Examination of Physical fitness, Body weight, Self-esteem, Body image and Eating attitudes among Adolescents

Ph.D. dissertation

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1. List of abbreviations

BAT: Body Attitude Test

BAT-B: Body Attitude Test- Better

BAT-W: Body Attitude Test- Worse

BMI: Body Mass Index

CR: Cognitive Restraint

CV: Cardiovascular

CVD: Cardiovascular Disease

EAT: Eating Attitude Test

EE: Emotional Eating

HFZ: Healthy Fitness Zone

HSSF: Hungarian School Sport Federation

IBM: International Business Machines Corporation

NIZ: Needs Improvement Zone

PA: Physical Activity

PE: Physical Education

PS: Personal System

RSES: Rosenberg Self-Esteem Scale

SBSH: Subjective Body Shape

SE: Self-esteem

SPSS: Statistical Product and Service Solutions

UE: Uncontrolled Eating

WHO: The World Health Organization

2. Introduction

2.1. Stages of adolescence

Adolescence is a transition from childhood into young adulthood during which adolescents experience physical, behavioral, cognitive, emotional, and social developmental changes. Adolescence is an important period in a person's life when main health behaviors can develop that may have a lifelong impact. The World Health Organization (WHO) defines an adolescent as any person between ages 10 and 19. 3 stages of adolescence can be distinguished. 1. Early adolescence: this first stage begins at the age of 10 or 11 and lasts until about 13 years of age. At this stage, children often start to grow more quickly. Other body changes, including hair growth under the arms and near the genitals, breast development in females and enlargement of the testicles in males, can also be observed. Adolescence usually starts a year or two earlier in girls than boys, and it can be normal to start as early as age 8 for females and age 9 for males. Many girls may start their period at around age 12. Adolescents at this age may already start looking for ways to become independent of their family. In this process, they can push the boundaries and react strongly if the parents confirm the limits. 2. Middle adolescence: This stage of adolescence includes those between 14 and 17 years of age. Physical changes continue in mid-adolescence. Most boys have already started to grow, and other changes related to puberty continue. Some adolescents develop acne, and the boys start mutating. In girls, the physical changes can be almost complete by the end of this stage, and most girls today have regular menstruation during this period. At this age, many teenagers are becoming interested in romantic and sexual relationships, which can be stressful if they don't get enough support from their peers, family, or community. Many middle-aged adolescents have more disputes with their parents while fighting for greater independence. They may spend less time with family and more time with friends. They are very worried about their appearance, and the influence of peers increase. The brain continues to change and mature, but there are still many differences in how an average adolescent think compared to an adult. This is partly because the frontal lobe is the last area of the brain which maturation begins. 3. Late adolescence: The last stage of adolescence is between about 17 and 19 years old, but it can last up to 21 years. Late adolescence may seem like a strange intermediate period, since they are no longer children, but not even adults. Physical changes and growth, especially among boys, continues. This stage usually involves great cognitive development. They have a stronger sense of identity and individuality and can define their own values. At this stage, adolescents gradually regain their balance by accepting, assimilating, and resolving the changes and conflicts (1).

2.2. General characteristics in adolescence

Puberty include rapid acceleration in physical growth, changes in body composition, metabolic changes, brain development, psychological and sexual maturation, and changes in social role (2).

One of the first visible signs of adolescence is a sudden acceleration of physical growth. Boys and girls grow faster during this period than at any time since infancy. Boys can get 23 cm taller and girls 15 to 17 cm taller in two to three years of rapid growth. Despite the fact that adolescents grow throughout puberty, they reach 98 percent of their adult height by the end of the period of sudden growth. The physical change in size is accompanied by a change in the shape and composition of the body. During puberty, physical characteristics that distinguish boys and girls develop. Generally boys lose fat during adolescence, making them look even more muscular and angular than girls, while girls retain a higher proportion of fat compared to their muscles. Before adolescence, boys and girls of the same size have little difference in physical strength. By the end of this period, boys have greater cardiorepiratory performance and they perform longer gymnastic exercises and exert more strength than girls of a similar age (3).

