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**INDIRECT MEASUREMENT OF MAXIMAL OXYGEN
CONSUMPTION IN 14-16-YEAR OLD ADOLESCENT GIRLS**

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LIST OF PUBLICATIONS

Articles:

1. Pomerants T, Jürimäe T (2003). 1500 meetri jooksutesti korratavus 14-16aastastel neidudel. Kehakultuuriteaduskonna teadus- ja õppemetoodiliste tööde kogumik XI, 224-228.
2. Pomerants T, Jürimäe T, Karelson K (2004). Indirect measurement of maximal oxygen consumption in 14-16-year old adolescent girls. Proceeding book of 62nd Scientific Conference of the University of Latvia, 13. February, 17-25.
3. Pomerants T, Jürimäe T, Karelson K (2004). Aeroobne töövõime 14-16aastastel neidudel. Eesti Arst (Accepted).

Abstracts:

1. Pomerants T, Jürimäe T, Karelson K (2004). 1500-meter running test for predicting $\dot{V}O_2\text{max}$ in 14-16-year old adolescent girls. Pre-Olympic Congress 2004, Thessaloniki, 6.-11. August (Accepted).
2. Pomerants T, Jürimäe T, Karelson K (2004). Indirect measurement of maximal oxygen consumption in 14-16-year old adolescent girls. 9th Annual Congress of the European College of Sport Sciences, Clermont-Ferrand, 3.-6. July (Accepted).

1. INTRODUCTION

The different components of health have been a target of interest in different investigations for decades, since physical, psychical and social well-being of people determines greatly the ability of the whole society to function normally. Physical activity is one of the easiest but nevertheless powerful possibilities of maintaining good health. It contributes for example to a lower risk of cardiovascular disease, diabetes, osteoporosis and some types of cancer, also reduces stress. Sufficient amount of physical activity assures a better state of health, which is often more or less characterized with the state of physical working capacity.

Physical working capacity is very complex and is directly linked to many variables of body and mind, one most influential of them probably being aerobic working capacity. A very precise evaluation of all different components of aerobic working capacity would give valuable detailed information about the health status of a person, but the procedure of this evaluation would also be very complicated and time-consuming. Therefore have simpler possibilities for estimation of health been searched. Many investigations through the years have by now led to a common conclusion that level of maximal oxygen consumption is the best single descriptive characteristic of aerobic working capacity, since it is connected to a such a significant amount of different physiological factors.

There is a considerable number of tests developed in many years for measuring the maximal oxygen consumption. It is well-known, that the best opportunity for aerobic testing would be in the equipped laboratory setting, but that way is not always possible or practical. Therefore has a number of more simple and feasible but still valid indirect tests been introduced for evaluation of aerobic working capacity in field conditions.

In spite of the amount of developed tests, there is still a lack of specific data about aerobic capacity and testing in some populations, one of these being adolescent girls. These indirect tests are very sensitive to testing population, so further research is needed for getting more trustworthy information.

Since it is important to evaluate the state of health through whole life span and possibilities for laboratory testing are somewhat limited, are reliable and differentiated indirect field tests for monitoring the physical working capacity needed. Motivation of our study was the wish to offer a possible alternative for indirect estimation of maximal oxygen consumption in field conditions for adolescent girls with regard to Estonian population.

2. REVIEW OF LITERATURE

2.1 Physical working capacity

There are many different definitions for physical working capacity. As an example has physical working capacity or physical fitness been defined as a state of being that consists 5 health-related and 6 skill-related components. Evidence suggests that possessing good levels of health-related components of physical fitness (body composition, cardiovascular fitness, flexibility, muscular endurance, and strength) is related to reduced risks of chronic diseases and has wellness benefits. Skill-related physical fitness components (agility, balance, coordination, power, speed and reaction time) are abilities that are associated with athletic performance, but are not generally associated with good health enhancement (USDHHS 1996). Most current fitness testing batteries focus on health-related fitness because these components are associated with good health and wellness (Corbin 2004).

Physical working capacity as mentioned already has many different components. For getting precise information about person's level of physical fitness, as many of these influential factors as possible should be taken into account during analysis. One possible interpretation (Aulik 1990) of factors influencing physical working capacity is shown on Figure 1 on page 7.

Physical activity as a simple way of maintaining of high working capacity and therefore also good health has been linked to reduced incidence of hypertension, cardiovascular disease, non-insulin-dependent diabetes, stroke, osteoporosis, depression and certain types of cancers. Low cardiovascular fitness has been found to be a strong and independent predictor of cardiovascular disease and all-cause mortality (Seefeldt et al. 2002; Wei et al. 1999). Thus accurate measurement of physical fitness levels in adolescence can play a substantial role in assessing health status and future health risks in young populations and can assist in planning intervention programs aimed at reducing health risks and promoting better health behaviour (Huerta et al. 2004; Keating 2003).

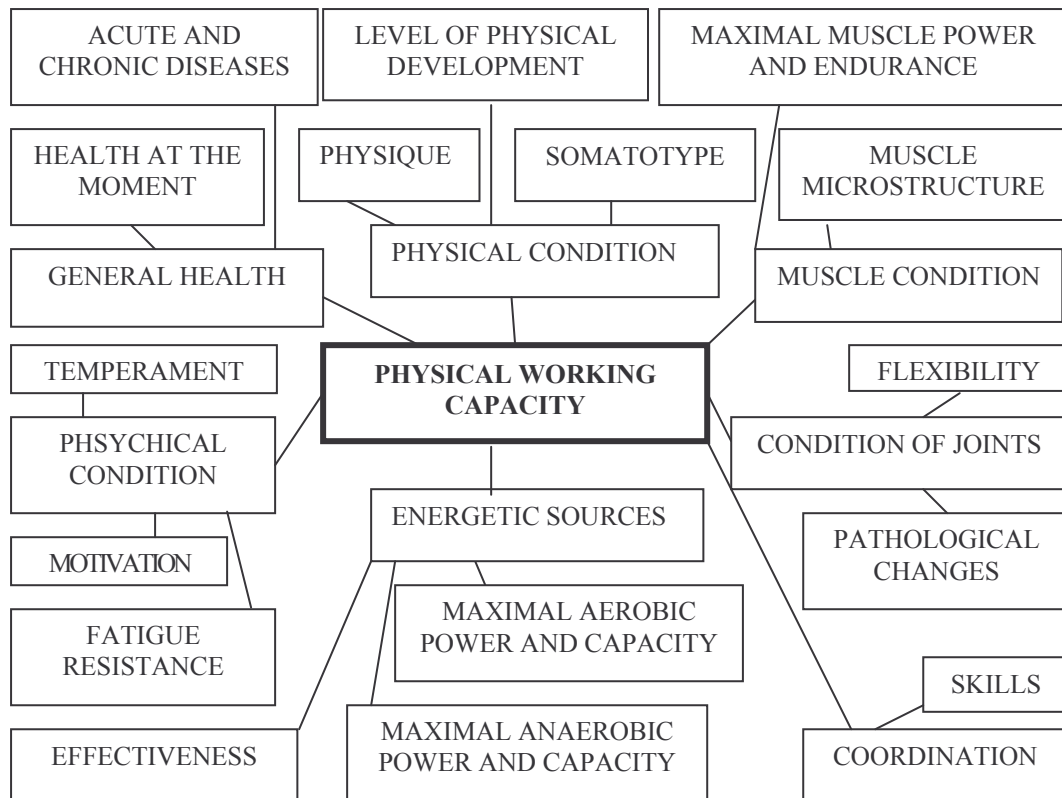


Figure 1. Complex of physical working capacity components (Aulik, 1990)

2.2. Aerobic working capacity

The ability to perform aerobic exercise is associated with the level of aerobic power or maximal oxygen consumption ($\dot{V}O_2\text{max}$), which is generally recognized and frequently used as the best single index of individuals cardiorespiratory fitness (Åstrand & Rodahl 1986; Armstrong et al. 1998; Larsen et al. 2002; Latin & Elias 1993). Maximal oxygen consumption has been defined as the maximum amount of oxygen per unit of time that can be extracted from the atmosphere and transported for utilization in tissues during progressively increasing effort of dynamic large-muscle-group activity (Åstrand & Rodahl 1986; Bassett & Howley 2000; Kent 1998).

Many potential factors limiting $\dot{V}O_{2\max}$ have been discussed through the years. One example of the limiting factors of $\dot{V}O_{2\max}$ (Rowell 1986) is illustratively brought on the Figure 2. Even now are some questions surrounding the issue of limitators/determinants of $\dot{V}O_{2\max}$ still not clear. However, the evidence shows that it is mainly the ability of the cardiorespiratory system (i. e heart, lungs and blood) to transport oxygen to the working muscles, that limits $\dot{V}O_{2\max}$, not other factors like for example the ability to consume oxygen (Bassett & Howley 1997).

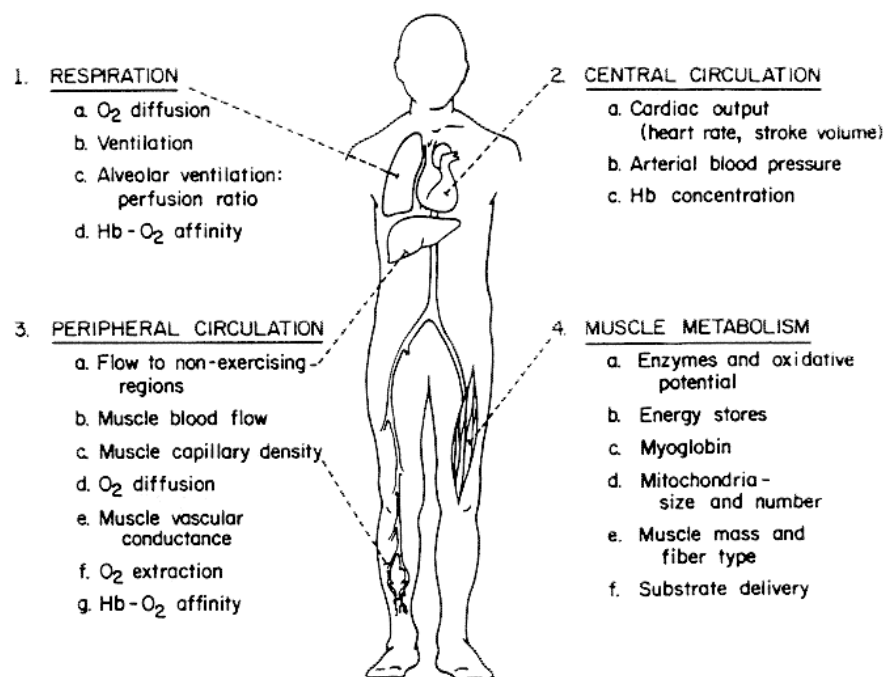


Figure 2 . Factors limiting maximal oxygen consumption (Rowell 1986)

Since $\dot{V}O_{2\max}$ is based on so many different physiological characteristics, it has become a common descriptive variable like are stature, body mass and age (Howley et al. 1995). Cardiorespiratory fitness has long been recognized as one of the fundamental components of physical fitness and a key factor in many athletic activities (Pate & Kriska 1984). In the scientific literature is the increase in $\dot{V}O_{2\max}$

the most common evidence in demonstrating aerobic training effect. In addition is $\dot{V}O_2\text{max}$ often used in the development of exercise prescription (Bassett & Howley 2000). A high $\dot{V}O_2\text{max}$ alone of course does not automatically guarantee high level of working capacity, it should not be forgotten that several other factors as technique of motion and psychological factors may influence performance the same way.

