVPA index (min/d)	0.40	0.37	0.50	0.46	0.48	0.30 (n.s)	0.47	0.48	0.41
Parent MVPA Index (min/d)	0.58	0.62	0.46	0.55	0.56	0.51	0.61	0.64	0.42
Body parameters									
Body height (cm)	0.92	0.91	0.95	0.97	0.97	0.97	0.97	0.96	0.98
Body mass (kg)	0.95	0.89	0.93	0.97	0.94	0.95	0.98	0.96	0.96
BMI (kg/m)	0.94	0.86	0.89	0.95	0.85	0.91	0.97	0.88	0.95*
Body fat (%)	0.88	0.73	0.81	0.93	0.82	0.90	0.95	0.90	0.93

Body mass index (BMI); light physical activity (LPA); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); Tartu Physical Activity Questionnaire (TPAQ); vigorous physical activity (VPA); all correlations except the three marked (n.s.) are significant ($p<0.05$); Normal and overweight & obese was defined by using the BMI cut-points from Cole et (2000); second wave (T1); third wave (T2); fourth wave (T3); T1-T3-correlations between T1 and T3; T1-T2-correlations between T1 and T2; T2-T3-correlations between T2 and T3; * = Correlations are significantly different ($p<0.05$) between normal weight and overweight & obese groups.

3.4. Physical activity levels and sedentary time as predictors overweight and obesity in boys during pubertal period

The main characteristics of the subjects are shown in Table 9. At follow-up, the boys had significantly higher values for all anthropometrical ckaracteristics. MPA, MVPA and total PA were significantly decreased, while sedentary time was significantly increased compared to baseline value. VPA did not change significantly compared to baseline. Pearson and partial correlation coefficients between BMI and PA levels in baseline are shown in Table 10.

Table 9. Descriptive characteristics and physical activity levels of subjects during the study period (n = 136) in study.

	Baseline Mean ± SD	Follow-up Mean ± SD
Age (y)	11.9 ± 0.7	13.9 ± 0.7*
Height (cm)	153.7 ± 8.2	168.2 ± 8.8*
Weight (kg)	49.0 ± 16.0	61.5 ± 19.1*
BMI (kg/m)	20.4 ± 5.0	21.5 ± 5.3*
Obese (%)	16.9	14.7
Overweight (%)	33.8	30.9
Sedentary time (min/d)	542.2 ± 72.3	579.3 ± 91.9*
MPA (min/d)	46.9 ± 16.0	37.1 ± 15.0*
VPA (min/d)	16.4 ± 13.2	18.0 ± 15.1
MVPA (min/d)	63.2 ± 25.4	55.1 ± 25.4*
Total PA (counts/min)	444.7 ± 143.4	387.6 ± 155.7*
Tanner stage	2.6 ± 0.7	4.0 ± 0.8*
1/2/3/4/5	5/50/69/12/0	0/3/33/59/39

Body mass index (BMI); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); physical activity (PA); standard deviation (SD); vigorous physical activity (VPA); Overweights include also obese subjects *significantly different from baseline, $p<0.05$.

Table 10. (a) Pearson correlations and partial correlations controlled for age and (b) Tanner stage between PA and BMI at baseline (n = 136).

	BMI (kg/m^2),r	p-Value
(a)		
Sedentary time (min/d)	0.128	0.144
MPA (min/d)	-0.152	0.082
VPA (min/d)	-0.317*	<0.001
MVPA (min/d)	-0.260*	0.003
(b)		
Sedentary time (min/d)	0.137	0.121
MPA (min/d)	-0.157	0.074
VPA (min/d)	-0.318*	<0.001
MVPA (min/d)	-0.264*	0.002

Body mass index (BMI); correlation coefficient (r); moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); probability level (p); vigorous physical activity (VPA); *p<0.05.

ROC analysis using BMI categories (Table 11) indicated that VPA ($p < 0.003$) and MVPA ($p < 0.036$) significantly discriminated between normal weight and overweight, and between normal weight and obese subjects, whereas MPA ($p > 0.102$) and sedentary time ($p > 0.078$) did not discriminate between BMI categories. The significant cut-off values for VPA and MVPA associated with normal weight were 10–14 minutes per day and 55–59 minutes per day respectively. From the results of ROC analyses, the thresholds according to this study were set at 59 minutes per day MVPA with the inclusion of at least 14 minutes per day of VPA for being overweight (38.6% of the subjects met this criteria) and 55 minutes per day MVPA with at least 10 minutes per day of VPA for being obese (52.3% met this criteria). In addition, a sedentary time threshold of 540 minutes per day was used as the result of ROC analysis.

Table 11. PA cut-off points to identify the risk of an excess of body fat according to BMI categories by ROC analysis (n = 136).

	Normal weight vs. overweight					Normal weight vs. obese				
	Cut-off (min/d)	Se (%)	Sp (%)	AUC (95% CI)	p-value	Cut-off (min/d)	Se (%)	Sp (%)	AUC (95% CI)	p-value
MPA (min/d)	46	54.6	50.6	0.54 (0.44–0.65)	0.444	46	69.6	51.1	0.61 (0.48–0.74)	0.102
VPA (min/d)	14	65.9	54.5	0.66 (0.56–0.76)	0.003	10	42.5	91.4	0.78 (0.67–0.89)	<0.001
MVPA (min/d)	59	39.1	71.6	0.61 (0.51–0.71)	0.036	55	34.0	88.9	0.70 (0.58–0.82)	0.003
Sedentary time (min/d)	543	52.3	56.8	0.48 (0.37–0.59)	0.757	559	65.2	67.1	0.38 (0.24–0.52)	0.078

Area under the curve (AUC); confidence intervals (CI); Moderate physical activity (MPA); moderate to vigorous physical activity (MVPA); probability level (p); standard error (Se); statistical power (Sp); vigorous physical activity (VPA).

Those boys who did not meet the thresholds of 5 and 20 minutes per day of VPA (both in baseline and follow-up) had an increased risk of being overweight (baseline: OR = 3.40, 95% CI 1.20 – 9.68, and OR = 3.64, 95% CI 1.30 – 10.23, respectively; follow-up: OR = 4.05, 95% CI 1.41–11.59, and OR = 4.14, 95% CI 1.35 – 12.73, respectively) and obese (baseline: OR = 7.44, 95% CI 2.38 – 23.24, and OR = 10.27, 95% CI 1.32 – 80.04, respectively; follow-up: OR = 6.54, 95% CI 1.97 – 21.69, and OR = 8.75, 95% CI 1.12 – 68.51, respectively) independent of sedentary time (Figure 8). In addition, the thresholds calculated with ROC analysis indicated significant ORs for overweight and obese at both baseline and follow-up. From MVPA thresholds, only 90 minutes per day of MVPA had an important OR for being overweight at baseline (OR = 8.14, 95% CI 1.03 – 64.04). Sedentary time did not have any significant ORs for being overweight or obese, even after the adjustment for MVPA or VPA.

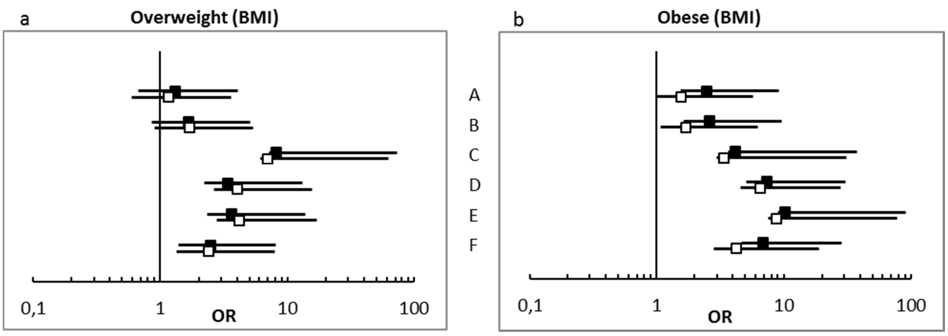

Figure 8. Odds ratios and 95% confidence intervals for being (a) overweight and (b) obese at follow-up if not meeting the physical activity recommendations compared to those meeting the physical activity recommendations.
Baseline (■); body mass index (BMI); follow-up (□); odds ratios (OR); Physical activity recommendations are the following: (A) present study: 540 minutes per day of sedentary behavior; (B) 60 minutes per day of MVPA; (C) 90 minutes per day of MVPA; (D) 5 minutes per day of VPA; (E) 20 minutes per day of VPA; (F) present study: 59 minutes per day of MVPA with 14 minutes per day of VPA (overweight) or 55 minutes per day of MVPA with 10 minutes per day of VPA (obese).