One of the physical changes in the growth rate during puberty is weight gain. In boys, this means primarily an increase in muscle mass, while in girls it means an increase in the fat content of the subcutaneous tissue. These changes are completely normal, but as they result in different body size and shape than before, as well as a different shape from the cultural ideal, especially in girls, they can cause psychological problems. The female ideal for instance is represented by a thin, prepubertal body that is advertised on television, in movies, and in magazines, and which is also reflected in the form of toy dolls. The thin body idealized by the media seems unattainable for most girls after puberty. As a result, adolescent girls are generally dissatisfied with their new, more mature bodies. They consider themselves fat and ugly and most of them do everything they can to lose weight. How satisfied or dissatisfied girls are with their bodies is determined not only by the media, but also by how their peers and family members react to their appearance. Many adolescent girls start dieting, which can mean significant deprivation of fats and carbohydrates and skipping meals. In extreme cases, they take medications to reduce their appetite and in severe cases permanent eating disorders develop (3).

Changes associated with adolescence, like all other events during development, depend on the complex interplay of genetic and environmental factors. Healthy eating in childhood and adolescence plays an important role in healthy development and growth. A healthy diet protects against micronutrient deficiencies, overweight, eating disorders and dental problems, and prevents most non- communicable chronic diseases. Physical activity in adolescence also an important tool in maintaining energy balance, supporting bone development, and reducing the risk of chronic diseases. Among children and adolescents, regular physical activity and physical fitness are protective factors against the development of high blood pressure and high cholesterol level, metabolic syndrome, low bone density, and depression. In addition to positive physical effects, physical exercise contributes to a good mood, life satisfaction, and a generally better state of mind (4).

Developmental changes during adolescence also include structural and functional changes in the brain. These neural changes are associated with behavioural changes such as increases in sensation-seeking and a reorientation of attention and motivation towards peers, social evaluation, status and prestige, and sexual interests (5). Adolescent development also involves profound changes in social contexts, social roles and social responsibilities (6). Changes in the social environment around the time of puberty often include the transition from primary to secondary educational settings, an increase in the number of peers, and an increase in time spent with peers relative to family. These changes present new challenges, including the need to integrate into large and unstable social networks and the possibility of peer rejection. Peer judgments influence adolescents' social and self-worth, and young people who adapt well to these changes by gaining a stable social position have better physical and psychological health outcomes (7).

Social cognitive processes, such as taking others' perspectives, regulating emotions, and managing peer influence, facilitate successful social transition into adulthood. Navigating the social environment is reliant on successfully employing these processes, and training certain abilities, such as emotion regulation, might foster resilience to mental health problems in adolescence (8).

2.3. Overweight and obesity among adolescents

The worldwide prevalence of obesity among adults as well as in children and adolescents has markedly increased over the past three decades leading to the so-called obesity epidemic. According to the latest data in related literature, the presence of childhood and adolescent obesity, defined as a body mass index (BMI) ≥ 95th percentile of the sex-specific BMI-for age, is as high as 18.5% in the USA (9), and 15% in Europe (10). The prevalence of obesity in adolescence has stabilized at a high level in developed countries (11) but is still increasing in developing countries (12). In Hungary, according to a recent survey, in which 6824 children and adolescents (54 % boys), aged 3-18 years were examined, 14.1% of the boys and 12.6% of the girls were found to be overweight, while 7.5% of the boys and 5.5% of the girls were obese (13). About 80% of obese adolescents remain in this condition as an adults (14). Adolescents with BMIs above the 85th percentile are more likely to be obese by age 35 than their normal weight counterparts (15). Besides the many short-term effects of obesity such as cardio-metabolic, respiratory, musculoskeletal, endocrine, psychosocial effects, and increased cancer risk (16), a high percentage of children and adolescents track their obesity into adulthood (17) resulting in several chronic diseases (18) and even premature death (19). Evidence suggests that childhood obesity plays a significant role in the development of risk factors for adult CV morbidity and mortality. Hypertension was the most common CV risk factor attributed to adolescent obesity (20). Childhood obesity has also been found to be a potent predictor of the development of insulin resistance as well as harmful fasting insulin and glucose levels (21). Additionally, there is an interplay between obesity and psychosocial health, as adolescents with obesity may have increased levels of stress, depressive symptoms, and reduced resilience (22).