$\dot{V}O_2\text{max}$ can be expressed as an absolute amount of consumed oxygen in time unit ($l\cdot\text{min}^{-1}$) for inducing the general working capacity, or as the relative amount of oxygen for every kilogram of body mass ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Adjustment of $\dot{V}O_2\text{max}$ to body size has been an object of discussion for a long time, though, and many different correction techniques (Bergh et al. 1991; Rogers et al. 1995) have been offered. The expression unit $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ is the most traditional one in this context, although the accuracy is in that case also weakened by confounding effect if body fat. Most appropriate means for “normalizing” $\dot{V}O_2\text{max}$ for body size and also to biological maturity stays at least in case of children and adolescents problematic (Pettersen et al. 2001; Rowland et al. 1997).

Mass-relative maximal oxygen consumption ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and running performance have been found to correlate poorly with the body mass, but by that has body mass still been found to account for a significant portion of the variance between maximal oxygen consumption and distance run performance for example in college-aged population (Anderson 1992).

The level of absolute maximal oxygen consumption increases with age, growth and maturation. The aerobic working capacity ($l\cdot\text{min}^{-1}$) in girls improves parallel to body growth until the last stages of maturity, the $\dot{V}O_2\text{max}/\text{kg}$ remains about the same. The highest level of $\dot{V}O_2\text{max}$ in females appears after menarche (Malina et al. 1991; Laaneots et al. 1996). An investigation made by Kemper et al. (1989) showed an increase of 10 % in $\dot{V}O_2\text{max}$ ($l\cdot\text{min}^{-1}$) during the school years from age 13.5 to 16.5

years, this was followed by a 5 % decrease by the age of 21.5 years. Boys exhibit higher values than girls throughout childhood and adolescence, the $\dot{V}O_{2\max}$ of adult females is about 80 % of the value achieved by the males (Jensen et al. 2001).

There are traditionally 3 explanations offered for gender differences in maximal oxygen consumption in adults: sex-related variations in body composition, hemoglobin concentration, and habitual physical activity (Rowland 1996). Girls' habitual physical activity participation is generally less frequent and of a lower intensity than that in boys. The physical activity levels reduce in both sexes during puberty (Armstrong & Welsman 1991; Pate 1997; Sallis 1993), but this reduction is more apparent in girls. The physiological changes in body composition during the growth spurt, as well as psychosocial influences, makes adolescence a particularly high risk period for girls to adopt sedentary habits. An inactive lifestyle during this period can result in augmented body fat and decreased cardiorespiratory fitness (Fairclough 2003).

2. 3. Evaluation of maximal oxygen consumption

There are essentially three types of testing for assessing aerobic performance from a single bout at a set intensity (Bosquet et al. 2002; Hopkins et al. 2001):

1. constant-work-test, sometimes referred as the time-trials – the subjects have to complete a set amount of work or a set distance (real or simulated) as quickly as possible.
Example: 1-mile run/walk test (George et al. 1993)
2. constant-duration-trials – similar to constant-work-trials, but the individual completes as much work or covers as much distance as possible in a set time.
Example: 12 minute run/walk test (Cooper 1968)
3. constant-power-tests – consist maintaining a constant power output to the point of exhaustion, defined by the inability to maintain power, speed or cadence
Example: multistage 20-meter shuttle run test (Leger et al. 1988).

2. 3. 1. Direct measurement of maximal oxygen consumption

The most precise assessments of $\dot{V}O_2\text{max}$ are performed directly in a laboratory setting using specialized equipment where highly motivated subjects perform a maximal graded test to exhaustion while using calorimetric analysis of expired gases. Multistage graded testing protocol gives reasonable time for ventilation, respiration and circulation to increase adequately (Bruce 1984; Dolgener et al. 1994; Grant et al. 1999; Greenhalgh et al. 2001; Larsen et al. 2002).

There are different possibilities between types of physical activity for testing aerobic working capacity: running or walking on a treadmill (TM), cycle ergometer, rowing ergometer and others. In general, researchers have found that $\dot{V}O_2\text{max}$ for combined arm-and-leg work is similar to that measured during leg work alone (Reybrouck et al. 1975; Nagle et al. 1984). Arm work alone typically elicits 65-75% of $\dot{V}O_2\text{max}$ values measured during maximal leg work (Reybrouck et al. 1975).

Higher values for $\dot{V}O_2\text{max}$ have been consistently observed during running TM exercise tests versus cycle ergometry and other types of testing, since TM exercise engages larger muscle mass. In case of children and adolescence is the difference between $\dot{V}O_2\text{max}$ values on a TM and cycle ergometer 8-12 % (Rowland 1993, 1996). Discipline-specific procedures and ergometers are recommended to evaluate maximal physiological responses of active and/or trained subjects (Riviera-Brown et al. 1998).

By direct measurement of oxygen consumption there are always some criteria that should be demonstrated so the variable achieved could be considered as the maximum of oxygen consumption. The most widely accepted criterion for achievement of $\dot{V}O_2\text{max}$ during graded exercise test is plateau in values of $\dot{V}O_2$ (mostly accepted as increase less than $2.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) as the work rate continues to increase (Davis 1995; Pettersen et al. 2001; Rowland et al. 1996).

However, since sometimes not all tested subjects actually demonstrate a plateau, there are some additional criteria also often used to defend the achievement of $\dot{V}O_2\text{max}$:

- ✧ Blood lactate concentration in the first 5 minutes of recovery $>8\text{mmol}\cdot\text{l}^{-1}$
- ✧ respiratory exchange ratio at test termination >1.00
- ✧ heart rate at test termination $>85\%$ of age-predicted ($220-\text{age}$) maximum. This criterion is the least rigorous because of the large variation in maximal heart rate at any given age (Davis 1995; Pettersen et al. 2001; Rowland et al. 1996).

In some cases are some of the subjective criteria like visible exhaustion, changes in safe moving technique and orally expressed exhaustion also considered as the signs of $\dot{V}O_2\text{max}$ achievement (Pettersen et al. 2001). The results of different studies (Rowland 1993; Pivarnik et al. 1995) indicate that in case the $\dot{V}O_2$ plateau is really reached, the reliability of direct $\dot{V}O_2\text{max}$ tests is extremely high: test-retest correlation coefficient $r=0.91-0.97$.

Optimal time for estimating $\dot{V}O_2\text{max}$ is 8-10 minutes, since after that it might be difficult to find motivation for continuing the test under metabolic acidosis, especially in young and/or untrained subjects (Brahler et al. 1995).

2. 3. 2. Indirect estimation of maximal oxygen consumption

Direct $\dot{V}O_2\text{max}$ testing in the laboratory must be done individually and monitored closely, the procedure is costly with regard to both time and money. Therefore is direct way of measuring maximal oxygen consumption not always practical in some situations, such as fitness testing or testing larger populations (Dolgener et al. 1994; Grant et al. 1999; Greenhalgh et al. 2001; Larsen et al. 2002). Because of these practical limitations of direct laboratory measures, numerous maximal or submaximal indirect field tests have been developed to estimate $\dot{V}O_2\text{max}$. The indirect field tests do not require special equipment or conditions, they are simple to administrate and it

is possible to test larger numbers of subjects at one time. Although the indirect tests are not as precise as direct measures, they are still considered acceptable predictors of $\dot{V}O_2\text{max}$ (Grant et al. 1999; Heil et al. 1995; Kline et al. 1987; Vehrs et al. 1998).

Valid and reliable estimates of $\dot{V}O_2\text{max}$ have been developed from the submaximal or maximal track jog/run with different duration and length (Cooper 1968; George et al. 1993; Larsen et al. 2002; Leger et al. 1988), there have also different bench stepping (Johnson & Siegel 1981), cycle ergometry (Åstrand & Rhyming 1954), treadmill (George et al. 1993), and walking (Donnelly et al. 1992; Kline et al. 1987; Oja et al. 1991) tests been used. There are even different nonexercise prediction equations introduced for estimating maximal aerobic power (Davis et al. 2002; Jackson et al. 1990; Matthews et al. 1999).

The repeatability of different field tests has been found to be high ($r=0.7-0.9$) (Dabonneville et al. 2003; Larsen et al. 2002; Roberts et al. 2002). The equations for estimating the level of aerobic power via field testing mostly include beside results of the concrete exercise test also several different characterizing variables – most often age, gender, body mass and heart rate.

The equations for estimating $\dot{V}O_2\text{max}$ via exercise testing that are based on heart rate measurement at one or more work loads have several limitations. First, by submaximal testing protocols - for any given rate of submaximal work, heart rate can vary independently of $\dot{V}O_2\text{max}$ due to for example emotional state or degree of excitement. Heart rate can also vary with elapsed time after the previous meal, total circulating hemoglobin, degree of hydration, and ambient temperature (Ward et al. 1995).

Inconsistent residuals with respect to prediction accuracy reported from cross-validation studies could arise from a variety of factors. These factors include possible problems with already mentioned factors affecting accuracy of heart rate; there are also limitations due too different methods of HR measurement from study to study.

Also, in some cases are limitations raised with subjects' inability to achieve a true $\dot{V}O_2\text{max}$ based on established criteria. Perhaps most important, the differences in test results may be developed because of the sample of inconsistencies in participant characteristics such as age, body mass, and initial fitness levels (Greenhalgh et al. 2001).

In case of maximal field tests depends the accuracy on a number of some different factors, including the willingness of subjects to undertake all-out exercise, their experience of testing technique and knowledge of an appropriate pace, the environmental conditions and the intersubject variance of maximum oxygen uptake (Shephard 1984).

Two of most common activities for indirect estimation of the aerobic power are running and walking. These protocols are easiest to administrate and therefore very appropriate by testing larger populations. There is still no agreement though, whether actually running or walking should be used and what distance or duration this test should have. However, the common opinion seems to be that running tests are more appropriate for younger subjects who have no problems whatsoever with health and it is also suitable for apparently healthy adults. Walking has more been used with older age groups or subjects who have some kind limitations for physical activity (Larsen et al. 2002).

There is a need for more reliable information about walking tests for healthy youngsters since some of the students do not like to run and so they are therefore not motivated to perform their best during a running fitness test. A walking field test could be more acceptable and produce more accurate results for these individuals (McSwegin et al. 1998). The information about walking tests could also be useful for the future in means of designing pediatric fitness programs and weight-control suggestions.

2. 3. 3. Field tests for predicting $\dot{V}O_2\text{max}$

Although there are different step and cycle ergometer tests been validated and recommended too, the most popular field tests are still by far based on running, especially in school-aged children and adolescents. Running tests are easy to administrate in groups and have provided good estimates of cardiovascular endurance (Garcia & Zakrajsek 2000). The meaningful length of the test for evaluation of cardiorespiratory fitness via running has been discussed for a long time, the main suggestion is that it should be at least 600 yards (~550 m) long, but under ideal circumstances, one mile or longer (Fernhall et al. 1996).

Most of the developed field tests are labeled as run/walk, but the intent has clearly been that the individual covers the distance as quickly as possible, which actually means running. True walking tests have generally been recommended and used for special populations as over-weight or obese, mentally impaired, cardiac or pulmonary patients (McSwegin et al. 1998). A short review about a few well-known running and walking field tests is given following.