4. DISCUSSION

4.1. Comparison of IPAQ-SF and two other physical activity questionnaires with accelerometer in adolescent boys

MVPA estimates from IPAQ-SF and TPAQ, as well as DSI Inactivity scale were moderately correlated with accelerometer derived MVPA. Pubertal boys underreported their MVPA using IPAQ-SF; however, TPAQ MVPA index overestimated MVPA compared to the accelerometer derived MVPA.

PA guidelines usually set a desired value in terms of daily or weekly minutes of PA – MPA, VPA, or MVPA. A common use of PA questionnaires is evaluating how well an individual or a group conforms to the guidelines. From the three above mentioned criteria, objective MVPA was best predicted by questionnaires, followed by VPA and MPA. One can speculate that VPA is easier to estimate subjectively, as it usually means relatively short episodes of effort that are clearly separated from other activities (e.g., a game of basketball, or a bout of running). In contrast, the upper and lower thresholds of MPA, and the lower threshold of VPA are not as clear intuitively; thus, the total minutes in MPA, as well as VPA are more difficult to estimate using a questionnaire. In addition, self-estimated MVPA is, in most cases, a sum of two estimates, and can thus be more reliable estimation than its individual components (random errors in each of the component may cancel each other out).

We also found that MPA and VPA, as well as MVPA were correlated with several variables derived from questionnaires, including sedentary time, screen time, and walking. For example, IPAQ-SF walking and sedentary time together contributed more to the prediction of MVPA than IPAQ-SF MPA and VPA. A significant proportion of MPA may be brisk walking which may be omitted from self-reports of MPA, being counted as "walking", especially because walking is a separate category in IPAQ. Self-reported sedentary time is negatively associated with MVPA; this is evidently an indirect association (more sedentary time means less time available for being physically active) which is statistically significant only because the other self-reported PA variables have imperfect reliability. Here, one should take into account that there is no one-to-one correspondence between the activity categories in subjective estimates, and those in objective measures. For example, brisk walking may be MPA when measured objectively, but it classifies as walking in IPAQ-SF. The behaviours that are reported as walking in IPAQ-SF may include some LPA or possibly even below that threshold, but walking is definitely not the only activity in the LPA. Thus, when estimating actual PA from questionnaires, it can be useful to take into account several different kinds of information that was recorded, not just the specific question about the intensity category that one wants to predict.

Sedentary time was more difficult to predict than PA in the current investigation. In the best regression model, it was predicted by screen time and walking (negative correlation). Inexactness of accelerometer derived sedentary time estimate may have contributed to following: we could only use a heuristic approximation for separating sleeping and nonwear time from sedentary time. In addition, sedentary time is probably difficult to estimate subjectively, as it consists of many episodes dispersed throughout the day. The fact that a more specific questionnaire item (screen time) was a better predictor of sedentary time ($r = 0.31$) than an overall sedentary time estimate from IPAQ-SF ($r = 0.16$) may reflect this cognitive difficulty.

The best predictor of LPA in our thesis was screen time – this was obviously a negative predictor. This makes sense considering that LPA and sedentary time together make up the largest proportion of time, thus if one of them increases, the other is likely to decrease. For example, in two-year-old boys in IDEFICS study (Konstabel et al., 2013) had, on the average, 400 daily minutes of LPA, and 200 minutes of sedentary time. At 10 years of age, however, they spent about 350 minutes in both sedentary time and LPA. Fourteen-year-old boys in our thesis had, on the average day, 168 minutes of LPA, and 545 minutes of sedentary time. This dramatic decrease in LPA is likely to play a bigger role in energy balance than small changes in MVPA, and indicates that the importance of LPA may be underestimated in PA guidelines.

The PA recommendation is at least 60 minutes MVPA per day (World Health Organization, 2010). If questionnaires are used to evaluate the conformance to guidelines, we need accuracy in addition to mere correlation agreement. We found that boys underreported their MVPA in IPAQ-SF as compared to accelerometer (respective averages 43 and 56 minutes). This is in contrast to other study where overreporting was found (respective average 66 and 34 minutes) (Hagströmer et al., 2008). Our study confirmed the finding that differences between self-reported and accelerometer measured MVPA are higher with higher activity levels (Dyrstad et al., 2014; Hong et al., 2012; Kim et al., 2011); this result makes sense as more active participants probably have a more varied pattern of activities and, as a result, the total volume of MVPA is more difficult to estimate. We found that standard error of the difference is larger in more active boys – that is, self-reports (using IPAQ) of PA may be usable in inactive boys, but they are less useful in more active boys. There may be several reasons for this, one being that in more active boys, PA is more varied therefore, estimating the total time in PA is a more difficult task for them, and forgetting something is more likely. We also found that to be true for bias: underestimation in self-reported MVPA was only significant in active boys (MVPA $\geq$ 60 minutes). This reduces the conflict with earlier studies which have found overestimation for IPAQ-SF: for example, in one study (Wang et al., 2013) the mean daily MVPA was 34 minutes, compared to 56 minutes in our study. The TPAQ MVPA index slightly overestimated accelerometer derived MVPA; the likely reason for this is that the index was calibrated against data from a previous (more physically active) year.

IPAQ-SF walking cannot be treated as an estimate of LPA – this would be an immense underestimation of about 147 daily minutes. In IPAQ-SF, the respondents are instructed to count only the episodes of walking lasting at least

10 minutes – this may be one source of discrepancy. On the other hand, LPA includes several different activities besides walking (e.g., many leisure-time activities), that may be difficult to count and ask in a questionnaire. IPAQ-SF underestimated sedentary time compared to accelerometer (mean difference about 25 minutes). Taken together with low intercorrelation (r = 0.19), this indicates that IPAQ-SF sedentary time is not a reliable estimate of actual sedentary time, even though the mean differences might not be large.

Based on our results, we would recommend using all IPAQ-SF items, not just the sum of MVP and VPA, to predict MVPA. IPAQ-SF walking and sedentary time contributed more to the prediction than the two PA variables. IPAQ-SF walking cannot be treated as an estimate of LPA – firstly, it probably includes some amount of MPA, and secondly, most of LPAs are not included.

The unique contribution of TPAQ was mostly confined to the screen time item; other information may be derived from IPAQ-SF. Nevertheless, TPAQ MVPA index, based on a linear combination of 5 different variables, was a reasonable predictor of MVPA. One has to take into account the fact that also in our study, TPAQ was self-administered, whereas assistance was provided with IPAQ-SF. Activities with few episodes in a day and with typically clear end and beginning (such asVPA, or, to some extent, screen time) are cognitively easier to estimate than activities that may occur in several short episodes dispersed over the day (such as sedentary time). If the respondent has to make big generalizations (e.g., estimating the total walking or sedentary time), the results are likely to be less useful.

In conclusion, none of the PA questionnaires can be used as a reliable estimate of MVPA at an individual level in pubertal boys. In previous analyses, over-reporting of MVPA has been found in IPAQ-SF; the opposite was found in our sample. Using IPAQ-SF for describing average population levels of activity, one should use a combination of self-reported minutes of MVPA and walking.

4.2. Association of subjective ratings to objectively assessed physical activity in pubertal boys with different BMI

Based on previous results in the literature (Trost, 2007; Gwynn et al., 2010; Machado-Rodrigues et al., 2011), a modest correlation was expected between MVPA assessed by PA questionnaire and accelerometer. There was no specific hypothesis as to which source of ratings would be more "accurate," as both self-reports and parent reports have been found to be inaccurate estimates of objectively measured PA (Telford et al., 2004); nevertheless, both are often used in assessing children's PA.

The results showed modest correlations between TPAQ indexes of MVPA and objective assessments; parent TPAQ were not better predictors of objective

MVPA than boys self-reports. The proportion of sedentary time could be predicted from just one questionnaire item (TPAQ screen time); the TPAQ MVPA index increased the prediction of sedentary time both in children and parent TPAQ. The correlations were, however, weak (or weak to moderate using parent TPAQ), similarly to previous study (Affuso et al., 2011). Sedentary time was better predicted using parent TPAQ than children TPAQ.

Previous studies have indicated that overweight and obese participants may overestimate their level of PA. For example, Buchowski et al. (1999) found that with increasing body fatness people significantly overestimated the duration of VPA. Stootmaker et al. (2009) found relative overreporting of VPA in overweight adults: they reported more VPA than normal weight peers, but no difference was seen in accelerometer data. A review by Ellery et al. (2014) discussed several reasons why overweight subjects might respond differently (e.g., issues related to self-esteem, body image, and social desirability of PA) but there is not much objective research done on these issues.