2.4. Eating habits among adolescents

Childhood and adolescence are important periods of life, since adult lifestyle behaviors are largely influenced by childhood habits. Healthy eating in childhood and adolescence is important for proper growth and development and to prevent various health conditions. Diet-related diseases are the leading cause of death worldwide (23). Diets, characterised by excessive saturated fat, sugar and salt, are associated with many chronic diseases, such as type 2 diabetes, cancer and CVD (24). As such, healthy eating is an area of high priority in public health (25).
Often harmful eating habits may develop in adolescence, such as high intake of fast foods and other foods high in fat, low intake of fruits, vegetables, fiber, and dairy products. Frequent snacks, irregular meals may occur at this stage of life. Skipping breakfast - common among adolescents - may affect concentration, learning, and school performance (26).

Individual characteristics that influence eating behavior include psychosocial factors, such as attitudes, beliefs, knowledge, self-efficacy, taste, and food preferences, as well as biological factors such as hunger. Adolescents' eating behaviors are also strongly influenced by their social environments, which include family, friends, and peer networks. Family is a major influence on adolescents' eating behavior. The family mediates adolescents' dietary patterns, being the provider of food, and the family influences food attitudes, preferences, and values that affect lifetime eating habits (27).

The eating behaviours of teenage youth are especially important because many lifestyle habits that have immediate and long-term health consequences (eg, eating behaviours, physical activity, sedentary behaviours) emerge during adolescence (28). For example, being overweight as an adolescent is associated with overweight as an adult, high fat intake during adolescence is associated with a high fat intake during adulthood leading to an increased risk for heart disease, and low calcium intake during adolescence is associated with low bone density and an increased risk for osteoporosis later in life (26).

Growing independence and eating away from home, concern with physical appearance and body weight, the need for peer acceptance, and busy schedules all have an effect on eating patterns and food choices in adolescence (29).

The Dietary Guidelines for Americans, 2020–2025 (30) recommend that people aged 2 years or older follow a healthy eating pattern that includes the following: a variety of fruits (especially whole fruits) and vegetables, whole grains, fat-free and low-fat dairy products, a variety of protein foods (including lean meats, poultry, and eggs, seafood, beans, peas, and lentils, nuts, seeds), oils including vegetable oils and oils in food, such as seafood and nuts. These guidelines also recommend that individuals limit calories from solid fats (major sources of saturated and trans fatty acids) and added sugars, and reduce sodium intake. In Hungary, in 2016 the New Hungarian Dietary Guideline, Smart Plate was released. „OKOSTÁNYÉR®" shows nutritional tips related to the basic food groups (vegetables, fruits, cereals, milk and dairy products, meat and meat products, fish and eggs) for adolescencents. The recommendations are also provided on how to reduce fat, sugar, and salt intake, and the recommended composition of a daily diet. Regular physical activity is an integral part of a healthy lifestyle, so the recommended amount of exercise is also included in the latest recommendation (31).