◇ 12-minute field run/walk test (Cooper 1968)

One of the most known field tests for evaluating maximal oxygen consumption is the 12-minute performance test developed by Cooper (1968). There is measured track or course needed for testing, also the stopwatch. The subjects have to cover the longest possible distance in 12 minutes; total distance covered will be recorded. The equation for calculating maximal oxygen consumption using the results of this test is:

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 35.97\cdot\text{miles} - 11.29$$

Cooper (1968) reported correlation coefficient $r=0.90$ between run/walk distance and directly measured $\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1})$ in 115 males aged 17 to 25 years. However, some researches have found lower correlations by testing different populations - even $r=0.30$ between run/walk scores and $\dot{V}O_2\text{max}$ (Safrit et al. 1988).

✧ **1-mile (~1600 m) run/walk test (George et al. 1993)**

Several fitness test batteries, for example Physical Best Test Battery (AAHPERD 1988) and President's Challenge Test Battery (PCPFS 1987), have incorporated a 1-mile run/walk test (1-MRW) as a measure of aerobic power, of cardiovascular endurance. Only measured track and stopwatch are needed administer this test but many subjects can be tested simultaneously. The instruction for given test is to run at the fastest pace that could be maintained for the 1-mile distance (Sloniger et al. 1997). Factors that affect performance on 1-mile run/walk test include experience, motor efficiency, environmental conditions, and motivation.

Different $\dot{V}O_2\text{max}$ prediction equations are available for 1-MRW, for example George et al. (1993):

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 100.5 + 8.34\cdot\text{gender (female=0, male=1)} - 0.164\cdot\text{body weight (kg)} - 1.438\cdot\text{1-MRW time (min)} - 0.193\cdot\text{HR (bpm)},$$

where $r=0.87$, $\text{SEE}=3.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$

or Cureton et al. (1995):

$$\dot{V}O_2\text{peak (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = -8.41\cdot(1\text{-MRW}) + 0.34\cdot(1\text{-MRW})^2 + 0.21\cdot(\text{age}\cdot\text{gender (female=0, male=1)}) - 0.84\cdot(\text{BMI}) + 108.94,$$

where correlation coefficient between results of TM test and 1-MRW $r=0.72$, $\text{SEE}=4.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

✧ **1-mile walk test (Kline et al. 1987)**

Measured track or course and stopwatch, also heart rate monitor if possible, are needed for testing. The subjects have to cover 1 mile as fast as possible without running. Time elapsed to complete the walk should be recorded to the nearest second. The average heart rate of last 2 minutes should be recorded, or if there is no heart rate monitor is the heart rate measured immediately after the test via palpation (Kline 1987).

There are few different equations available for predicting $\dot{V}O_2\text{max}$ using 1-mile walk (1-MW). For example the equation by Kline et al. (1987) (correlation coefficient $r=0.8-0.9$ between directly measured $\dot{V}O_2\text{max}$ and prediction):

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 132.85 - 0.077\cdot\text{body mass (lb)} - 0.39\cdot\text{age (y)} + 6.32\cdot\text{gender (0=F, 1=M)} - 3.26\cdot\text{1-MW time (min)} - 0.16\cdot\text{HR (bpm)};$$

or Dolgener et al. (1994):

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 88.77 + 8.89\cdot\text{gender (female=0, male=1)} - 0.096\cdot\text{body mass} - 1.453\cdot\text{1-MW time} - 0.119\cdot\text{HR,}$$

where $r=0.69$, SEE $5.50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

✧ **2-km walk test (Oja et al. 1991)**

The subjects have to walk 2 km as fast as possible without risking their health. Walking time has to be recorded to the nearest second, also HR at the finish line.

Men: $\dot{V}O_2\text{max (l}\cdot\text{min}^{-1}) = 13.69 - 0.495\cdot\text{2-KMW time (min)} - 0.017\cdot\text{HR (bpm)} - 0.26\cdot\text{age (y)} + 0.035\cdot\text{BMI,}$
 where $r=0.82$; SEE= $0.51 \text{ l}\cdot\text{min}^{-1}$

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 184.9 - 4.65\cdot\text{2-KMW time (min)} - 0.22\cdot\text{HR (bpm)} - 0.26\cdot\text{age (y)} + 1.05\cdot\text{BMI,}$$

where $r=0.87$; SEE= $5.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

Women: $\dot{V}O_2\text{max (l}\cdot\text{min}^{-1}) = 6.31 - 0.202\cdot\text{2-KMW time (min)} - 0.008\cdot\text{HR (bpm)} - 0.014\cdot\text{age (y)} + 0.044\cdot\text{BMI}$
 ($r=0.81$; SEE= $0.20 \text{ l}\cdot\text{min}^{-1}$)

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 116.2 - 2.98\cdot\text{2-KMW time (min)} - 0.11\cdot\text{HR (bpm)} - 0.14\cdot\text{age (y)} + 0.39\cdot\text{BMI}$$

($r=0.85$; SEE= $3.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)

As seen in this short overview, the variability of field tests for indirect estimation of maximal oxygen consumption is wide. Further analysis is needed for more profound

information about different age groups since the validity of the test and equations is very population sensitive (Greenhalgh et al. 2001).

2.4 Maximal oxygen consumption of adolescent girls

Maximal oxygen consumption of adolescent girls has been measured on laboratory setting in in many studies. It has been stated that test-retest reliability coefficients for $\dot{V}O_{2\max}$, HRmax, and time to exhaustion in an incremental treadmill protocol are extremely reliable ($r=0.91-0.93$) in adolescent girls. The single-trial reliability values have also been very high ($r > 0.84$), so the subjects were able to achieve the $\dot{V}O_{2\max}$ level performing only one exercise test after a short familiarization with the equipment (Pivarnik et al. 1996). There have high correlations ($r=0.7-0.8$) been found between childrens and adolescents' directly measured absolute aerobic power and either body mass or stature. However by expressions of $\dot{V}O_{2\max}$ relatively to body mass are the correlations not as high (Armstrong & Welsman 1994).

Directly measured maximal oxygen consumption in Estonian different age populations was last comprehensively studied in 1982 by Pärnat and coauthors. Based on their data of $\dot{V}O_{2\max}$ tests on veloergometer, a standard scales for evaluating the level of $\dot{V}O_{2\max}$ was developed, but by now this scale is already probably somewhat out of date, though.

The data about anthropometrical characteristics and levels of $\dot{V}O_{2\max}$ from different studies concerning adolescent girls are shown in Table 1 (page 20).

It has been stated that the indirect tests meant for evaluating $\dot{V}O_{2\max}$ in adults tend to over- or underestimate the level of $\dot{V}O_{2\max}$ in younger populations. Thus, tests for

evaluating $\dot{V}O_2\text{max}$ in adults should before using in youth be adjusted to age and also level of physical fitness (Walker et al. 1999).

The most popular tests for indirect estimating the maximal oxygen consumption in school-aged individuals are performance-based distance runs: 1-MWR, 1.5 mile run, 12 minute run (Buono et al. 1991; Hunt et al. 2000; Rowland et al. 1999; Thomas et al. 1991). The boys have been tested more often; there is less information about the girls.

There is no comprehensive and critical data about using walking as a test mode on adolescent population. Since walking as a simple and accessible form of physical activity and is gaining more and more popularity in Estonia, should walking tests be analyzed more deeply for making informed decisions about their adequacy in assessing maximal oxygen consumption of different age groups.

Table 1. Anthropometrical characteristics and levels of $\dot{V}O_2$ max from different studies concerning adolescent girls

	n	Age (y)	Stature (cm)	Body mass (kg)	BMI (kg·m ²)	$\dot{V}O_2$ max (l·min ⁻¹)	$\dot{V}O_2$ max/kg (ml·kg ⁻¹ ·min ⁻¹)	State
Walker et al. 1999	35	14.9±1.1	163.8±6.3	60.6	22.7±6.6		33.9±4.3	USA
Cureton et al. 1997	7	15	162.5±4.7	51.2±5.2	19.4±2.3		46.2±8.3	USA
McMurray et al. 2002	~500	14-16	161-163	59.3-59.9	22.5-22.6	1.88-1.93 (c)	32.3-33.5 (c)	USA
Amarwaey et al. 2003	14	16±0.8	163.0±4.9	50.7±4.4	19.1		56.6±4.9	UK
Hunt et al. 2000	42	15±1.5	164.0±6.5	55.6±9.7	20.67		43.2±4.6	USA
Andersen et al. 1987	42	16	168.2±4.9	57.8±8.2	20.48	2.36±0.34 (c)	41.2±4.9 (c)	DAN
Eisenmann et al. 2001	50	14-16	163.1	50.9	19.16	2.8	55.8	USA
Eisenmann & Malina 2002		16	173	65.3	21.8	2.49	45.6	USA
Sheng et al. 1996	98	14-16	159.1	49.4	19.54	2.06	41,8	CHI
Armstrong & Welsman 2000	96	14-16				2.6-2.7		NED
Pettersen et al. 2001	27	14-16	164-165	54-56	19.9-20.0	2.5-2.6	46-47	NOR
Tomkinson et al. 2003	3302	14-15	164-166	55.4-56.5	20.7		39.2-39.7*	AUS
Janz et al. 1998	57	14-15	160.0±6.0	59.0±14.0	23.0±5.0	1.91±0.29 (c)	34.0±5.0 (c)	USA
Pärnat et al. 1982	134	14-15	164.4±0.6	54.8±0.8		1.755±0.031 (c)	32.3±0.5 (c)	EST
Mäll et al. 2003	11	14.8±0.3	167±5.6	56.8±7.0	20.4	1.88±0.46 (c)	34.0±5.9	EST

*predicted from Leger et al. 1988

c – cycle ergometry

3. PURPOSES OF THE STUDY

The reason for present investigation was the fact that information about studies which include data about maximal oxygen consumption and indirect field tests, investigated on larger groups of adolescent girls, is limited. Since the validity of the test and accompanying regression model is highly dependent on the group of subjects used for developing the complex (Greenhalgh et al. 2001), we selected one of the less investigated groups for getting more reliable information.

We hypothesized that the running tests will still be more suitable for this selected population, and the results of the walking tests have most likely no significant associations with the level of directly measured maximal oxygen consumption. Also we presumed that different anthropometrical characteristics (stature, body mass, body mass index, body fat %) are going to affect the results of the different exercise tests in a significant matter.

The purposes of this study were to:

1. determine most appropriate duration or distance of walking or running field test for indirect estimation of maximal oxygen consumption in 14-16-year old adolescent girls
2. develop a practical regression equation for indirect estimating of maximal oxygen consumption via selected field test
3. offer the norms for the estimation of maximal oxygen consumption with regard to Estonian standards.

4. METHODS

The main block of this study took place during the fall and winter of 2002/2003, test-retest reliability was tested in September of 2003. Testing procedures were conducted in the sport hall and laboratories of sport physiology of University of Tartu.

4. 1. Subjects

One hundred and two healthy adolescent girls of age 14-16 years from 5 schools in Tartu volunteered for this study. Additionally, the reliability of the field test which correlated most significantly with directly measured $\dot{V}O_2\text{max}$ was examined on another group (n=29) of 14-16-year old girls.