This result of the current thesis indicated a relatively strong association between TPAQ MVPA index and accelerometer derived MVPA in the overweight and obese group, and a significantly weaker association in normal weight group. In the current study thus, the overweight and obese group and their parents provided more "useful" questionnaire data: based on their reports, the objective MVPA was better predicted than in the normal weight group.

We found that overweight and obese groups and the parents' TPAQ overestimated the MVPA in relation to the normal weight group and their parents - or to put it different, MVPA was underestimated in the normal weight group as compared to the overweight and obese group. Despite the fact that by objective measurement the normal weight group was considerably more active in MVPA range (a difference of 12.8 minutes), the differences were much smaller in indexe based subjective estimates (3.1 minutes in self-ratings and 1.6 minutes in parental TPAQ; significant only inchildren TPAQ). Consequently, self-report questionnaires may lead to biased estimates when used to compare PA levels across BMI groups. The difference in objective MVPA was approximately 4 times larger than in self-report, and approximately 8 times larger than in parent report. In relative terms, the overweight and obese group overestimated and/or the normal weight group underestimated their MVPA when filling out the questionnaires. This adds to the converging evidence that the weight status of participants should be taken into account if assessing PA using questionnaires. In addition, sedentary time was better predicted in overweight and obese group, and only very weak prediction was obtained in normal weight group. Tentatively, this could be explained by sedentary time being perceived as more problematic and thus being more noticeable and in overweight and obese children.

The season has some effect on adolescents' PA in this thesis; levels of PA tend to be higher in spring and summer and lower in winter (Kolle et al., 2009). In this paper, the season effect was not associated with children's and parents' TPAQ MVPA indexes but there was a small yet significant correlation with accelerometer measured MVPA. In winter, boys' PA was lower than in spring or autumn. The subjective reports appeared to be insensitive to seasonal variation in PA, although the questions specifically referred to the PA behavior in the last week. One reason for this finding could be that respondents took a long-term perspective when answering to the questionnaire, focusing on their general behavior rather than on a specific week.

In conclusion, the results of this thesis indicate a relatively poor agreement between PA questionnaires and objectively measured MVPA, which is insufficient for making individual level judgments, for example, about (in) sufficiency of PA level. Furthermore, children's weight status may affect their reporting of PA, as well as parent reports. Questionnaire results in the overweight and obese group conformed better with the objective assessments of their MVPA than in the normal weight group. Therefore, the weight status of children needs to be taken into account when using questionnaires to assess PA. Parent reports were no better predictors of objective MVPA than self-reports, but parent reports predicted sedentary time better. Seasonal effects were found for objective assessments of MVPA but not in questionnaire based indexes, which may limit the comparability of objective and subjective assessment. Future studies must consider that the source of rating (child vs. parent), season, and child weight status are possible sources of confounding when using subjective assessments of PA.

4.3. Tracking of physical activity in pubertal boys with different BMI over two-year period

We found moderate tracking for PA assessed by accelerometers, or derived from parental or children TPAQ in 12–14-year-old normal weight and overweight or obese pubertal boys. The tracking of PA was not dependent on BMI group, with a few exceptions that may be due to chance. Parents TPAQ MVPA indexes tended to track better than both the objectively measured MVPA, and the childrens TPAQ MVPA indexes. We also found a decrease in both LPA and MPA and an increase in sedentary time (relative to total weartime) over the period of two-years, but a slight increase in VPA in the obese and overweight group.

The finding of moderate tracking of MVPA is consistent with a number of other studies using either questionnaires (Corder et al., 2010; Telama, 2009) or objective measures (Corder et al., 2010; Kristensen et al., 2008; Nilsson et al., 2009) in this age group. Some previous studies have shown better tracking for inactivity than for activity (Janz et al., 2000).

In our study the tracking correlations of sedentary time were similar to those of LPA, MVP and VPA. Corder et al. (2010) found greater decline in MVPA in children with higher body fat over 12-month period. In contrast, we found no differences in tracking of MVPA between the BMI groups. The only interesting difference in tracking between BMI groups was lower tracking of VPA in obese and overweight group when comparing T2-T3; this result, if not chance finding, may reflect increases in VPA in the overweight boys that were found in study. Increases in sedentary time are also consistent with earlier findings (Ortega et al., 2013) and may partly reflect increases in screen time that we saw in parental reports, as well as increasing time spent at school.

It is known and discussed previously that objective measurement of PA improves validity and avoids the recall bias associated with self-reported PA data (Nyberg et al., 2009; Telama, 2009). Better validity should, if other things being equal result in better tracking, but this were not seen in our study. In some cases, we even found an opposite pattern of results: the parens TPAQ MVPA index tended to track better than either children's TPAQ MVPA index, or objectively measured MVPA. Does this really indicate better validity of parent reports? While in the absence of direct proof, indirect and conjectural evidence does not support a "yes" answer to this question.

One could imagine questionnaire based measures as being a summary of a series of observations of behaviour. However, this is not the whole truth: other sources, such as stereotypes and schemas are known to influence both reports about the self and acquaintances. Generalisations about oneself and others can be stored in semantic memory, and accessed directly when responding to a questionnaire, with no need to get any specific behavioural observations involved (Srull & Wyer, 1993). This means that once a parent has got the idea that their child is, for example, moderately active, they may respond to even quite specific questions based on just this general idea – leading to good tracking but not necessarily good validity. The same logic applies equally to self-reporting. It has been shown, though, that in periods of change, people tend to base their answers to generalised questions more on specific behavioural observations (Klein et al., 1997): therefore, one might expect better validity from PA questionnaires when the person is experiencing a significant change in their PA.

Objective measures in our study showed a decline in PA, consistent with numerous previous results (Ortega et al., 2013). This was somewhat reflected also in parent TPAQ MVAP index: there was a 0.3%-point decline from T1 to T3, corresponding to an average decline of 2.3 minutes ($0.3/100 \times 771$). In contrast, the objective measures showed a decline from 65 to 56 minutes, i.e., approximately 9 minutes. In summary, the change appears almost 4 times larger when measured by objective methods as opposed to parental TPAQ. In addition, children's TPAQ showed no change in MVPA index over the two-years. This has important implications for use of questionnaires for indexing PA, especially when one attempts to measure a change.

It has been suggested, that it is important to adjust the tracking correlation for possible confounders (such as wearing time and season variation) to have higher reliability of the results (Kristensen et al., 2008; Telama, 2009). In our study, the proportion of sedentary time correlation tracked better than the raw (untransformed) minutes of sedentary time correlation, indicating that tracking of sedentary time measured by accelerometer depends on accurate detection of the non-wear time. Studies indicate that seasonal variation affects tracking of

PA in pubertal boys (Nyberg et al., 2009; Telama, 2009) with tends to decreases in PA more in winter and in the presence of adverse weather conditions (Dumith et al., 2011; McKee et al., 2012). In the current study, season effects were, if anything, minimal because the T1 assessments were during the same time of year as the T2 and T3 assessments and the effect of measurement time was not significant.

One of the confounding factors in studies like this might be the body mass. The tracking of body parameters (body height, body weight, BMI and body fat %) was high over one and two years in pubertal boys indicating that individual changes in body composition were not significant. It has been reported previously that BMI is moderately stable (rs varied from 0.29 to 0.53) over 22 years in males through childhood into adulthood, while subjectively measured PA tracks less well (Herman et al., 2009). We found the body composition parameters to be fairly stable in 12–14 year pubertal boys in different BMI groups.

Our results showed that objectively measured PA decreased over two-year period in pubertal boys and therefore, the subjects advanced to less activity during their pubertal period. This change was reflected in parent report, although appearing 4 times smaller than the objective change. In contrast, children's self-reports indicated, on the average, no change in MVPA. This makes it problematic to use questionnaires as a measure of change in PA, whether in longitudinal or intervention studies. Even if subjective assessments are validated with reference to objective measures, it has to be demonstrated that the former is sensitive to change. A significant and relatively large change in MVPA in two years found in the current investigation was not reflected in boys' self-reports, and was considerably diminished in parent reports. Therefore, for this age group, it is not advisable to use self-reports as a measure of change in PA, and parent reports can only be used as a last resort, and with caution.