2.5. Physical activity among adolescents

Physical inactivity has become a serious worldwide problem, especially in North America and Europe, and it is the fourth leading cause of death worldwide (32). As noted by Kohl and colleagues, "In view of the prevalence, global reach, and health effect of physical inactivity, the issue should be appropriately described as pandemic, with far-reaching health, economic, environmental, and social consequences" (33). The World Health Organization (WHO) estimates that 1.9 million deaths worldwide are attributable to physical inactivity (34) and this inactivity is associated with increased risk of several diseases and health conditions, such as coronary and cerebrovascular diseases, congestive heart failure, certain cancers, osteoporosis, obesity, type 2 diabetes mellitus and hypertension (35). Despite guidelines and recommendations, a decline in PA and fitness levels has been reported worldwide among children and adolescents as well (36). It is recommended that children and adolescents aged 6–17 years do 60 min or more of physical activity each day (37). The health benefits of regular PA are well established. High levels of physical fitness in adolescence are favorably associated with CV health, normal BMI-for-age, insulin sensitivity, bone health, psychological health, and academic performance (38). An innovative textbook has been created to support student development and enhancement of healthy behaviors that influence their lifestyle choices and fitness, health, and wellness. A key feature of this curriculum is the complete integration of physical education and health concepts and skills to maximize student interest, learning, and application. The five steps of the Physical Activity Pyramid helps to understand the five kinds of physical activity, which build different parts of fitness and produce different health and wellness benefits (Figure 1). Several types of activities are available to meet the recommended 60 minutes of daily activity. Performation of all activities of the Physical Activity Pyramid at least twice a week maximize its benefits. For the same volume of activity, activities at or near the bottom of the pyramid may need to be done more frequently or for longer periods of time than those at the top (39).