The subjects were recruited from compulsory physical education classes which took place twice a week. All the participants, their parents and teachers were informed about the purposes and contents of testing. This study was approved by the Medical Ethics Committee of the University of Tartu (Estonia). Written informed consent was given by each subject.

4. 2. Anthropometry and body composition

The stature was measured to the nearest 0.1 cm using the Martin's metal anthropometer and body mass (kg) with the participants dressed in light clothing was measured to the nearest 0.05 kg using medical scales (A&D Instruments Ltd, UK). Body mass index (BMI) was calculated ($\text{kg}\cdot\text{m}^{-2}$).

Body composition (body fat %, lean body mass) was assessed using bioelectrical impedance analysis (BIA) using Bodystat-500 (Isle of Man, UK). Four electrodes

were placed on the right hand and foot and BIA in ohms (Ω) was determined at the frequency of 50 kHz.

4. 3. Exercise tests

Each participant performed 3 exercise tests:

- ✧ 15-minute walking field test on an 150 m indoor track
- ✧ 15-minute running field test on an 150 m indoor track, and
- ✧ direct measurement of $\dot{V}O_2\text{max}$ on the running treadmill.

The participants were asked to avoid fatiguing the day before and on a day of the testing, also not to consume heavy meals for at least 3 hours before testing. The subjects wore comfortable sport clothes and shoes. There was a 10-15-minute warm-up (light running and stretching exercises) conducted before the exercise tests. Heart rate (HR) in beats per minute (bpm) was recorded every 5 seconds (Sporttester Polar Vantage NV, Kempele, Finland) during different tests. After completing the test were subjects asked to continue walking slowly for 3-5 minutes.

The time space between different tests was at least 48 hours, but not more than 96 hours. For avoiding possible effects of the circadian (within-day) rhythm, the laboratory and field tests were completed at the same time of day (afternoon).

The reliability of the chosen field test was tested under the same conditions twice, the time space between test and retest was one week. Test was conducted in 2 groups (14 and 15 persons).

4. 3. 1 Field tests

All participants were instructed individually before the field tests to walk (walking test) or run (running test) the longest possible distance in 15 minutes, but by doing that also consider the length of the test. By running test it was allowed to walk if the test could not be finished otherwise. The subjects were asked to practice pacing before testing to be sure they understood the character of the test. The tests were performed

in pairs – first we released one of two participants, the 2nd followed when the 1st reached the point of 75 meters. Test was terminated and reinstruction given if the first minutes of testing showed that subject did not understand the task correctly.

During testing we recorded:

1. walking or running time (± 1 s) every 500 meters (with stopwatch)
2. the distance covered (± 5 m) every minute (visually), and
3. HR (bmin) at one minute intervals beginning from the 5th minute (with Polar HR monitor).

Additionally, the participants were asked after completion of the 2nd field test if they would choose walking or running as a testing mode if it was optional in physical education classes.

4. 3. 2 Testing in laboratory.

Maximum oxygen uptake of the participants was measured on a running treadmill Technogym Runrace HC 1400 (Italy), using the Conconi protocol – track degree 0°, 1st speed 8 km·h⁻¹, speed increased 0.5 km·h⁻¹ every 200 meters until the volitional exhaustion (see more detailed Conconi protocol in Table 2 on page 25). The expired gas was sampled continuously breath-by-breath for the measurement of oxygen consumption (TrueMax 2400 Metabolic Measurement System, Parvo Medics, USA).

$\dot{V}O_2$ values were considered maximal, when two of the following three criteria were met:

1. $\dot{V}O_2$ plateau defined as a failure of oxygen uptake to increase by greater than 2.0 ml·kg⁻¹·min⁻¹ with treadmill speed increase
2. HR \geq 95% from the predicted individual maximum (formula 220-age)
3. Respiratory exchange ratio \geq 1.05 (Pettersen et al. 2001).

In addition the test-administrator subjectively evaluated as the characteristics of maximal performance if:

1. the exhaustion of the subject was expressed by her orally or with body language

2. the subject could not continue to run properly and safely because of exhaustion (Pettersen et al. 2001).

Participants who failed to meet the maximal level of $\dot{V}O_2$ were dropped from this study (n=4 (extra to 102 participants)).

✧ *Hereby would the author like to thank senior research fellow of the Chair of Exercise Physiology Kalle Karelson for the professional help in administrating running tests on the running treadmill.*

Table 2. Conconi protocol used for $\dot{V}O_2$ max testing on a TM

Time (Min)	Speed (km·h ⁻¹)	Tempo min·km ⁻¹)
1.00	8.0	7.30
1.45	8.5	7.00
3.09	9.0	6.36
4.28	9.5	6.18
5.45	10.0	6.00
6.56	10.5	5.42
8.30	11.0	5.24
9.10	11.5	5.12
10.12	12.0	5.00
11.12	12.5	4.48
12.10	13.0	4.36
13.05	13.5	4.24
14.00	14.0	4.12
14.51	14.5	4.06
15.40	15.0	4.00
16.30	15.5	3.48
17.14	16.0	3.42
18.00	16.5	3.36
18.43	17.0	3.30
19.25	17.5	3.24
20.07	18.0	3.18
20.47	18.5	3.12
21.25	19.0	3.06
22.03	19.5	3.00
22.40	20.0	3.00
23.17	20.5	2.54
23.51	21.0	2.48
24.25	21.5	2.42
25.00	22.0	2.42
25.32	22.5	2.36
26.00	22.5	2.36

4. 4 Statistical analysis

Standard statistical methods were used to calculate mean (M) and standard deviation (\pm SD). Pearson's correlation coefficients were calculated to determine the strength of the relationship between walking/running distance/time measured every 500 meters/every minute and directly measured $\dot{V}O_{2\max}$, also between anthropometrical measures and $\dot{V}O_{2\max}$ measured in laboratory. The statistical significance of differences between the anthropometrical characteristics groups, also different exercise tests results were analyzed via Student's t-test. The level of significance was set at $p \leq 0.05$.

The effects of different anthropometric measures and body composition parameters on $\dot{V}O_{2\max}$ measured in laboratory and 1500 m running field test were analyzed using stepwise multiple regression analysis.

Limits of agreement between directly measured and indirectly calculated (using the results of 1500 meter run) $\dot{V}O_{2\max}$ were derived following the procedures recommended by Bland and Altman (1986).

A standard scale for estimation of maximal oxygen consumption in adolescent Estonian girls was developed based on our data of directly measured $\dot{V}O_{2\max}$ values. We used the traditional scheme where value of one grade point is defined with the amplitude of 1 standard deviation.

The intra-class correlation coefficient (ICC) was calculated for analyzing the test-retest repeatability of 1500 m field run.

Statistical analysis was performed with SPSS release 10.0 for Windows.

5. RESULTS

Anthropometrical measures. The anthropometric characteristics and the results of treadmill test of the participants are presented in Table 3. The variance of participants' stature (20 cm), body mass (34 kg), BMI ($13.7 \text{ kg}\cdot\text{m}^{-2}$), lean body mass (26 kg) and fat % (20%) in our study was wide; the extreme measures were presented very rarely, though. For example there was only 1 subject with the BMI under $15 \text{ kg}\cdot\text{m}^{-2}$. Even bigger were the differences in results of the TM running test: $\dot{V}\text{O}_2\text{max}$ varied $2.3 \text{ l}\cdot\text{min}^{-1}$ and $34.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

Table 3. Anthropometric characteristics of the participants (n=102) and the results of treadmill test

	M±SD	Minimum	Maximum
Age (yr)	15.4±0.5	14.0	16.0
Stature (cm)	166.7±4.9	156.0	177.0
Body mass (kg)	55.6±6.5	38.0	71.7
Body mass index ($\text{kg}\cdot\text{m}^{-2}$)	20.0±2.2	13.4	27.1
Lean body mass (kg)	45.3±4.4	33.6	59.8
Body fat (%)	18.0±4.3	8.9	29.1
$\dot{V}\text{O}_2\text{max}$ ($\text{l}\cdot\text{min}^{-1}$)	2.21±0.46	1.32	3.65
$\dot{V}\text{O}_2\text{max}$ ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	39.35±6.92	20.43	54.82

Walking and running field tests. The results of the walking and running field tests are presented in Tables 4 (page 28) and 5 (page 29). The subjects performed the 15-minute walking test in rather even pace, the mean velocity was $2.0 \text{ m}\cdot\text{s}^{-1}$ ($7.3 \text{ km}\cdot\text{h}^{-1}$).

The difference between minimum and maximum walking test results was a little more than 700 m. As an example of different velocities shown during testing: the mean walking velocity of 11 subjects who reached 1650 m or less was $6.4 \text{ km}\cdot\text{h}^{-1}$; same characteristic for 11 subjects who reached more than 2000 meters was $8.2 \text{ km}\cdot\text{h}^{-1}$. The running test was also performed in even pace, the mean velocity was $2.9 \text{ m}\cdot\text{s}^{-1}$ ($10.3 \text{ km}\cdot\text{h}^{-1}$); the final results varied from 1950 m to 3420 m. The mean velocity of 8 participants who reached 3000 m or more was $12.4 \text{ km}\cdot\text{h}^{-1}$, at the same time the mean velocity of 8 girls who ran 2200 m or less was $8.3 \text{ km}\cdot\text{h}^{-1}$.

Table 4. The distance (m) covered during walking or running field tests (n=102) every minute beginning from 5th minute (M±SD)

Time	Walking	Running
5'	606.1±51.0	901.1±94.6
6'	726.1±59.6	1073.1±113.6
7'	847.4±67.4	1247.1±144.0
8'	968.6±76.5	1410.0±161.5
9'	1089.6±85.5	1580.0±182.7
10'	1209.7±95.6	1741.9±206.6
11'	1332.8±104.7	1908.5±221.6
12'	1452.6±111.7	2059.2±234.5
13'	1575.0±121.1	2234.2±250.9
14'	1698.8±129.4	2404.0±272.6
15'	1825.3±138.1	2582.3±291.4

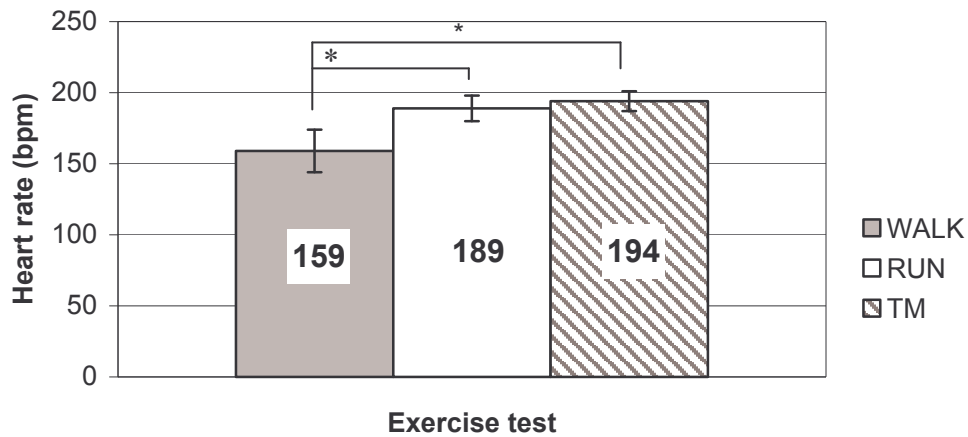
Table 5. Walking or running field test time (s) recorded every 500 meters

Distance	Walking		Running	
	n	M±SD	n	M±SD
500 m	102	255.1±36.1	102	165.4±23.4
1000 m	102	498.9±40.2	102	338.6±39.3
1500 m	102	748.5±58.7	102	521.7±62.9
2000 m	11	877.7±29.6	95	698.3±80.3
2500 m			58	816.7±55.3
3000 m			8	868.1±40.5

The mean HR was during walking and running field tests acceptably high – 159±15 bpm and 189±9 bpm, respectively and during treadmill test 194±7 bpm (see Figure 3 on page 30). The difference between mean HR of field running and treadmill test was not significant. The mean of maximal HR during treadmill test was 198±7 bpm.