Another implication of our study concerns the importance of LPA in characterising the change in PA. In two years, the light activity decreased from 221 to 168 minutes, corresponding to approximately 24% of change. Both in absolute and relative terms, this change is larger than for MVPA, and has obvious implications for energy balance. Moreover, even if an increase in MVPA is achieved with an intervention, it is important to make sure that this is not counterbalanced by a much larger decrease in light activity. This finding is in line with the pivotal role of non-exercise activity thermogenesis in energy balance that is being stressed by several researchers (e.g. Levine, 2007).

In conclusion, the tracking correlations of objectively measured PA and subjectively measured PA were fairly similar across the 12–14-year-old boy's weight groups over two-year period. Tracking correlations of objectively measured PA and subjectively measured PA were not significantly different over two-year period between both BMI groups. MVPA as assessed by parent reports tended to track better than both objectively measured MVPA and boys' self-reported MVPA; however, this does not indicate a superior validity of parent reports.

4.4. Physical activity levels and sedentary time as predictors overweight and obesity in boys during pubertal period

We found that VPA was the most important factor from the measured PA intensities if predicting overweight and obesity using both cross-sectional and longitudinal approaches. Moreover, the boys who did not achieve about 60 minutes per day of MVPA with the inclusion of 10–14 minutes per day of VPA had an approximately 2.5 times increased risk of being overweight and 4.3 times increased risk of being obese in later adolescence compared to those boys who met the criteria. Sedentary time had no significant impact of predicting overweight and obesity either cross-sectionally or longitudinally.

Puberty is a period when a decline in PA and increase in sedentary time usually occur (Ortega et al., 2013; Lätt et al., 2013). Therefore, especially at this time, it is important to pay attention to different kinds of activities to promote being physically active. There are few longitudinal studies that have investigated how PA predicts overweight and obesity in later adolescence, and the results are contradictory. For example, an association between MVPA and body fat mass has been found (Kwon et al., 2013; Riddoch et al., 2009). In contrast, He et al. (2011) and Aires et al. (2010) found no longitudinal relationships between self-reported PA and being overweight. It was interesting to note that in our study, MVPA was not a good predictor of being overweight or obese, especially by the criteria of 60 minutes per day of MVPA. One of the reasons might be that the contribution of other factors (e.g. diet) has a stronger long-term effect. It can therefore be suggested that the longitudinal prediction of obesity using PA is rather difficult. Therefore, if restricting PA activity analysis only on MVPA, the suggested beneficial amount would be at least 90 minutes per day, which could be considered an important result of the current study and it could be further suggested that the recent World Health Organization global recommendation for children and adolescents to participate in at least 60 minutes per day of MVPA was not sufficient to predict being overweight or obese in later adolescence. It should be noted that the criteria of 60 minutes per day of MVPA should include VPA to have any significant impact on body-weight status. In the current study, the thresholds obtained from the ROC analysis suggested that 60 minutes per day of MVPA was sufficient if at least 10–14 minutes per day of VPA was included. This is slightly less than in a cross-sectional study by Martinez-Gomez et al. (2010), who indicated that in adolescent boys at least 20 minutes per day of VPA might have a major benefit in reducing body fat in this life period. Another important finding was that the prediction of VPA for being obese had stronger cross-sectional than longitudinal prediction, while this tendency was not revealed for overweight. Therefore, special attention must be paid to the increase of daily VPA because it seems that this type of activity level is most important in decreasing the risk of overweight and obesity. We found that those boys who did not meet the 5 and

20 minutes per day of VPA threshold criteria were about 3.5 times more likely to be overweight at baseline and about 4.0 times more likely to be overweight in two years at follow-up. The comparison of normal-weight boys with obese boys indicated that those boys who did not meet the 5 and 20 minutes per day of VPA thresholds were more likely to be obese by about 7.5–10.3 times at baseline and 6.5–8.7 times at the two-year follow-up. These findings are in accordance with previous studies. For example, Martinez-Gomes et al. (2010), Wittmeier et al. (2008) and Ortega et al. (2007) found that VPA is the most important factor for decreasing the possibility of being overweight. Based on the results of the current thesis, we could say that even a small amount of VPA (five minutes per day) plays an important role in being overweight or obese in later adolescence. As the tracking of VPA was quite high in our study, it could be argued that those boys who had a higher amount of VPA at baseline also had higher VPA at two-year follow-up. This finding has also an important relevance for everyday practice, indicating that the promotion of VPA in puberty probably has not only a short-term but also long-term effect.

Although several previous studies have found that sedentary time in particular is associated with body weight status (Maher et al., 2020; Mitchell et al., 2013), our study did not support those findings. Moreover, sedentary time did not predict longitudinally for being overweight or obese during puberty. Similar results have been found by Kwon et al. (2013) and De Bourdeaudhuij et al. (2013), with the latter indicated that only MVPA and not sedentary time was related to being overweight in 10- to 12-year-old European boys. Our study indicated that the impact of sedentary time remained insignificant even if the effect of PA was controlled. Therefore, the health-related effect of PA should rather be targeted for the increase of MVPA (the more VPA, the better) not for the decrease in sedentary time solely.

In conclusion, the results of this thesis indicate that PA, especially VPA, is important for predicting overweight and obesity in boys during puberty. The effect of sedentary time was not significant, even after adjusting of PA. The results support the recommendation that boys should undertake at least 60 minutes per day of MVPA, and they contribute to the recommendations suggesting that a minimum of 15 minutes per day of VPA would be desired to reduce the risk of developing overweight and obesity in later puberty. Local government and healthcare specialists should pay particular attention (e.g. construct new playgrounds, facilities or parks where children can play safely; improve schools sport facilities, etc.) to increase PA, especially for VPA in order to prevent overweight and obesity in children. In addition to VPA and MVPA, LPA may also be of importance to public health: the largest longitudinal decline was in LPA (50 minutes per 2 years).

5. CONCLUSIONS

1. Pubertal boys underreported their moderate-to-vigorous physical activity (MVPA) with subjective ratings as compared to objectively assessed physical activity. Underreporting was more marked in active boys, whose daily MVPA was at least 60 minutes, and was not significant in less active boys. Subjective items referring to specific everyday activities (e.g., screen time) are likely to be more useful than items requiring large generalizations (e.g., sedentary time).
2. Overweight and obese boys assessed subjectively their physical activity better compared to normal weight boys during the pubertal period. Parental subjective ratings predicted sedentary time better than boys' self-report but no difference was found for MVPA. The sources of rating, season, and weight status may be possible sources of confounding when using subjective assessments of physical activity.
3. The objectively measured physical activity of the subjects decreased over two-year period. The tracking correlations of physical activity between objective assessment and subjective ratings of physical activity were similar across the two-year period in pubertal boys of different weight status.
4. Vigorous physical activity is important for predicting overweight and obesity in boys during puberty. The boys who did not reach 60 minutes of MVPA per day with the inclusion of 10–14 minutes per day of vigorous physical activity had an approximately 2.5 times increased risk of being overweight and 4.3 times increased risk of being obese in later adolescence compared to those boys who met the criteria. Sedentary time had no significant impact of predicting overweight and obesity either cross-sectionally or longitudinally.