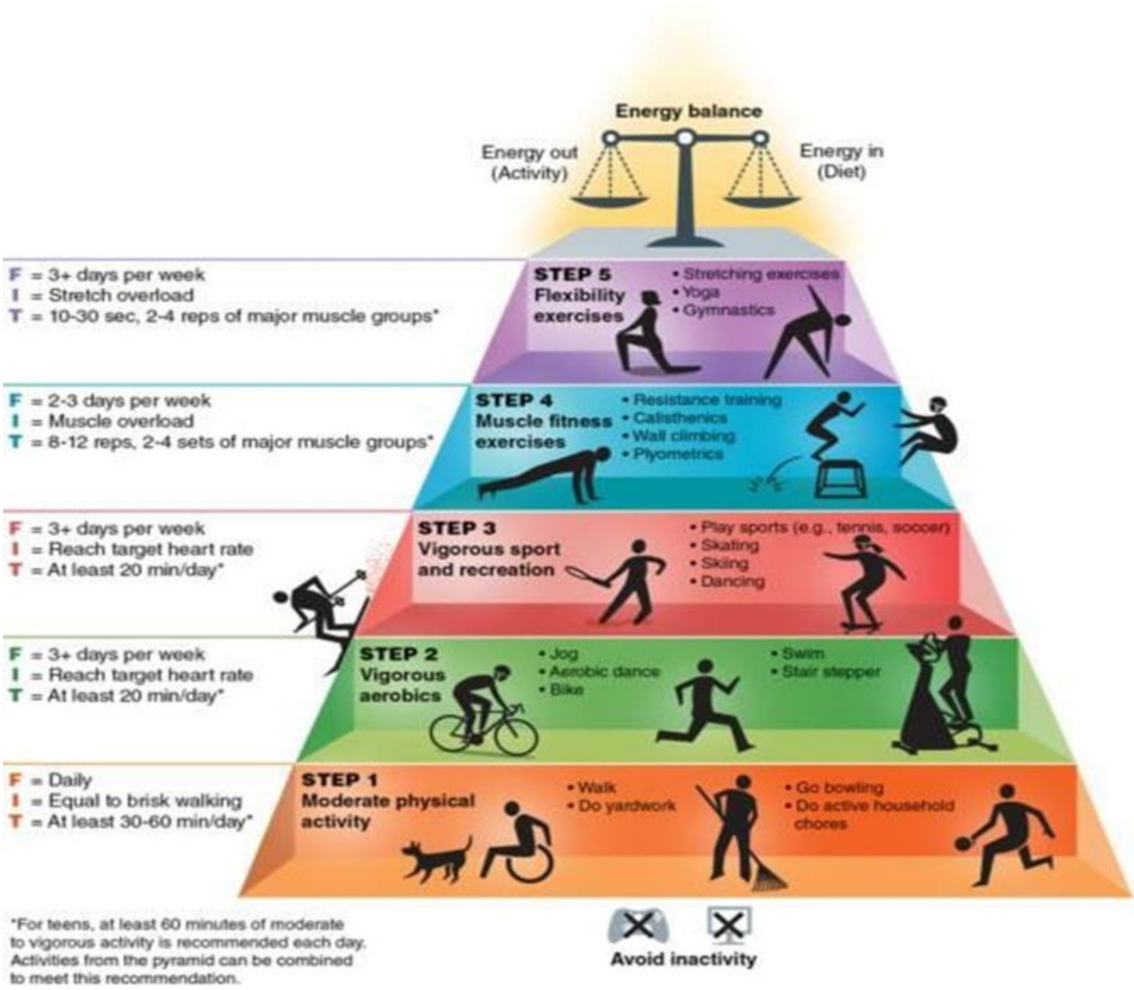


Figure 1. Physical Activity Pyramid for Teens (39). F: frequency of the physical activity, I: intensity of the physical activity, T: time or duration of the physical activity.

For children and adolescence, changes in school curricula have reduced opportunities to be physically active, with many schools cutting or eliminating physical education in recent years. In addition, screentime hugely increased in the past decades and even more during Covid measures. Thus, the monitor time substantially increased and the active leisure time siginificantly decreased even in the past couple of years. According to a recent survey only 1 in 5 children have met the WHO Global physical activity recommendations under pandemic conditions (40). The effects of these factors are of particular concern, as there is clear evidence of the health benefits of physical activity and the health risks of inactivity.

Participating in sports also favor mental health. Apart from the physical exercise aspect of practicing a sport, which is known to have positive effects on mental health, the most prevalent effects of sport lie in expanding and strengthening social networks, which is associated with a better perceived wellbeing (41).

A variety of opportunities are available at schools to increase physical activity levels on a daily basis (e.g., active breaks between classes, extracurricular physical and sport activities); Physical education classes are viewed as the foundation for a comprehensive school physical activity program. In Hungary, the 2012 Public Act on Education introduced mandatory daily physical education (PE) to schools starting in the 2012–2013 school year. Hungarian education has been reorganized in conjunction with this directive, including a new National Core Curriculum that regulates the objectives and contents of physical education classes.

Subsequently the Hungarian School Sport Federation (HSSF) established the Strategic Actions for Health-Enhancing Physical Education project, commonly known as TESI (Testnevelés az Egészségfejlesztésben Stratégiai Intézkedések, Strategic Measures in Physical Education in Health Development) (42).

2.6. Psychosocial aspects in adolescence

Adolescence is a developmental period marked by heightened stress reactivity and sensitivity, increased emotionality, and increased incidence of both risk-taking and harm-avoidant behaviors (43). Gender and developmental differences in emotional and behavioural problems are well documented: girls report greater emotional difficulties and boys report more behavioural problems (44).