The participants were asked after the completion of both field tests which of these two field tests they would have preferred as a testing mode – 63 subjects found walking field test more likeable and 39 said that they would rather run than walk.

Correlation analysis showed that absolute $\dot{V}O_{2\max}$ ($l \cdot \text{min}^{-1}$) had most significant correlation with body mass ($r=0.50$) and lean body mass ($r=0.52$), somewhat lower were the correlation coefficients with BMI, fat (kg) and stature ($r=0.37$, $r=0.28$ and $r=0.25$, respectively). No significant correlation was found between body fat % and directly measured maximal oxygen consumption. The relationships between relative $\dot{V}O_{2\max}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and different anthropometrical characteristics were not found to be statistically significant.



* statistically significant difference between variables ($p < 0.05$)

Figure 3. Mean values of heart rates during different exercise tests ($M \pm SD$)

The results of the walking field test had no significant correlations with directly measured maximal oxygen consumption. The highest correlation coefficient was for example between the results of walking test and $\dot{V}O_{2max}$ found at the point of 1000 meter walk – $r = -0.034$ with absolute and $r = -0.119$ with mass-relative $\dot{V}O_{2max}$ (but as said already - the correlation was not significant).

Stature, BMI and body fat % correlated significantly ($r \geq 0.26$ in all cases) with the results of 5th to 15th minute of walking test. The most important anthropometric variable for walking test was found to be body fat % (all correlation coefficients were higher than 0.33; the highest $r = 0.39$ on 14th minute). Body mass had no statistical importance during walking tests. The heart rate showed no logical correlation pattern with the results of neither walking nor running field test.

The results of the 15-minute running field test were most affected by body fat % (correlation coefficient values from $r = -0.29$ on the 8th minute to $r = -0.39$ on the 15th). The strongest correlation with both absolute and mass-relative directly measured maximal oxygen consumption had from the whole 15-minute test the result of 1500 m running field test ($r = -0.32$ with absolute and $r = -0.39$ with mass-relative $\dot{V}O_{2max}$). The other correlations between field running and laboratory tests reached more

significant level mostly by mass-relative $\dot{V}O_2\text{max}$ – for example $r=0.35$ at the points of 6, 9, 10, 14 and 15 minutes – but absolute $\dot{V}O_2\text{max}$ correlated in those cases with the field test results in a less significant matter ($r=0.21-0.24$).

The further analysis of 1500 m run showed that from measured anthropometrical characteristics were test results most affected by body fat % ($r=0.28$), but also stature ($r=0.22$). The correlations between 1500 m run and other anthropometrical characteristics were not significant. The main findings of stepwise multiple regression analysis showed that the combination of body mass and 1500 m run result explained 33.9% ($R^2 \times 100$) of absolute $\dot{V}O_2\text{max}$ ($\text{l} \cdot \text{min}^{-1}$). The relative $\dot{V}O_2\text{max}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and body fat % explained 19.8% ($R^2 \times 100$) of the 1500 m run time.

The developed equation for predicting maximal oxygen consumption from 1500 m running field test

$$\dot{V}O_2\text{max} (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = -0.04529 \cdot 1500\text{m run (s)} + 62.57$$

was found to be moderately acceptable – correlation coefficient $r=0.65$ between measured and predicted $\dot{V}O_2\text{max}$ ($\text{SEE}=6.79 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). The limits of agreement between directly measured and predicted $\dot{V}O_2\text{max} / \text{kg}$ are presented on the Figure 4.

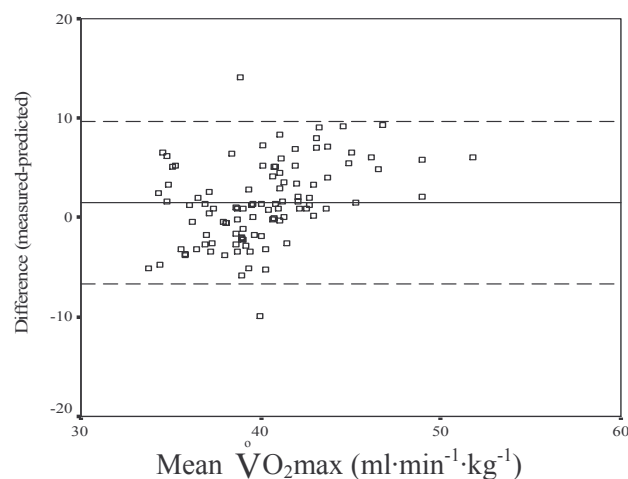


Figure 4. Magnitude of difference between directly measured and predicted $\dot{V}O_2\text{max}$

The standard scale based on our data for evaluating $\dot{V}O_2\text{max}$ in adolescent Estonian girls of age 14-16 is presented in Table 6.

Table 6. Standard scale for evaluating $\dot{V}O_2\text{max}$ in adolescent Estonian girls

	$\dot{V}O_2\text{max}$ ($l \cdot \text{min}^{-1}$)	$\dot{V}O_2\text{max}$ ($\text{ml} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$)
Weak	< 1.5	< 28.9
Satisfactory	1.5-1.9	29.0-35.9
Average	2.0-2.4	36.0-42.9
Good	2.5-2.9	43.0-49.9
Excellent	> 3.0	> 50.0

The anthropometrical data characterizing 29 participants of the reliability tests of 1500 m running field test are presented in Table 7. The stature, body mass and BMI of the participants in test-retest examination were similar to the same characteristics of 102 girls from the main part of this study, there were no significant differences ($p < 0.05$) between groups.

Table 7. Anthropometric characteristics of the participants of reliability test of 1500 m field run (n=29)

	M\pmSD	Minimum	Maximum
Age (y)	15.1 \pm 0.7	14.0	16.0
Stature (cm)	166.6 \pm 5.1	157.0	177.0
Body mass (kg)	54.4 \pm 6.8	43.2	66.9
Body mass index ($\text{kg} \cdot \text{m}^{-2}$)	19.6 \pm 1.8	16.4	22.6

The results of 1500 m field run test-retest are presented in Table 8. All 29 participants were able to complete the 1500 m run both times. Distance was mostly covered faster during retest; only 5 subjects were faster during 1st time of testing. The difference

between results of 1500 m run test-retest was not found to be significant ($p < 0.05$). The test-retest repeatability of 1500 m run was very high: ICC=0.93.

Table 8. 1500 m run test-retest results (n=29)

	M±SD	Minimum	Maximum
First test (s)	452.3±32.7	398	526
Second test (s)	442.9±37.1	392	522

6. DISCUSSION

As our results showed, the highest correlation coefficient ($r=-0.39$) was found between directly measured relative $\dot{V}O_2\text{max}$ ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and the time elapsed on 1500 m field run. The prediction equation developed for indirect estimation of maximal oxygen consumption in Estonian adolescent girls based on the results of the 1500 m field run, showed moderate accuracy ($r=0.65$). Results of the walking field test had no significant relationships with $\dot{V}O_2\text{max}$ measured in laboratory. The body fat % was found to be somewhat more important than the other anthropometrical characteristics by influencing the results of different running and walking tests, although the correlation coefficients were relatively low. We also found that the reliability of 1500 m running field test is high ($\text{ICC}=0.93$).

The closer analysis of anthropometrical characteristics of our subjects led to a conclusion that the mean stature of the participants of our study was similar (difference 1-3 cm) to data shown in earlier studies performed on Estonian schoolchildren (Pärnat et al. 1982; Loolaid et al. 2001; Veldre 2003), the situation was the same with body mass and BMI. Based on the results of the studies from other countries (Ekelund et al. 2001; Hunt et al. 2000; McMurray et al. 2002; Thomas et al. 1991) we found that our subjects were mostly 3-4 cm taller, body mass was similar to data from most of the earlier studies among adolescent girls in Scandinavia and USA (Ekelund et al. 2001; Hunt et al. 2000; Pettersen et al. 2001). Exceptions were studies of Eisenmann & Malina (2002) and McMurray et al. (2002), where subjects' body mass was 4-10 kg bigger. BMI of our subjects was in most cases a bit smaller than in studies mentioned before, as was the fat %.

The larger comparative data about directly measured $\dot{V}O_2\text{max}$ of adolescent girls in Estonia is more than 20 years old – Pärnat et al. (1982) reported about 20% lower mean values of maximal oxygen consumption in both absolute and relative dimension than shown in our study. The $\dot{V}O_2\text{max}$ of the participants in our study was according

to standard scale of Pärnat et al. (1982) between “good” and “very good” in both absolute and mass-relative $\dot{V}O_2\text{max}$. That however is not a firm sign of an increase of 20% in level of maximal aerobic power nowadays too, since in mentioned study was veloergometer test used for measuring of $\dot{V}O_2\text{max}$ and it is a well-known fact that as a rule there are 8-12 % lower values (Rowland 1996) of $\dot{V}O_2\text{max}$ demonstrated on a veloergometer compared to testing on a running treadmill, so rather high grades were expected even prior testing. But even fully considering the formentioned differences caused by methodical approaches, we still find that our subjects had higher level of maximal oxygen consumption then counterparts in the study of Pärnat et al. (1982).

The comparison of our data of maximal oxygen consumption with data of studies performed in the USA (Eisenmann & Malina 2002; McMurray et al. 2002) led to a conclusion that adolescent girls in Estonia have lower level of aerobic power. The level of $\dot{V}O_2\text{max}$ in both absolute and mass-relative terms in our study was somewhat lower than shown in studies about girls of same age in Norway and Netherlands (Pettersen 2001; Armstrong and Welsman 2000) also.

In the analysis of exercise field tests we concluded that the main velocity during our walking tests was acceptably high ($2.03 \text{ m}\cdot\text{min}^{-1}$), since the transition from walk to run is commonly referred to be at $2.23 \text{ m}\cdot\text{min}^{-1}$ (Tseh et al. 2002). Participants' mean HR during walking tests was comparing to running field ($159\pm 15 \text{ bpm}$ vs. $189\pm 9 \text{ bpm}$) or treadmill test ($194\pm 7 \text{ bpm}$) rather high too. But since the correlation analysis showed no meaningful relation between walking test results and $\dot{V}O_2\text{max}$, we still presume that walking was - even concerning the velocity, which reached almost running and acceptably high HR, which demonstrated the high level of effort - not intensive enough for getting more remarkable correlations to directly measured maximal oxygen consumption.

The lower intensity of the walking test can partly be explained with the unfamiliar type of the test – walking is common in everyday life, but it is rather unaccustomed as an exercise mode in maximum pace. Therefore it was probably difficult for the participants to find the accomplishable pace even after the familiarization with the walking test.