6. REFERENCES

1. Affuso O, Stevens J, Catellier D, McMurray RG, Ward DS, Lytle L, Sothern MS, Young DR. Validity of self-reported leisure-time sedentary behavior in adolescents. J Negat Results Biomed. 2011; 10: 2.
2. Aires L, Silva P, Silva G, Santos MP, Ribeiro JC, Mota J. Intensity of physical activity, cardiorespiratory fitness, and body mass index in youth. J Phys Act Health. 2010; 7: 54–9.
3. Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, Anderssen SA. Physical activity and clustered cardiovascular risk in children: a crosssectional study. The European Youth Heart Study. Lancet. 2006; 368: 299–304.
4. Armstrong N, Welsman JR. The physical activity patterns of European youth with reference to methods of assessment. Sports Med. 2006; 36(12): 1067–1086.
5. Baggett CD, Stevens J, McMurray RG, Evenson KR, Murray DM, Catellier DJ, He K. Tracking of Physical Activity and Inactivity in Middle School Girls. Med Sci Sports Exerc. 2008; 40: 1916–1922.
6. Benitez-Porres J, Delgado M, Ruiz JR. Comparison of physical activity estimates using International Physical Activity Questionnaire (IPAQ) and accelerometry in fibromyalgia patients: The Al-Andalus study. J Sports Sci. 2013; 31(16): 1741–1752.
7. Bland JM, Altman DG. Statistical-methods for assessing agreement between 2 methods of clinical measurements. Lancet. 1986; 1(8476): 307–310.
8. Blundell JE, Stubbs RJ, Hughes DA, Whybrow S, King NA. Cross talk between physical activity and appetite control: does physical activity stimulate appetite? Proc Nutr Soc. 2003; 62: 651–661.
9. Boon RM, Hamlin MJ, Steel GD, Ross JJ. Validation of the New Zealand physical activity questionnaire (NZPAQ-LF) and the international physical activity questionnaire (IPAQ-LF) with accelerometry. Br J Sports Med. 2010; 44(10): 741–746.
10. Buchowski MS, Townsend KM, Chen KY, Acra SA, Sun K. Energy Expenditure Determined by Self-Reported Physical Activity Is Related to Body Fatness. Obes Research. 1999; 7: 23–33.
11. Carstensen B, Gurrin L, Ekstrom C, Figurski M. MethComp: Functions for analysis of agreement in method comparison studies. R package version 1.22. 2013. Available: http://CRAN.R-project.org/package=MethComp/9/12/15.
12. Cleland V, Dwyer T, Venn A. Which domains of childhood physical activity predict physical activity in adulthood? A 20-year prospective tracking study. Br J Sports Med. 2012; 46: 595–602.
13. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. Br Med J. 2000; 320: 1240–1243.
14. Corder K, Ekelund U, Steele RM, Wareham NJ, Brage S. Assessment of physical activity in youth. J Appl Physiol. 2008; 105(3): 977–987.
15. Corder K, van Sluijs EMF, Ekelund U, Jones AP, Griffin SJ. Changes in Children's Physical Activity Over 12 Months: Longitudinal Results From the SPEEDY Study. Pediatrics. 2010; 126: E926-E935.
16. Corder K, van Sluijs EMF, Wright A, Whincup P, Wareham NJ, Ekelund U. Is it possible to assess free-living physical activity and energy expenditure in young people by self-report? Am J Clin Nutr. 2009; 89(3), 862–870.

17. De Bourdeaudhuij I, Verloigne M, Maes L, Lippevelde WV, Paw MCA, Velde SJT, ManiosY, Androutsos O. Kovocs E, Doessegger A, Brug J. Associations of physical activity and sedentary time with weight and weight status among 10- to 12-year-old boys and girls in Europe: a cluster analysis within the ENERGY project. Pediatr Obes. 2013; 8: 367–7.
18. Dhurandhar NV, Schoeller D, Brown AW, Heymsfield SB, Thomas D, Sørensen TIA, Speakman JR, Jeansonne M, Allison DB, Energy Balance Measurement Working Group. Energy balance measurement: when something is not better than nothing. Int J Obes. 2015; 39: 1109–1113.
19. Dumith SC, Gigante DP, Domingues MR, Kohl III HW. Physical activity change during adolescence: a systematic review and a pooled analysis. Int J Epidemiol. 2011; 40: 685–698.
20. Duncan SC, Duncan TE, Strycker LA, Chaumeton NR. A cohort-sequential latent growth model of physical activity from ages 12 to 17 years. Ann Behav Med. 2007; 33: 80–89.
21. Dyrstad SM, Hansen BH, Homle IM, Andersssen SA. Comparison of self-reported versus accelerometer-measured physical activity. Med Sci Sports Exerc. 2014; 46(1): 99–106.
22. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA. 2012; 307: 704–12.
23. Ellery CVL, Weiler HA, Hazell TJ. Physical activity assessment tools for use in overweight and obese children. Int J Obes. 2014; 38: 1–10.
24. Foley LS, Maddison R, Jiang Y, Olds T, Ridley K. It's not just the television: Survey analysis of sedentary behaviour in New Zealand young people. Int J Behov Nutr Phys Act. 2011; 8: 132.
25. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. Med Sci Sports Exer. 2005; 37(11): S523-S530.
26. Gomersall SR, Rowlands AV, English C, Maher C, Olds TS. The ActivityStat Hypothesis. Sports Med. 2013; 43:135–149.
27. Graig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International Physical Activity Questionnaire: 12-Contry Reliability and Validity. Med Sci Sports Exerc. 2003; 35(8): 1381–1395.
28. Grydeland M, Hansen BH, Ried-Larsen M, Kolle E, Anderssen SA. Comparison of three generations of Actigraph activity monitors under free-living conditions: do they provide comparable assessments of overall physical activity in 9-year old children? BMC Sports Sci Med Rehabil. 2014; 6: 26.
29. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. Am J Clin Nutr. 2005; 81: 746–50.
30. Gwynn JD, Hardy LL, Wiggers JH, Smith WT, D'Este CA, Turner N, Cochrane J, Barker DJ, Allia JR. The validation of a self-report measure and physical activity of Australian aboriginal and Torres Strait Islander and non-Indigenous rural children. Aust NZ J Public Health. 2010; 34 (1): S57-S65.
31. Hagströmer M, Bergman P, De Bourdeaudhuij I, Ortega FB, Ruiz JR, Manios Y, Rey-Lopez JP, Phillipp K, von Berlepsch J, Sjöström M. Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELEN Study. Int J Obes. 2008; 32: S42-S48.

32. Hajian-Tilaki K. Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. Caspian J Intern Med. 2013; 4(2): 627–635.
33. Ham SA, Ainsworth BE. Disparities in Data on Healthy People 2010 Physical Activity Objectives Collected by Accelerometry and Self-Report. Am J Public Health. 2010; 100: S263-S268.
34. Harro J, Merenakk L, Nordquist N, Konstabel K, Comasco E, Oreland L. Personality and the serotonin transporter gene: Associations in a longitudinal population-based study. Biological Psychology. 2009; 81(1).
35. He QQ, Wong TW, Du L, Jiang ZQ, Yu TS, Qiu H, Gao Y, Liu WJ, Wu JG. Physical activity, cardiorespiratory fitness, and obesity among Chinese children. Prev Med. 2011; 52: 109–13.
36. Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. Tracking of obesity and physical activity from childhood to adulthood: The Physical Activity Longitudinal Study. Int J Pediatr Obes. 2009; 4: 281–288.
37. Hills AP, Mokhtar N, Byrne NM. Assessment of Physical Activity and Energy Expenditure: An Overview of Objective Measures. Front Nutr. 2014; 1: 5.
38. Hong TK, Trang NHHD, van der Poleg HP, Hardy LL, Dibley MJ. Validity and reliability of a physical activity questionnaire for Vietnamese adolescents. Int J Behov Nutr Phys Act. 2012; 9: 93.
39. International Physical Activity Questionnaire. Guidelines for data processing and analysis. Available: https://sites.google.com/site/theipaq/9/12/15.
40. Jago R, Fox KR, Page AS, Brockman R, Thompson JL. Parent and child physical activity and sedentary time: Do active parents foster active children? BMC Public Health. 2010; 10: 194.
41. Janz K, Burns T, Levy S. Tracking of activity and sedentary behaviors in childhood - The Iowa Bone Development Study. Am J Prev Med. 2015; 29: 171–178.
42. Janz K, Dawson J, Mahoney L. Tracking physical fitness and physical activity from childhood to adolescence: the Muscatine study. Med Sci Sports Exerc. 2000; 32: 1250–1257.
43. Jáuregui A, Villalpando S, Rangel-Baltazar E, Lara-Zamudio YA, Castillo-Garcia MM. Physical activity and fat mass gain in Mexican school-age children: a cohort study. BMC Pediatr. 2012; 12: 109.
44. Kim Y, Park I, Kang M. Convergent validity of the International Physical Activity Questionaire (IPAQ): meta-analysis. Public Health Nutr. 2011; 16(3): 440–452.
45. Kjonniksen L, Torsheim T, Wold B. Tracking of leisure-time physical activity during adolescence and young adulthood: a 10-year longitudinal study. Int J Behov Nutr Phys Act. 2008; 5: 69.
46. Klein SB, Babey SH, Sherman JW. The functional independence of trait and behavioral self-knowledge: Methodological considerations and new empirical findings. Social Cognition. 1997; 15: 183–203.
47. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Objectively assessed physical activity and aerobic fitness in a population-based sample of Norwegian 9- and 15-year-olds. Scand J Med Sci Sports. 2010; 20: e41–7.
48. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: A cross-sectional study. Int J Behov Nutr Phys Act. 2009; 6: 36.
49. Konstabel K, Veidebaum T, Verbestel V, Moreno LA, Bammann K, Tornaritis M, Eiben G, Molnar D, Siani A, Sprengeler O, Wirsik N, Ahrens W, Pitsiladis Y.