The psychosocial stress arising from poor body image and social exclusion, especially associated with adolescent obesity, may further promote stress and corresponding health-compromising coping mechanisms (45). Adolescents typically experience heightened stress sensitivity and prolonged reactivity to stressors. Repeated exposure to psychosocial stressors, and the resultant consumption of highly palatable foods ultimately increase the risk of developing overweight and obesity (46). Analysis of depression and obesity among adolescents revealed that adolescents who were depressed had a 70% increased risk of being obese, conversely obese adolescents had an increased risk of 40% of being depressed (47). In a large metaanalysis a positive association was found between childhood and adolescent obesity and depression and more severe depressive symptoms in the obese groups, overweight subjects were not more likely to have either depression or depressive symptoms (48). The psychosocial stress arising from poor body image and social ostracization, especially associated with adolescent obesity, may further promote stress and corresponding health-compromising coping mechanisms (45). Chronic psychosocial stress promotes abnormal eating behaviors including over- or under-eating, and preferentially selecting highly palatable foods (49). Palatable foods are typified by sweet taste and tend to be foods high in rapidly digesting, simple carbohydrates (50). The physiologic signals that arise from consuming palatable foods rich in simple carbohydrates orchestrate cognitive, metabolic, and behavioral responses to stress, which, over time, may increase obesity risk (51). The maturation in brain regions involved in reward seeking may reinforce the desire for delicious food during adolescence. The repeated consumption of palatable foods at this critical stage of neurodevelopment may derail normal maturation processes, thus predisposing adolescent brain to abnormal eating behaviors (52).

Obesity can be a stressful condition due to weight stigma (53) and adolescents who experience stress related to social exclusion are more likely to rely on food-related coping mechanisms (54). This behavior is immediately rewarding and may contribute to transient calming and improvement in mood (55), however, repeated intake of excess calories will result in weight gain, thus perpetuating the cycle (56). Psychogenic stress as a result of weight stigma may contribute to disordered eating habits in adolescents, such as binge eating (57). Furthermore, adolescents are at an increased risk for dieting with the goal of weight loss (58), and those who experience personal factors such as weight concern, body dysmorphia, and depression are more likely to develop disordered eating behaviors 10 years later (59).

3. Focus and Aims of the present work

3.1. Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents

Physical fitness and body weight are important markers of children's and adolescents's physical health. Obesity has become a major epidemic in the 21st century. The incidence of overweight and obesity among children and adolescents has risen even more dramatically in the past decades than in adults. Obesity is associated with a high incidence of well-known cardiovascular risk factors such as dyslipidemia, hypertension and diabetes, and pathological processes may already begin in childhood. Low levels of physical activity, cardiorespiratory fitness and sedentary behavior are associated with the prevalence of obesity. An interesting question is how physical fitness and body weight relate to each other. There are many data in the literature on this topic, but the results are diverse. The goal of our first study was to examine the possible association between obesity and overweight and cardiorespiratory and muscle performance during a 4-year follow up period in adolescents. The BMI-for age and the physical performance of adolescents, 360 girls and 348 boys, between 14–18 years of age was measured twice a year, and the correlation between overweight and obesity and cardiorespiratory and muscle performances were investigated.

3.2. Examination of Self-Esteem, Body Image, Eating Attitudes and Cardiorespiratory Performance in Adolescents

In addition to physical fitness, mental health is another important element of adolescent health. Self-esteem, body image, eating attitudes are important component of mental health. There is a well-known relationship between body dissatisfaction, low self esteem and disordered eating attitudes. It is thought that body dissatisfaction has an indirect impact on eating behaviours, and that self-esteem and negative emotions are the intermediate mechanisms through which the effect is transmitted. An important question is how real body weight and physical fitness effect these mechanisms. In our second work, we aimed to investigate the correlations depicted in areas of self-esteem, body image, eating attitudes and BMI-for-age and cardiorespiratory performance among adolescent boys and girls. We also examined whether there is a gender difference concerning our physical and psychological variables.

4. Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents

4.1. Introduction

Cardiorespiratory performance determines the body’s ability to deliver oxygen from the atmosphere to skeletal muscle and use it to produce energy to support muscle activity during exercise (60). A recent scientific statement by the American Heart Association concluded that healthy cardiorespiratory fitness is positively associated with cardiovascular health, as well as brain health in youth (61). Cardiorespiratory fitness promotes better cognitive functioning throughout life and is associated with increased learning outcomes and brain development in children and adolescents (62,63). Children with higher cardiorespiratory performance often perform better than when compared with less fit children in tasks requiring greater cognitive performance (64). Low or unhealthy cardiorespiratory fitness is a strong independent predictor of cardiovascular disease (CVD) and adult mortality (65).