It should for sure be taken notice, that our subjects preferred walking as a testing mode to running. Therefore should walking tests be investigated further, since adolescence is a very important life phase in forming an opinion about physical activity per se and pleasant testing modes provide more reliable results by giving less negative emotions.

The walking and running tests in our study were performed faster than in earlier similar investigations (Hunt et al. 2000; McSwegin 1998; Thomas et al. 1991; Weiller et al. 1994), although the comparison is here somewhat questionable due speed limitations in some of these studies.

As shown in correlation analysis, was the highest found connection between lean body mass (kg) and absolute $\dot{V}O_2\text{max}$, this agrees well with the common knowledge that the absolute aerobic power depends on the total rate of working muscles (Åstrand & Rodahl 1986).

The results of our correlation analysis concerning the field testing were on one hand predictable, since we did assume that walking test will not be strenuous enough for predicting level of $\dot{V}O_2\text{max}$. On the other hand, it was surprising that correlation coefficients between results of treadmill and field running tests were not greater, since different running field tests have been found to have rather high correlation coefficients with $\dot{V}O_2\text{max}$ (Rowland et al. 1999; Larsen et al. 2002; Grant et al. 1999).

One reason of this rather weak connection between results of the running field test and directly measured $\dot{V}O_2\text{max}$ could most likely be the length of our running field test. Some of the participants (especially the ones with lower level of physical fitness) probably chose somewhat lower running velocity so they could by all means run all 15 minutes of the test without walking or even quitting. It could be assumed though, that the motivation of majority of our subjects for giving the maximal effort during testing was high, since the participants of our study were volunteers and therefore probably more interested in to trying show good results then for example regular students in physical education classes might be.

Anyway, as the analysis of different running field tests showed, were correlation coefficients with $\dot{V}O_2\text{max}$ significant in many cases, and as typical for weight-bearing activities were these connections higher in mass-relative terms.

The fact that HR showed no logical patterns with anthropometrical or field test characteristics in correlation analysis was a little surprising, but quite explainable with the dependability of HR on mood, excitement and other personal characteristics mentioned in literature review. These personal characteristics affecting HR are unlike testing environment unfortunately rather complicated to control.

It is known that $\dot{V}O_2\text{max}$ relative to body mass plays a limited role in determining the endurance running capacity, as does body fat (Rowland et al. 1999). Our regression analysis showed the same baseline, although body fat % and directly measured $\dot{V}O_2\text{max}$ relative to body size explained only 20% ($R^2 \times 100$) of 1500 m running field test results, earlier studies have shown even 60% (Rowland et al. 1999). The rather low relative importance of body fat % and $\dot{V}O_2\text{max}$ for 1500 m run which was shown in regression analysis, was probably caused by the small differences in participants' body fat %. Our group was actually rather homogeneous although the extremities of body fat % values differed about 20% - but by that for example only 3 participants had body fat % lower than 10 or higher than 25. So it is possible that this subjects'

similarity of body composition characteristics could partly explain lower significance of body fat in determining exercise test results then demonstrated earlier.

The accuracy of developed equation for predicting mass-relative $\dot{V}O_2\text{max}$ from 1500 m running field test was moderately satisfying ($r=0.65$) for a field test. The difference between values of predicted and directly measured maximal oxygen consumption was not bigger than $5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for majority of the participants. This fact is rather satisfying, since SEE for prediction of $\dot{V}O_2\text{max}$ in the range of $3\text{-}6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ is both typical and acceptable for testing children and adolescents (McSwegin et al. 1998).

Our formula tended to rather underestimate the level of maximal aerobic power in case the directly measured $\dot{V}O_2\text{max}/\text{kg}$ was relatively high and overestimate the level of maximal aerobic power in less fit subjects. It is a common knowledge though, that prediction formulas tend to be more accurate for subjects who have results closer to the mean for a given variable, comparing to subjects who have more extreme values (Larsen et al. 2002).

The standard scale for evaluating the level of maximal oxygen consumption, developed based on our data has higher demands for subjects than analogical standard scale introduced by Pärnat et al. (1982). Basically it means that a certain level of maximal oxygen consumption would be evaluated with one step lower grade in our scale than in one of Pärnat et al. (1982). By evaluation of maximal oxygen consumption it would be appropriate to take both of these standard scales into consideration in accordance to testing methods, though.

By performing the reliability analysis of 1500 m running field test was one of our first concerns to compare the anthropometrical characteristics of the subjects with these 102 girls who participated in first part of the study. Statistical analysis showed no significant differences between the groups, so the results of test-retest can be taken seriously, since test population is one of the most important factors, affecting the results.

The reliability study for 1500 m field running test gave us good results, since test-retest intraclass correlation coefficient has in different literature sources been thought to be meaningful when it is equal to or higher than 0.8 (Rowland 1996; Dabonneville et al. 2003) and the ICC of the 1500 m running field test in our study was $r=0.93$. That demonstrates very well the high reliability of the 1500 m running field test. As an example - there was an $ICC=0.89$ found for the popular 20-meter shuttle run test in the study of Léger et al. (1988). The rather wide amplitude of test results and anthropometrical characteristics of participants lets us even more presume that the reliability of 1500 m running test is acceptably high.

It has been stated that by field testing there are 4 groups of variables that affect the results: subjects, test administrators, weather and other ambient variables (Dabonnenville et al. 2003). In our study were testing procedures conducted by the same persons, environmental conditions were the same too. So we can state that the testing environment was controlled in highest possible way during 1st and 2nd test and the subjects were the only ones influencing the results.

High motivation is also probably one of the reasons of having comparatively small differences in times of test and retest. The results of 2 tests differed more than 20 seconds in 4 subjects in our study, but in their case was the big difference apparently caused by the wrong pacing judgments during 1st test. More than a half of our participants were able to find the suitable pace for both tests and so differed the times of their test-retest only by 3-6 seconds. The results of our study are even more satisfying in comparison with Dollman et al. (2002) which reported the differences as big as 37-48 s in results of 1-MRW times in Scottish schoolgirls of age 12-15 years. Apparently high motivation of our subjects can also be characterized with the fact that we saw only 8 cases of walking stride before the end of the test during 58 performed tests.

The physical education experience promotes the attitudes towards physical activity after compulsory education and trough the lifespan (Sallis & McKenzie 1991; Telama et al. 1996; Trudeau et al. 1999), so special attention should be turned on the adequacy of fitness tests used in classes and during training, since the main task is after all to

give positive emotions through physical activity. As our results showed, is the most appropriate field test for evaluation of maximal oxygen consumption 1500 m running test, our results of popular 12-minute run (Cooper 1968) had lower correlation with directly measured $\dot{V}O_2\text{max}$.

So – although for example in 12-minute exercise test most of the participants would probably cover more than 1500 m and thereby a better effect of exercise would be given, the shorter distance can offer more convenience to the participants. This applies especially to subjects with lower level of physical fitness – they are less frightened of the length of the test and so they will not gain negative emotions towards physical education classes. That however helps all in all to form a positive attitude towards physical activity in adult life as well, since as it is known, being forced to do unpleasant exercises has potential negative consequences for later activity (Taylor et al. 1999).

The 1500 m running field test involves activity that is familiar to the most of individuals, so it can be safely tested simultaneously without long familiarization period. This test is as simple to administrate as for example the 12-minute run which is frequently used now, since 1500 m run too requires minimal equipment – measured track and stopwatch. Plus the participants end the test at the same location and only one parameter has to be monitored, so actually it makes the registration of results even easier. The result of 1500 m run can both characterize the level of physical performance and be used for indirect determination of maximal oxygen consumption in field conditions.

Commonly acknowledged main characteristics for any exercise test are physiological accuracy, feasibility and safety (Laukkanen 1993). As discussed previously, 1500 m running field test is comparatively satisfying in all these characteristics. Of course there are probably some limitations in interpreting the results of our study in everyday physical education classes. For example the test results of 1500 m run may not be as good as they were in our study, since after all - we had time to explain the idea of the study to each and every subject personally and also for correcting the different mistakes made during testing. Therefore were the participants of our study probably

much more motivated than the regular pupils in the school might be. In physical education classes have teachers mostly no time for such personal approach as we did in our study.

Since motivation is one of the most important factors affecting the results of different field tests, we presume that by interpreting data of 1500 m running field test conducted in usual physical education classes, the dimension of underestimation of maximal oxygen consumption might be somewhat wider. For example when we graded our 1500 m running field test-retest group based on our $\dot{V}O_2\text{max}$ prediction formula, were 18 subjects graded as average and 11 as good, but most likely was the actual $\dot{V}O_2\text{max}$ somewhat higher.

In conclusion we presume that 1500 m running field test is a possible alternative for assessing the level of maximal oxygen consumption in Estonian adolescent girls. Also that walking field tests give no reliable information about the level of aerobic working capacity of the investigated population.

7. CONCLUSIONS

The results of our study led to following conclusions:

1. most reliable test in field conditions for estimating the level of maximal oxygen consumption in 14-16-year old Estonian adolescent girls is the 1500 m run. The reliability of 1500 m running field test is high;
2. walking field tests are not suitable for evaluating the level of maximal oxygen consumption in 14-16-year old Estonian adolescent girls;
3. developed equation based on the results of 1500 m running field test

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = -0.04529\cdot 1500\text{m run (s)} + 62.57$$

predicts reasonably the level of maximal oxygen consumption in 14-16-year old Estonian adolescent girls.

8. REFERENCES

1. Amarwaey OA, AM Jones, and K Tolfrey. Physiological correlates with endurance running performance in trained adolescents. *Med Sci Sports Exerc.* 35: 480-487, 2003.
2. American Alliance for Health, Physical Education, Recreation and Dance. *Physical Best.* VA: Reston, 1988.
3. Andersen LB, P Henckel, and B Saltin. Maximal oxygen uptakes in Danish adolescents 16-19 years of age. *Eur J Appl Physiol.* 56: 74-82, 1987.
4. Anderson GS. The 1600-m run and multistage 20-m shuttle run as predictive tests of aerobic working capacity in children. *Ped Ex Sci.* 4: 312-318, 1992.
5. Armstrong N, and JR Welsman. Assessment and interpretation of aerobic fitness in children and adolescents. *Exerc & Sports Sci Rev.* 88: 435-476, 1994.
6. Armstrong N, JR Welsman, and BJ Kirby. Peak oxygen uptake and maturation in 12-yr olds. *Med Sci Sports Exerc.* 30: 165-169, 1998.
7. Armstrong N, and JR Welsman. Development of aerobic fitness during childhood and adolescence. *Ped Ex Sci.* 12: 128-149, 2000.
8. Armstrong N, and JR Welsman. Peak oxygen uptake in relation to growth and maturation in 11- to 17-year-old humans. *Eur J Appl Physiol.* 85: 546-551, 2001.
9. Åstrand P-O, and I Ryhming. A nomogram for calculating aerobic capacity (physical fitness) from pulse rate during submaximal work. *J Appl Physiol.* 7:218-221, 1954.
10. Åstrand P-O, and K Rodahl. *Textbook of Work Physiology.* 3rd Ed., NY: McGraw Hill, 1986.
11. Aulik I. *Evaluation of Physical Working Capacity in Clinics and in Sports.* Moscow: Medicine, 1990 (in Russian).
12. Bassett DR Jr, and ET Howley. Maximal oxygen uptake: classical versus contemporary viewpoints. *Med Sci Sports Exerc.* 29: 591-603, 1997.
13. Bassett DR Jr, and ET Howley. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Exerc Sports.* 32: 70-84, 2000.