Objectively measured physical activity in European children: the IDEFICS study. Int J Obes. 2014; 38: S135-S143.
50. Kristensen PL, Moeller NC, Korsholm L, Kolle E, Wedderkopp N, Froberg K. Andersen LB. The association between aerobic fitness and physical activity in children and adolescents: the European youth heart study. Eur J Appl Physiol. 2010; 110: 267–275.
51. Kristensen PL, Moller NC, Korsholm L, Wedderkopp N, Andersen LB, Froberg K. Tracking of objectively measured physical activity from childhood to adolescence: The European youth heart study. Scand J Med Sci Sports. 2008; 18: 171–178.
52. Kwon S, Burns TL, Levy SM, Janz KF. Breaks in Sedentary Time during Childhood and Adolescence: Iowa Bone Development Study. Med Sci Sports Exerc. 2012: 44: 1075–1080.
53. Kwon S, Burns TL, Levy SM, Janz KF. Which contributes more to childhood adiposity-high levels of sedentarism or low levels of moderate-through-vigorous physical activity? The Iowa Bone Development Study. J Pediatr. 2013; 162: 1169–74.
54. Lachat CK, Verstraeten R, Khanh LNB, Hagströmer M, Cong Khan N, Van NDA, Dung NQ, Kolsteren PW. Validity of two physical activity questionnaires (IPAQ and PAQA) for Vietnamese adolescents in rural and urban areas. Int J Behov Nutr Phys Act. 2008; 5: 37.
55. Laguna M, Ruiz JR, Lara MT, Aznar S. Recommended levels of physical activity to avoid adiposity in Spanish children. Pediatr Obes. 2013; 8: 62–9.
56. Lätt E, Mäestu J, Rääsk T, Rubin DA, Purge P, Saar M, Utsal L, Jürimäe J, Maasalu K, Jürimäe T. Association of physical activity to cardiovascular fitness and fatness in 12–13-year-old boys in different weight status. J Public Health. 2013; 21: 231–239.
57. Lee PH, Macfarlane DJ, Lam TH, Stewart SM. Validity of the international physical activity questionnaire short from (PAQ-SF): A systematic review. Int J Behov Nutr Phys Act. 2011; 8: 115.
58. Lee ST, Wong JE, Shanita SN, Ismail MN, Deurenberg P, Poh BK. Daily Physical Activity and Screen Time, but Not Other Sedentary Activities, Are Associated with Measures of Obesity during Childhood. Int J Environ Res Public Health. 2015; 12: 146–161.
59. Levin JA. Nonexerise activity thermogenesis-liberatimg the life-force. J Intern Med. 2007; 262(3): 273–287.
60. Machado-Rodrigues AM, Coelho-E-Silva MJ, Mota J, Cyrino E, Cumming SP, Riddoch C, Beunen G, Malina RM. Agreement in activity energy expenditure assessed by accelerometer and self-report in adolescents: Variation by sex, age, and weight status. J Sport Sci. 2011; 29(14): 1503–1514.
61. Maher C, Olds TS, Eisenmann JC, Dollman J. Screen time is more strongly associated than physical activity with overweight and obesity in 9- to 16-year-old Australians. Acta Paediatr. 2012; 101: 1170–4.
62. Martinez-Gomez D, Ruiz JR, Ortega FB, Casajús JA, Veiga OL, Widhalm K, Manios Y, Béghin L, González-Gross M, Kafatos A, España-Romero V, Molnar D, Moreno LA, Marcos A, Castillo MJ, Sjöström M. Recommended levels and intensities of physical activity to avoid low-cardiorespiratory fitness in European adolescents: The HELENA study. Am J Hum Biol: The Official Journal of the Human Biology Council. 2010; 22(6): 750–756.

63. Martinez-Gomez D, Gomez-Martinez S, Ruiz JR, Diaz LE, Ortega FB, Widhalm K, Cuenca-Garcia M, Manio Y, De Vriendt T, Molnar D, Huybrechts I, Breidenassel C, Gottrand F, Plada M, Moreno S, Ferrari M, Moreno LA, Sjostrom M, Marcos A, HELENA Study Group. Objectively-measured and self-reported physical activity and fitness in relation to inflammatory markers in European adolescents: The HELENA study. Atherosclerosis. 2012; 221(1): 260–267.
64. Martinez-Gomez D, Ruiz JR, Ortega FB, Veiga OL, Moliner-Urdiales D, Mauro B. Recommended levels of physical activity to avoid an excess of body fat in European adolescents: the HELENA Study. Am J Prev Med. 2010(1); 39: 203–11.
65. Martinez-Gomez D, Welk GJ, Calle ME, Marcos A, Veiga OL, AFINOS Study Grp. Preliminary evidence of physical activity levels measured by accelerometer in spanish adolescents; the AFINOS study. Nutr Hosp. 2009; 24(2): 226–232.
66. McKee DP, Murtagh EM, Boreham CAG, Nevill AM, Murphy MH. Seasonal and Annual Variation in Young Children's Physical Activity. Med Sci Sports Exerc. 2012: 44.
67. Mitchell JA, Pate RR, Beets MW, Nader PR. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. Int J Obes. 2013; 37: 54–60.
68. Moliner-Urdiales D, Ruiz JR, Ortega FB, Rey-Lopez JP, Vicente-Rodriguez G, España-Romero V, Munguía-Izquierdo D, Castillo MJ, Sjöström M, Moreno LA; HELENA Study Group. Association of objectively assessed physical activity with total and central body fat in Spanish adolescents: the HELENA study. Int J Obes (Lond). 2009; 33: 1126–35.
69. Murphy MH, Rowe DA, Belton S, Woods CB. Validity of a two-item physical activity questionnaire for assessing attainment of physical activity guidelines in youth. BMC Public Health. 2015; 15:1080.
70. Ness AR, Leary SD, Mattocks C, Blair SN, Reilly JJ, Wells J, Ingle S, Tilling K, Smith GD, Riddoch C. Objectively measured physical activity and fat mass in a large cohort of children. PLoS Med. 2007; 4: e97.
71. Nilsson A, Andersen LB, Ommundsen Y, Froberg K, Sardinha LB, Piehl-Aulin K, Ekelund U. Correlates of objectively assessed physical activity and sedentary time in children: a cross-sectional study (The European Youth Heart Study). BMC Public Health. 2009; 9: 322.
72. Nyberg G, Ekelund U, Marcus C. Physical activity in children measured by accelerometry: stability over time. Scand J Med Sci Sports. 2009; 19: 30–35.
73. Ortega FB, Konstabel K, Pasquali E, Ruiz JR, Hurtig-Wennlöf A, Mäestu J, Löf M, Harro J, Bellocco R, Labayen I, Veidebaum T, Sjöström M. Objectively measured physical activity and sedentary time during childhood, adolescence and young adulthood: a cohort study. PloS One. 2013; 8: a60871.
74. Ortega FB, Ruiz JR, Sjöström M. Physical activity, overweight and central adiposity in Swedish children and adolescents: the European Youth Heart Study. Int J Behav Nutr Phys Act. 2007; 4: 61.
75. Ottevaere C, Huybrechts I, De Bourdeaudhuij I, Sjostrom M, Ruiz JR, Ortega FB, Hagströmer M, Widhalm K, Molnar D, Moreno LA, Beghin L, Kafatos A, Polito A, Manios Y, Martinez-Gomez D, De Henauw S. Comparison of the IPAQ-A and actigraph in relation to VO(2)max among european adolescents: The HELENA study. J Sci Med Sport. 2011; 14 (4): 317–324.
76. Public Health Canada. Family guide to physical activity for youth 10–14 years of age. Ottawa: Governmental of Canada, 2002.

77. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing.2012; ISBN 3–900051–07–0.Retreived from http://www.R-project.org/22/06/12.
78. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2014; ISBN 3–900051–07–0. Available: http://www.R-project.org/9/12/15.
79. Rauner A, Mess F, Woll A. The relationship between physical activity, physical fitness and overweight in adolescents: a systematic review of studies published in or after 2000. BMC Pediatr. 2013; 13: 19.
80. Razzoli M, Bartolomucci A. The Dichotomous Effectof Chronic Stress on Obesity. Trends Endocrinol Metab. 2016; 27(7): 504–515.
81. Revelle W. Psych: Procedures for Personality and Psychological Research, Northwestern University, Evanston, Illinois, USA. 2013; http://CRAN.R-project.org/package=psych Version = 1.3.10/9/12/15.
82. Riddoch CJ, Leary SD, Ness AR, Blair SN, Deere K, Mattocks C, Griffiths A, Smith GD, Tilling K. Prospective associations between objective measures of physical activity and fat mass in 12–14 year old children: the Avon Longitudinal Study of Parents and Children (ALSPAC). BMJ. 2009; 339: b4544.
83. Ruiz JR, Rizzo NS, Hurtig-Wennlöf A, Ortega FB, Wärnberg J, Sjöström M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. Am J Clin Nutr. 2006; 84: 299–303.
84. Slootmaker S, Schuit A, Chinapaw M, Seidell J, Mechelen WV. Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. Int J Behov Nutr Phys Act. 2009; 6(1):17–17.
85. Srull TK, Wyer RS. The Mental Representation of Trait and Autobiographical Knowledge About the Self. Hillsdale, NJ: Lawrence Erlbaum Associates. 1993.
86. Steele RM, Brage S, Corder K, Wareham NJ, Ekelund U. Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. J Appl Physiol. 2008; 105: 342–51.
87. Steiger JH. Tests for comparing elements of a correlation matrix, Psych Bull. 1980; 87: 245–251.
88. Tanner J. Growth at adolescence. Oxford: Blackwell. 1962.
89. Telama R, Yang X, Leskinen E, Kankaanpää A, Hirvensalo M, Tammelin T, Viikari JS, Raitakari OT. Tracking of physical activity from early childhood through youth into adulthood. Med Sci Sports Exerc. 2014; 46(5): 955–962.
90. Telama R. Tracking of Physical Activity from Childhood to Adulthood: A Review. Obes Facts. 2009; 2.
91. Telford A, Salmon J, Jolley D, Crawford D. Reliability and validity of physical activity questionnaires for children: The children's leisure activities study survey (CLASS). Pediatr Exerc Sci. 2004; 16(1): 64–78.
92. Torrance B, McGuire KA, Lewanczuk B, McGavock J. Overweight, physical activity and high blood pressure in children: a review of the literature. Vasc Health Risk Manag. 2007; 3(1): 139–149.
93. Trost SG. State of the art reviews: Measurement of physical activity in children and adolescents. Am J Lifestyle Med. 2007; 1(4): 299–314.
94. Tsukayama E, Duckworth AL, Kim B. Resisting everything except temptation: Evidence and an explanation for domain-specific impulsivity. Eur J Pera. 2012; 26(3): 318–334.

95. Utsal L, Tillmann V, Zilmer M, Mäestu J, Purge P, Jürimäe J, Saar M, Lätt E, Maasalu K, Jürimäe T. Elevated Serum IL-6, IL-8, MCP-1, CRP, and IFN-γ Levels in 10- to 11-Year-Old Boys with Increased BMI. Horm Res Paediatr. 2012; 78(1): 31–9.
96. Villablanca PA, Alegria JR, Mookadam F, Holmes DR, Wright RS, Levine JA. Nonexercise Activity Thermogenesis in Obesity Management. Mayo Clin Proc. 2015; 90(4): 509–519.
97. Wang C, Chen P, Zhuang J. Validity and reliability of International Physical Activity Questionnaire-Short Form in Chinese youth. Res Q Exerc Sport. 2013; 84: S80-S86.
98. Wedderkopp N, Froberg K, Hansen H, Riddoch C, Andersen L. Cardiovascular risk factors cluster in children and adolescents with low physical fitness: The European youth heart study (EYHS). Pediatr Exer Sci. 2003; 15(4): 419–427.
99. Wittmeier KDM, Mollard RC, Kriellaars DJ. Physical activity intensity and risk of overweight and adiposity in children. Obesity. 2008; 16: 415–20.
100. World Health Organization. Global recommendations on physical activity for health. 2010. Geneva. Switzerland WHO. Available: http://www.who.int/dietphysicalactivity/publications/9789241599979/en/21/10/15.

SUMMARY IN ESTONIAN

Subjektiivselt ja objektiivselt mõõdetud kehalise aktiivsuse seosed normaal- ja ülekaaluga puberteedielistel poistel.

Kehaline aktiivsus väheneb eluaaja jooksul ning sama-aegselt suureneb ka istuva eluviisi aeg. Uuringutes on leitud, et subjektiivsed kehalise aktiivsuse mõõtmise meetodid on mõõdukalt seotud objektiivselt mõõdetud kehalise aktiivsuse meetodidega, kuid see seos on pigem nõrk, ning subjektiivsed hinnangud pigem alahindavad kehalist aktiivsust. Käesoleva doktoritöö eesmärgiks oli uurida subjektiivselt ja objektiivselt mõõdetud kehalise aktiivsuse seost normaal- ja ülekaalulistel puberteedieas poistel.

Vastavalt uurimistöö eesmärgile püstitati järgmised konkreetsed ülesanded:
1. võrrelda omavahel puberteedialiste poistel subjektiivseid ja objektiivseid kehalise aktiivsuse parameetreid;
2. võrrelda normaal- ja ülekaalulistel puberteedialiste poiste lapse ja lapsevanema subjektiivseid kehalise aktiivsuse hinnanguid akselerومeetriga määratud kehalise aktiivsuse tasemetega;
3. analüüsida normaal- ja ülekaaluliste puberteedialiste poiste objektiivselt ja subjektiivselt mõõdetud kehalise aktiivsuse muutust kahe aasta jooksul;
4. uurida kahe aasta jooksul puberteedialistel poistel kehalise aktiivsuse seost ülekaalulisusega.

Antud uuringus osalesid 11–14-aastased poisslapsed. Vaatlusalused jaotati kehamassiindeksi järgi normaal- ja ülekaalulisteks ning neid uuriti kahe aastase perioodi jooksul kolmel korral. Igal aastal toimusid mõõtmised samal aastaajal ning uurimispäeval määrati vaatlusalustel keha koostis ning samuti täitsid uuritavad kehalise aktiivsuse küsimustikud. Seejärel kandsid nad aktseleromeetrit seitsme järjestikuse päeva jooksul. Lisaks täitis lapsevanem küsimustiku oma lapse kehalise aktiivsuse kohta sama uuritava perioodi kohta.

Käesoleva doktoritöö põhjal tehti järgmised järeldused:
1. Vaatlusalused alahindasid subjektiivselt mõõduka kuni tugeva kehalise aktiivsuse (MTKA) taset võrreldes akselerومeetriga määratud kehalise aktiivusega. MTKA alahindamine leiti aktiivsematel poistel, kelle igapäevane MTKA hulk oli vähemalt 60 minutit päevas, seevastu vähem aktiivsetel poistel usutavat seost ei leitud.
2. Subjektiivselt määrasid oma kehalise aktiivsuse taset oluliselt täpsemini ülekaalulised vaatlusalused võrreldes normaalkaalulistega. Lapsevanema subjektiivne hinnang ennustas oluliselt paremini lapse inaktiivsuse taset, võrreldes lapse enda subjektiivse hinnanguga, seevastu mingit erinevust lapse ja lapsevanemate hinnangutes ei leitud MTKA vahel.
3. Subjektiivselt ja objektiivselt mõõdetud kehalise aktiivsuse muutus normaal- ja ülekaalulistel puberteedialistel poistel oli kahe aasta jooksul üsna stabiilne.

4. Tugeva kehalise aktiivsuse tase omab puberteedieas poistel kõige tugevamat seost ülekaalulisuse ja rasvumisega ning päevane liikumine peab sisaldama vähemasti 15 minutit tugevat kehalist aktiivsust 60 minuti MTKA hulgas, et vältida ülekaalu või rasvumist puberteedieas.

ACKNOWLEDGEMENTS

My special thanks to:

- My academic supervisors researcher Dr. Kenn Konstabel, Senior Lecturer Dr. Jarek Mäestu and Professor Dr. Toivo Jürimäe for all the support and advice throughout preperation my thesis;
- Professor Jaak Jürimäe for academic support.
- Researchers Dr. Evelin Lätt, Dr. Priit Purge, Dr. Meeli Saar, Dr. Sille Vaiksaar and Rhoda Vaiksaar for all support and helping to conduct the procedures;
- All the participants, who went through this demanding project;
- My family for all the support during my PhD studies.