In adolescence, motor abilities and skills are transformed. Restructuring takes place unnoticed in children who exercise regularly, but there are signs that are easily noticeable in children who do not exercise. The movements become difficult to perform, the lack of tiredness and lightness that is otherwise characteristic of childhood, decreased motor skills, recurrent side movements, convulsive, rigid performance, regression of motor learning may appear. These phenomena can be explained by a sudden increase in height and the resulting disharmony, and in girls by weight gain (66).

Cardiorespiratory fitness is defined as the overall capacity of the CV and respiratory systems to provide adequate amount of oxygen to the body during prolonged or strenuous exercise.

Cardiorespiratory fitness, also called as aerobic fitness or cardiorespiratory endurance, reflects the capacity of the cardiovascular and respiratory system to perform prolonged exercise, while muscular fitness represents the muscular strength, local muscular endurance and muscular power of a muscle or a muscle group (67,68).

Beside physical fitness, overweight is also an important risk factor in CV health, but which one is more important is still debated. According to a recent meta-analysis in adults overweight and even obese but fit individuals had similar all-cause mortality risks as normal weight and fit individuals (69). On the other hand, studies investigating the impact of excess weight and physical fitness on children and adolescents’ health (70) found that the adverse health consequences of overweight were only partially ameliorated by physical fitness.

Low cardiorespiratory fitness in children and adolescents has been associated with increased body fat (71,72), hypertension, (71,73) increased risk of metabolic syndrome (74), and worse academic performance (75,76). Besides cardiorespiratory fitness, muscular fitness is independently and inversely associated with clustered metabolic risk during adolescence (77). The main health-related muscular fitness components are maximal (isometric and dynamic), explosive, endurance, and isokinetic strength (76). Muscular endurance is the ability of a muscle or muscle group to perform repeated contractions. A large meta-analysis revealed negative association between muscular fitness in childhood and adolescence and adiposity and cardiometabolic parameters in adulthood. The effects of endurance (push-ups, sit-ups, bent arm hang, etc.) and strength tests (handgrip, standing long jump, vertical jump, etc.) were similar. (78). Furthermore, a negative association between standing long jump test, which assesses lower-limb maximal dynamic contraction, and total cholesterol in overweight and obese male adolescents was observed (79).

Previous studies have shown a strong correlation between increased BMI and reduced cardiorespiratory fitness in children and adolescents (11,80). The association between increased body weight and decreased cardiorespiratory fitness is unequivocal in most of the studies (81–83) but its interaction with muscle performance is more ambiguous (77). Furthermore, most of the studies examining the association between childhood and adolescence physical fitness and BMI are cross-sectional.

4.2. Materials and methods

4.2.1. Subjects

A total of 708 students from four-grade high school classes were enrolled in the study (360 girls with an average age of 14.2 ± 0.4 years, and 348 boys with an average age of 14.1 ± 0.4 years) at the beginning of high school (9th grade) in Baranya county, Hungary. Measurements (body weight and height, cardiorespiratory and muscle performance) were performed twice a year (autumn and spring) for 4 years, until the end of high school (12th grade). The inclusion criteria were as follows: students who had just started high school and agreed to participate in the study. Exclusion criteria were any medical conditions that prevented student attending physical exercise classes or did not agree to participate in the study. A written informed consent was obtained from the adolescents for the measurements and the anonymous use of data for scientific purposes. Parents were also asked to sign the form to allow the measurements and data handling. The study was approved by the Regional Ethics Committee of the University of Pecs.