14. Bergh U, B Sjödin, A Forsberg, and J Svedenhag. The relationship between body mass and oxygen uptake during running in human. *Med Sci Sports Exerc.* 23: 205-211, 1991.
15. Bland JM, and DG Altman. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet.* 1: 307-310, 1986.
16. Bosquet L, L Leger, and P Legros. Methods to determine aerobic endurance. *Sports Med.* 32: 675-700, 2002.
17. Brahler CJ, and SE Blank. VersaClimbing elicits higher $\dot{V}O_2$ max than does treadmill running or rowing ergometry. *Med Sci Sports Exerc.* 27:249-254, 1995.
18. Bruce RA. Exercise, functional aerobic capacity, and aging – another viewpoint. *Med Sci Sport Exerc.* 16: 8-13, 1984.
19. Buono MJ, JJ Roby, FG Micale, JF Sallis, and WE Shepard. Validity and reliability of predicting maximum oxygen uptake via field tests in children and adolescents. *Ped Ex Sci.* 3: 250-255, 1991.
20. Cooper KH. A means of assessing maximal oxygen intake. *JAMA.* 203:135-138, 1968.
21. Corbin CB. What every physical educator should know about teaching physical activity and fitness. *Teach El Phys Ed.* 15: 7-9, 2004.
22. Cureton KJ, MA Sloniger, JP O'Bannon, DM Black, and WP McCormack. A generalized equation for prediction of $\dot{V}O_2$ peak from 1-mile run/walk performance. *Med Sci Sports Exerc.* 27: 445-451, 1995.
23. Cureton KJ, MA Sloniger, DM Black, WP McCormack, and DA Rowe. Metabolic determinants of the age-related improvement in one-mile run/walk performance in youth. *Med Sci Sports Exerc.* 29: 259-267, 1997.
24. Dabonneville M, P Berthon, P Vaslin, and N Fellmann. The 5 min running field test: test and retest reliability on trained men and women. *Eur J Appl Physiol.* 88: 353-360, 2003.
25. Davis JA. Direct determination of aerobic power. *In: Physiological Assessment of Human Fitness.* Maud PJ, and C Foster (Eds). Champaign, Ill: Human Kinetics, 9-18, 1995.

26. Davis JA, TW Storer, VJ Caiozzo, and PH Pham. Lower reference limit for maximal oxygen uptake in men and women. *Clin Physiol & Func Im.* 22: 332-338, 2002.
27. Dolgener FA, LD Hensley, JJ Marsh, and JK Fjestul. Validation of the Rockport Fitness Walking Test in college males and females. *Res Q Exerc Sport.* 65:152-158, 1994.
28. Dollman J, K Norton, and G Tucker. Anthropometry, fitness and physical activity of urban and rural South Australian children. *Ped Ex Sci.* 14: 297-312, 2002.
29. Donnelly JE, DJ Jacobsen, JM Jakicic, J Whatley, S Gunderson, WJ Gillespie, GL Blackburn, and ZV Tran. Estimation peak of oxygen consumption from a sub-maximal half mile walk in obese females. *Int J Obes Relat Metab Disord.* 16:585-589, 1992.
30. Eisenmann JC, JM Pivarnik, and RM Malina. Scaling peak $\dot{V}O_2$ to body mass in young male and female distance runners. *J Appl Physiol.* 90: 2172-2180, 2001.
31. Eisenmann JC, and RM Malina. Secular trend in peak oxygen consumption among United States youth in 20th century. *Am J Hum Biol.* 14: 699-706, 2002.
32. Ekelund U, E Poortvliet, A Nilsson, A Yngve, A Holmberg, and M Sjöström. Physical activity in relation to aerobic fitness and body fat in 14- to 15-year-old boys and girls. *Eur J Appl Physiol.* 85: 195-201, 2001.
33. Fairclough SJ. Girls' physical activity during high school physical education: influences of body composition and cardiorespiratory fitness. *J Teach Phys Ed.* 22: 382-395, 2003.
34. Fernhall B, K Pittetti, N Stubbs, and L Stadler Jr. Validity and reliability if the 1/2 – mile run-walk as an indicator of aerobic fitness in children with mental retardation. *Ped Ex Sci.* 8: 130-142, 1996.
35. Garcia AW, and JS Zakrajsek. Evaluation of the Canadian Aerobic Fitness test with 10 to 15-year-old children. *Ped Ex Sci.* 12: 300-311, 2000.

36. George JD, P Vehrs, PE Allsen, GW Fellingham, and AG Fisher. $\dot{V}O_2$ max estimation from a submaximal 1-mile track jog for fit college-age individuals. *Med Sci Sport Exerc.* 25: 401-406, 1993.
37. Grant JA, AN Joseph, and PD Campagna. The prediction of $\dot{V}O_2$ max: a comparison of 7 indirect tests of aerobic power. *J Strength Cond Res.* 13:346-352, 1999.
38. Greenhalgh HA, JD George, and RL Hager. Cross-validation of a quarter-mile walk test using two $\dot{V}O_2$ max models. *Meas Phys Ed Exerc Sci.* 5: 139-151, 2001.
39. Heil DP, PS Freedson, LE Ahlquist, J Price, and JM Rippe. Nonexercise regression models to estimate peak oxygen consumption. *Med Sci Sports Exerc.* 27: 599-606, 1995.
40. Hopkins WG, EJ Schabert, and JA Hawley. Reliability of power in physical performance tests. *Sports Med.* 31: 211-234, 2001.
41. Howley ET, DR Bassett Jr, and HG Welch. Criteria for maximal oxygen uptake: review and commentary. *Med Sci Sports Exerc.* 27: 1292-1301, 1995.
42. Huerta M, I Grotto, S Shelma, I Ashkenazi, O Shpilberg, and JD Kark. Cycle ergometry estimation of physical fitness among Israeli soldiers. *Mil Med.* 169: 217-220, 2004.
43. Hunt BR, JD George, PR Vehrs, A Garth Fisher, and G Fellingham. Validity of a submaximal 1-mile track jog test in predicting $\dot{V}O_2$ max in fit teenagers. *Ped Ex Sci.* 12: 80-90, 2000.
44. Jackson AS, SN Blair, MS Mahar, LT Weir, and JE Stuterville. Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc.* 22: 863-870, 1990.
45. Janz KF, TL Burns, JD Witt, and LT Mahoney. Longitudinal analysis of scaling $\dot{V}O_2$ for differences in body size during puberty: the Muscatine study. *Med Sci Sports Exerc.* 30:1436-1444, 1998.
46. Jensen K, L Johansen, and NH Secher. Influence of body mass on maximal oxygen uptake: effect of sample size. *Eur J Appl Physiol.* 84: 201-205, 2001.

47. Johnson J, and D Siegel. The use of selected submaximal step tests in predicting change in the maximal oxygen intake of college women. *J Sports Med Phys Fit.* 21: 259-264, 1981.
48. Keating XD. The current often implemented fitness tests in physical education programs: problems and future directions. *Quest.* 54: 141-160, 2003.
49. Kemper HCG, R Verschuur, and L de Mey. Longitudinal changes of aerobic fitness in youth ages 12 to 23. *Ped Ex Sci.* 1: 257-270, 1989.
50. Kent M. *Oxford Dictionary of Sport Science & Medicine.* 2nd edition. Oxford University Press, 1998.
51. Kline GM, JP Porcari, R Hintermeister, PS Freedson, A Ward, RF McCarron, J Ross, and JM Rippe. Estimation of $\dot{V}O_2\text{max}$ from a one-mile track walk, gender, age, and body weight. *Med Sci Sport Exerc.* 19:253-259, 1987.
52. Laaneots L, K Karelson, and A Viru. Relation of aerobic capacity to the stage of sexual maturation in girls. *Biol Sport.* 13: 137-144, 1996.
53. Larsen GE, JD George, JL Alexander, GW Fellingham, SG Aldana, and AC Parcell. Prediction of maximum oxygen consumption from walking, jogging, or running. *Res Q Exerc Sport.* 73:66-72, 2002.
54. Latin RW, and BA Elias. Predictions of maximum oxygen uptake from treadmill walking and running. *J Sports Med Phys Fit.* 33:34-39, 1993.
55. Laukkanen R. Development and evaluation of a 2-km walking test for assessing maximal aerobic power of adults in field conditions. Doctoral dissertation, University of Kuopio, Kuopio, Finland, 1993.
56. Leger LA, D Mercier, C Gadoury, and J Lambert. The multistage 20-metre shuttle run test for aerobic fitness. *J Sports Sci.* 6: 93-101, 1988.
57. Loolaid K, Kaarma H, Loolaid V, and Saluste L. 15-16aastaste Tartu tütarlaste antropomeetriliste andmete analüüs. In: *Eesti Antropomeetriaregistri aastaraamat.* 149-158, 2001 (in Estonian).
58. Malina RM, and C. Bouchard. *Growth, Maturation and Physical Activity.* Champaign, Ill: Human Kinetics, 1991.
59. Mäll M, K Karelson, M Viru, and A-M Viru. Reduction of relative maximum oxygen uptake in girls of advanced sexual maturation. *Kinesiology.* 35: 131-134, 2003.

60. Matthews CE, PD Heil, PS Freedson, and H Pastides. Classification of cardiorespiratory fitness without exercise testing. *Med Sci Sports Exerc.* 31: 486-493, 1999.
61. McMurray RG, JS Harrell, CB Bradley, S Deng, and SI Bangdiwala. Predicted maximal aerobic power in youth is related to age, gender, and ethnicity. *Med Sci Sports Exerc.* 34: 145-151, 2002.
62. McSwegin PJ, SA Plowman, GM Wolff, and GL Guttenberg. The validity of a one-mile walk test for high school individuals. *Meas Phys Ed Exerc Sci.* 2: 47-63, 1998.
63. Nagle F, J Richie, and M Giese. $\dot{V}O_2$ max responses in separate and combined arm and leg air-braked ergometer exercise. *Med Sci Sports Exerc.* 16: 563-566, 1984.
64. Oja P, R Laukkanen, M Pasanen, T Tyry, and I Vuori. A 2-km walking test for assessing the cardiorespiratory fitness of healthy adults. *Int J Sports Med.* 12: 356-362, 1991.
65. Pärnat J, A Viru, T Matsin, T Jürimäe, and E Seppet. Hapniku tarbimise maksimumi ja välise hingamise näitajate ealine dünaamika Eesti NSV elanikel. *Nõukogude Eesti Tervishoid.* 4: 252-236, 1982 (in Estonian).
66. Pate RR. Physical activity in children and adolescents. In: *Physical Activity and Cardiovascular Health. A National Consensus.* Leon AS (Ed). Champaign, Ill: Human Kinetics, 210-217, 1997.
67. Pate RR, and A Kriska. Physiological basis of the sex difference in cardiorespiratory endurance. *Sports Med.* 2: 87-98, 1984.
68. Pettersen SA, PM Fredriksen, and F Ingjer. The correlation between peak oxygen uptake ($\dot{V}O_{2peak}$) and running performance in children and adolescents. Aspects of different units. *Scand J Med Sci Sports.* 11: 223-228, 2001.
69. Pivarnik JM, MC Dwyer, and MA Lauderdale. The reliability of aerobic working capacity ($\dot{V}O_2$ max) testing in adolescent girls. *Res Q Exerc Sport.* 67: 345-348, 1996.
70. President's Council on Physical Fitness and Sports. *President's Challenge Physical Fitness Program.* Washington, DC: 1987.