PUBLICATIONS

CURRICULUM VITAE

Name: Triin Rääsk
Date of Birth: June 18, 1986
Citizenship: Estonia
Phone: +372 5650 4161
E-mail: triin.raask@ut.ee
Languages: Estonian, English, Russian

Educational Career:

2010–	Doctoral study, Institute of Sport Sciences and Physiotherapy, Faculty of Medicine, University of Tartu, Estonia
2008–2010	MSc, Faculity of Exercise and Sport Sciences, University of Tartu, Estonia
2005–2008	BSc, Faculity of Exercise and Sport Sciences, University of Tartu, Estonia
2002–2005	Kohtla-Järve Järve Gymnasium
1993–2002	Lüganuse Gymnasium

Professional Career:

2016–	Instructor in sport center "Atlantis H2O Aquapark"
2011–2016	Swimming coach in sport center "OÜ Tartu Veekeskus"
2007–2016	Swimming coach in sport club "Ujumise Spordiklubi"
2008–2015	Swimming coach in sport club "Tartu Ujumisklubi"
2006–2007	Swimming coach in sport club "Spordiklubi Arena"

ELULOOKIRJELDUS

Nimi: Triin Rääsk
Sünniaeg: 18. juuni, 1986
Kodakondsus: eesti
Telefon: +372 5650 4161
E-mail: triin.raask@ut.ee
Keeled: Estonian, English, Russian

Haridus:

2010– Doktoriõpe, Meditsiiniteaduste valdkond, Tartu Ülikool
2008–2010 Magistriõpe, Tartu Ülikooli kehakultuuriteaduskond
2005–2008 Bakalaureuseõpe, Tartu Ülikooli kehakultuuriteaduskond
2002–2005 Kohtla-Järve Järve Gümnaasium
1993–2002 Lüganuse Gümnaasium

Töökogemus:

2016– Instruktor Viimsi veekeskuses "Atlantis H2O Aquapark"
2011–2016 Ujumistreener Aura Veekeskuses "OÜ Tartu Veekeskus"
2007–2016 Ujumistreener spordiklubis "Ujumise Spordiklubi"
2008–2015 Ujumistreener spordiklubis "Tartu Ujumisklubi"
2006–2007 Ujumistreener spordiklubis "Spordiklubi Arena"

DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

1. **Lennart Raudsepp.** Physical activity, somatic characteristics, fitness and motor skill development in prepubertal children. Tartu, 1996, 138 p.
2. **Vello Hein.** Joint mobility in trunk forward flexion: methods and evaluation. Tartu, 1998, 107 p.
3. **Leila Oja.** Physical development and school readiness of children in transition from preschool to school. Tartu, 2002, 147 p.
4. **Helena Gapeyeva.** Knee extensor muscle function after arthroscopic partial meniscectomy. Tartu, 2002, 113 p.
5. **Roomet Viira.** Physical activity, ecological system model determinants and physical self-perception profile in early adolescence. Tartu, 2003, 167 p.
6. **Ando Pehme.** Effect of mechanical loading and ageing on myosin heavy chain turnover rate in fast-twitch skeletal muscle. Tartu, 2004, 121 p.
7. **Priit Kaasik.** Composition and turnover of myofibrillar proteins in volume – overtrained and glucocorticoid caused myopathic skeletal muscle. Tartu, 2004, 123 p.
8. **Jarek Mäestu.** The perceived recovery-stress state and selected hormonal markers of training stress in highly trained male rowers. Tartu, 2004, 109 p.
9. **Karin Alev.** Difference between myosin light and heavy chain isoforms patterns in fast- and slow-twitch skeletal muscle: effect of endurance training. Tartu, 2005, 117 p.
10. **Kristjan Kais.** Precompetitive state anxiety, self-confidence and ahtletic performance in volleyball and basketball players. Tartu, 2005, 99 p.
11. **Aire Leppik.** Changes in anthropometry, somatotype and body composition during puberty: a longitudinal study. Tartu, 2005, 161 p.
12. **Jaan Ereline.** Contractile properties of human skeletal muscles: Association with sports training, fatigue and posttetanic potentiation. Tartu, 2006, 133 p.
13. **Andre Koka.** The role of perceived teacher feedback and perceived learning environment on intrinsic motivation in physical education. Tartu, 2006, 137 p.
14. **Priit Purge.** Performance, mood state and selected hormonal parameters during the rowing season in elite male rowers. Tartu, 2006, 101 p.
15. **Saima Kuu.** Age-related contractile changes in plantarflexor muscles in women: associations with postactivation potentiation and recreational physical activity. Tartu, 2006, 101 p.
16. **Raivo Puhke.** Adaptive changes of myosin isoforms in response to long-term strength training in skeletal muscle of middle-aged persons. Tartu, 2006, 99 p.

17. **Eva-Maria Riso.** The effect of glucocorticoid myopathy, unloading and reloading on the skeletal muscle contractile apparatus and extracellular matrix. Tartu, 2007, 114 p.
18. **Terje Sööt.** Bone mineral values in young females with different physical activity patterns: association with body composition, leg strength and selected hormonal parameters. Tartu, 2007, 94 p.
19. **Karin Tammik.** Neuromuscular function in children with spastic diplegic cerebral palsy. Tartu, 2007, 102 p.
20. **Meeli Saar.** The relationships between anthropometry, physical activity and motor ability in 10–17-year-olds. Tartu, 2008, 96 p.
21. **Triin Pomerants.** Ghrelin concentration in boys at different pubertal stages: relationships with growth factors, bone mineral density and physical activity. Tartu, 2008, 80 p.
22. **Tatjana Kums.** Musculo-skeletal function in young gymnasts: association with training loads and low-back pain. Tartu, 2008, 128 p.
23. **Maret Pihu.** The components of social-cognitive models of motivation in predicting physical activity behaviour among school students. Tartu, 2009, 116 p.
24. **Peep Päll.** Physical activity and motor skill development in children. Tartu, 2009, 102 p.
25. **Milvi Visnapuu.** Relationships of anthropometrical characteristics with basic and specific motor abilities in young handball players. Tartu, 2009, 114 p.
26. **Rita Gruodytė.** Relationships between bone parameters, jumping height and hormonal indices in adolescent female athletes. Tartu, 2010, 82 p.
27. **Ragnar Viir.** The effect of different body positions and of water immersion on the mechanical characteristics of passive skeletal muscle. Tartu, 2010, 142 p.
28. **Iti Müürsepp.** Sensorimotor and social functioning in children with developmental speech and language disorders. Tartu, 2011, 90 p.
29. **Ege Johanson.** Back extensor muscle fatigability and postural control in people with low back pain. Tartu, 2011, 106 p.
30. **Evelin Lätt.** Selected anthropometrical, physiological and biomechanical parameters as predictors of swimming performance in young swimmers. Tartu, 2011, 90 p.
31. **Raul Rämson.** Adaptation of selected blood biochemical stress and energy turnover markers to different training regimens in highly trained male rowers. Tartu, 2011, 84 p.
32. **Helen Jõesaar.** The effects of perceived peer motivational climate, autonomy support from coach, basic need satisfaction, and intrinsic motivation on persistence in sport. Tartu, 2012, 108 p.
33. **Sille Vaiksaar.** Effect of menstrual cycle phase and oral contraceptive use on selected performance parameters in female rowers. Tartu, 2012, 86 p.

34. **Anna-Liisa Parm.** Bone mineralization in rhythmic gymnasts before puberty: associations with selected anthropometrical, body compositional and hormonal parameters. Tartu, 2012, 96 p.
35. **Jelena Sokk.** Shoulder function in patients with frozen shoulder syndrome: the effect of conservative treatment and manipulation under general anaesthesia. Tartu, 2012, 125 p.
36. **Helena Liiv**. Anthropometry, body composition and aerobic capacity in elite DanceSport athletes compared with ballet and contemporary dancers. Tartu, 2014, 80 p.
37. **Liina Remmel**. Relationships between inflammatory markers, body composition, bone health and cardiorespiratory fitness in 10- to 11-year old overweight and normal weight boys. Tartu, 2014, 94 p.
38. **Doris Vahtrik.** Leg muscle function in relation to gait and standing balance following total knee arthroplasty in women. Tartu, 2014, 105 p.
39. **Artūrs Ivuškāns.** Bone mineral parameters in 11–13-year-old boys: associations with body composition and physical activity. Tartu, 2014, 95 p.
40. **Antonio Cicchella.** Relationships of multifunctional hormone leptin with anthropometry, aerobic capacity and physical activity in peripubertal boys. Tartu, 2014, 87 p.
41. **Martin Mooses**. Anthropometric and physiological determinants of running economy and performance from Estonian recreational to Kenyan national level distance runners. Tartu, 2014, 94 p.