71. Reybrouck T, GF Heigenhauser, and JA Faulkner. Limitations to maximum oxygen uptake in arm, leg, and combined arm-leg ergometry. *J Appl Physiol.* 38: 774-779, 1975.
72. Riviera-Brown AM, and WR Frontera. Achievement of plateau and reliability of $\dot{V}O_2$ max in trained adolescents tested with different ergometers. *Ped Ex Sci.* 10: 164-175, 1998.
73. Roberts DE, DM Pober, KJ McInnis, JM Rippe, and PS Freedson. A review of selected submaximal walking tests: good predictors of aerobic capacity and functional fitness? *Clin Ex Physiol.* 4: 68-74, 2002.
74. Rogers DM, KR Turley, KI Kujawa, KM Harper, and JH Wilmore. Allometric scaling factors for oxygen uptake during exercise in children. *Ped Ex Sci.* 7: 12-25.
75. Rowell LB. *Human Circulation: Regulation During Physical Stress.* NY: Oxford University Press, 1986.
76. Rowland TW. Aerobic exercise protocols. In: *Pediatric Laboratory Exercise Testing.* Rowland TW (Ed). Champaign, Ill: Human Kinetics, 20-41, 1993.
77. Rowland TW. *Developmental Exercise Physiology.* Champaign, Ill: Human Kinetics, 27-47, 1996.
78. Rowland T, P Vanderburgh, and L Cunnigham. Body size and the growth of maximal aerobic power in children: a longitudinal analysis. *Ped Ex Sci.* 9: 262-274, 1997.
79. Rowland T, G Kline, D Goff, L Martel, and L Ferrone. One-mile run performance and cardiovascular fitness in children. *Arch Pediatr Adolesc Med.* 153: 845-849, 1999.
80. Safrit MJ, M Glauca Costa, LM Hooper, P Patterson, and SA Ehlert. The validity generalization of distance run tests. *Can J Sport Sci.* 13: 188-196, 1988.
81. Sallis JF. Epidemiology of physical activity and fitness in children and adolescents. *Crit Rev Food Sci Nutr.* 33: 403-408, 1993.
82. Sallis JF, and TL McKenzie. Physical education's role in public health. *Res Q Exerc Sport.* 62: 124-137, 1991.
83. Seefeldt V, RM Malina, and MA Clark. Factors affecting levels of physical activity in adults. *Sports Med.* 32: 143-168, 2002.
84. Sheng WL, JC Ye, ZY Qing, M Živicnjak, SL Xin, and GM Jie. Maximal aerobic power in children and adolescents of Beijing, China. *Am J Hum Biol.* 8: 497-503, 1996.

85. Shephard RJ. Tests of maximum oxygen uptake. *Sports Med.* 2: 99-124, 1984.
86. Sloniger MA, KJ Cureton, and PJ O'Bannon. One-mile run-walk performance in young men and women: role of anaerobic metabolism. *Can J Appl Physiol.* 22: 337-350, 1997.
87. Taylor WC, SN Blair, SS Cummings, CC Wun, and RM Malina. Childhood and adolescent activity patterns and adult physical activity. *Med Sci Sports Exerc.* 31: 118-123, 1999.
88. Telama R, E Leskinen, and X Yang. Stability of habitual physical activity and sport participation: a longitudinal tracking study. *Scand J Med Sci Sports.* 6: 371-378, 1996.
89. Thomas JR, JK Nelson, and G Church. A developmental analysis of gender differences in health related physical fitness. *Ped Ex Sci.* 3: 28-42, 1991.
90. Tomkinson GR, TS Olds, and J Gulbin. Secular trends in physical performance of Australian children. *J Sports Med Phys Fit.* 43: 90-98, 2003.
91. Trudeau F, L Laurencelle, J Tremblay, M Rajic, and RJ Shephard. Daily primary school education: effects on physical activity during adult life. *Med Sci Sports Exerc.* 31: 111-117, 1999.
92. Tseh W, J Bennett, JL Caputo, and DW Morgan. Comparison between preferred and energetically optimal transition speeds in adolescents. *Eur J Appl Physiol.* 88: 117-121, 2002.
93. US Department of Health and Human Services. Physical activity and health: a report of surgeon general. Atlanta, GA: US Department of Health and Human Services, Centre for Chronic Disease Prevention and Health Promotion, 1996.
94. Vehrs P, JD George, and GW Fellingham. Prediction of $\dot{V}O_2$ max before, during, and after 16 weeks of endurance training. *Res Q Exerc Sport.* 69: 297-303, 1998.
95. Veldre G. Somatic status of 12-15-year-old Tartu schoolchildren. Doctoral dissertation, University of Tartu, Tartu, Estonia, 2003.
96. Walker JL, AS Murray, JR Jackson, and TJ Michaud. The energy cost of horizontal walking and running in adolescents. *Med Sci Sports Exerc.* 31:311-322, 1999.

97. Ward A, CB Ebbeling, and LE Ahlquist. Indirect methods for estimation of aerobic power. *In: Physiological Assessment of Human Fitness*. Maud PJ, and C Foster (Eds). Champaign, Ill: Human Kinetics, 37-56, 1995.
98. Wei M, JB Kampert, CE Barlow, MZ Nichaman, LW Gibbons, RS Paffenbarger Jr, and SN Blair. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *JAMA*. 282: 1547-1553, 1999.
99. Weiller KW, AW Jackson, and RD Meyer. 1-mile run performance and body mass index in Hispanic youth: passing rates for the Fitnessgram. *Ped Ex Sci*. 3: 267-274, 1994.
100. Welsman JR, and N Armstrong. Longitudinal changes in submaximal oxygen uptake in 11- to 13-year-olds. *J Sport Sci*. 18: 183-189, 2000.

9. SUMMARY (in estonian)

Kehaline töövõime kui üks tervise aluskomponente on olnud huviobjektiks kõige erinevamatel uuringutes. Kehaline töövõime on väga kompleksne ja kõigi tema komponentide hindamine annaks küll täpset informatsiooni, kuid oleks samas keerukas ning seetõttu on püütud leida lihtsustatud võimalusi kehalise töövõime kohta informatsiooni saamiseks. Üks üldisemaid kehalise töövõime näitajaid on aeroobne töövõime, mis iseloomustab organismi võimet varustada organeid ja lihaseid töö ajal hapnikuga. Aeroobse töövõime hindamisel on enamasti parimaks iseloomustavaks üksiknäitajaks peetud maksimaalse hapnikutarbimise ($\dot{V}O_2\text{max}$) võimet, mida kõige täpsemini saab hinnata laboratoorsel teel, kasutades astmelist koormustesti. Kuna $\dot{V}O_2\text{max}$ otsene hindamine laboris pole alati võimalik või praktiline, on välja töötatud erinevaid kaudseid teste aeroobse töövõime taseme määramiseks. Senitehtu hulgas napib selleteemalist informatsiooni suuremamahulistest uuringutest 14-16aastaste neidude kohta ning praktiliselt teadmata on ka käigutestide sobivuse tase aeroobse töövõime määramisel noorte puhul.

Lähtudes eelnevast püstitati antud uuringus eesmärgiks

1. selgitada, millise pikkusega käigu- või jooksutest on sobivaim aeroobse töövõime taseme kaudseks määramiseks 14-16aastastel neidudel
2. töötada sobivaima käigu- või jooksutesti põhjal välja valem maksimaalse hapnikutarbimise taseme kaudseks hindamiseks
3. koostada antud uuringu andmete põhjal hindetabel aeroobse töövõime hindamiseks Eesti 14-16aastastel neidudel.

Uuringus osales 102 Tartu koolide 14-16aastast neidu (15.4 a; 166.7±4.9 cm; 55.6±6.5 kg; keha rasva % 18.0±4.3). Kõik vaatlusalused läbisid 3 kehalist testi: 15 minuti pikkune käigutest ja 15 minuti pikkune jooksutest TÜ 150 m pikkusel rajal sisehallis ning maksimaalse hapnikutarbimise test TÜ KK spordifüsioloogia laboris liikuval jooksurajal kasutades Conconi protokollit. Esimese kahe testi käigus registreeriti läbitud distants igal täisminutil ning kulunud aeg iga 500 meetri järel.

Käigutesti ajal oli vaatlusaluste keskmine kiiruse 7.3 km·h⁻¹ ning läbiti 1825±138 m, jooksutestil läbiti keskmiselt 2582±291 m kiirusega 10.3 km·h⁻¹. Laboratoorsel teel määratud maksimaalse hapnikutarbimise keskmised näitajad olid 2.21±0.46 (l·min⁻¹) ja 39.35±6.92 (ml·kg⁻¹·min⁻¹).

Andmeanalüüsi tulemusena selgus, et otsesel teel laboris määratud maksimaalse hapnikutarbimise tasemel oli kõige tugevam seos 1500 m jooksutesti tulemusega (r=-0.39). Leiti ka, et käigutestid ei paku piisavalt informatsiooni aeroobse töövõime taseme kohta ning et antropomeetristest näitajatest mõjutab kehaliste testide tulemusi teistest mõnevõrra olulisemal määral keha rasva %.

Antud uuringu tulemuste põhjal töötati välja järgmine valem maksimaalse hapnikutarbimise võime taseme kaudseks hindamiseks 1500 m jooksutesti põhjal:

$$\dot{V}O_2\text{max (ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = -0.04529\cdot 1500\text{m jooksu tulemus (s)} + 62.57$$

Selle valemi põhjal arvatud ning laboratoorsel teel määratud maksimaalse hapnikutarbimise (ml·kg⁻¹·min⁻¹) vaheline korrelatsioonikoefitsient oli r=0.65 (SEE=6.79 ml·kg⁻¹·min⁻¹).

Liikoval jooksurajal tehtud maksimaalse hapnikutarbimise testide käigus saadud info põhjal töötati välja ka hindetabeli $\dot{V}O_2\text{max}$ taseme hindamiseks Eesti 14-16aastastel neidudel (vt. all).

Maksimaalse hapnikutarbimise võime taseme hindekskala 14-16-aastastele neidudele

	$\dot{V}O_2\text{max (l}\cdot\text{min}^{-1})$	$\dot{V}O_2\text{max (ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1})$
Nõrk	< 1.4	< 28.9
Rahuldav	1.5-1.9	29.0-35.9
Keskmine	2.0-2.4	36.0-42.9
Hea	2.5-2.9	43.0-49.9
Väga hea	> 3.0	> 50.0

1500 m jooksutesti korratavust kontrollisime nädalase vahega 29 sarnaste antropomeetriliste karakteristikutega sama vanusegrupi neiuga. Testitulemuste statistiline analüüs näitas, et antud testi korratavus on väga kõrge – ICC=0.93.

Antud uuringu tulemuste põhjal võib järeldada, et 14-16aastaste neidude aeroobse töövõime kaudseks hindamiseks on sobivaim 1500 m jooksutest, selle jooksutesti korratavus antud vanusegrupi neidudel on kõrge. Käigutestid selle kontingendi maksimaalse hapnikutarbimise võime taseme hindamiseks ei sobi.