4.2.2. Body Weight, BMI, and Obesity Measurements

Body weight was measured to the nearest 0.1 kg using an electronic digital body weight weighing scale. The scale was on a clean, hard and level surface. Once the scale was switched on, the students stepped on it in light sports clothing (no sweatpants), without shoes, and recorded their weight on the data sheet to the nearest 0.1 kg. The height was measured to the nearest 0.1 cm with a manual height board. Weight and height were measured once per measurement. To screen for overweight and obesity, BMI and sex- and age-specific BMI-for-age were calculated using the BMI-for-age BMI growth charts (84). Adolescents with a BMI-for-age ≥95th percentile were considered obese, between the 85th and 95th percentiles were classified as overweight, and with a BMI-for-age of <85th percentile were considered normal. The cut-off value for underweight was less than the 5th percentile of the BMI-for-age (84).

4.2.3. Measurements of Cardiorespiratory Performance

For the assessment of the cardiorespiratory performance of the adolescents, the 12-min run–walk test was used. The students ran, jogged, or walked on a flat course as far as they could in 12 min, and the distance covered was recorded in meters (85).

4.2.4. Measurements of Muscle Performance

Muscle performance was assessed using three motor tests.
Standing long jump test: To assess leg dynamic muscle strength, standing long jump tests were performed. Children stood behind a line marked on the ground and attempted to jump as far as they could, landing on both feet without falling backwards. The measurement was taken by a tape measure from the take-off line to the nearest point of contact, with 1 cm accuracy, on the landing (back of the heels). A maximum of three attempts were allowed, and the best result was recorded in centimeters. Standing long jump test was used to assess muscular fitness as previously described (86). Push-up test: The endurance and dy-namic strength of shoulder and arm muscles were measured by push-up tests. Students bent and stretched the arms in a push-up position with only the hands and the toes touching the floor, while their torso remained straight. They performed as many repeti-tions as they could until exhaustion, and the number of push-ups was recorded. Push-up test was used to assess muscular endurance as previously

described (87). Sit-up test from supine position: To measure the endurance and dynamic strength of abdominal muscles, sit-up tests were performed. Students lied on a mat on their back while bending both knees at 90-degree angles, keeping their feet on the mat, pointing the elbows forwards, putting the fingers behind the ears, and flattening the stomach. They raised the torso off the floor, touching their thighs with the elbows, then descended back and returned to the starting position with quick steady tempo/space until exhaustion or for a maximum of 4 min. The test ended when the students were no longer able to continue the sit-ups or until the end of the 4th minute. The number of sit-ups was recorded. Sit-up test was used to assess muscular endurance as previously described (87).

4.2.5. Statistical Analysis

The significance level was defined as $p < 0.05$. IBM SPSS statistical software (New York city, USA), version 11.0.1 was used to conduct descriptive analyses and to describe the sample. According to the Kolmogorov–Smirnov normality test, data collection revealed a significant deviation from the normal distribution. Therefore, the nonparametric Friedman test together with the post-hoc analysis through Wilcoxon signed-rank tests were conducted with a Bonferroni correction to analyze potential changes between gender groups, and the nonparametric Kruskal–Wallis test was performed to describe potential changes between the different weight subgroups.

A gender specific sample size and power analysis was performed for the investigated population using PS program version 3.1.2. For the sample size of $n = 254$ boys needed to detect a true difference of $\delta = 10.25$ in sit-up test values with 90.08% power, where type I error probability is $\alpha = 0.05$. For the sample size of $n = 255$ girls needed to detect a true dif-ference of $\delta = 8.28$ in sit-up test values with 93.52% power, where type I error probability is $\alpha = 0.05$.

4.3. Results

4.3.1. Results from Gender Within-Groups Analyses

Changes in the BMI-for-Age during the 4 years

At the beginning of our study, 4 percent of the girls were underweight, 75 percent normal weight, 15 percent overweight, and 6 percent obese. With respect to the boys, 6 percent were underweight, 69 percent normal weight, 15 percent overweight, and 10 percent obese. In the spring of 12th grade, 8 percent of the girls were underweight, 75 percent normal weight, 12 percent overweight and 5 percent obese. With respect to the boys, 7 percent were underweight, 72 percent normal weight, 11 percent overweight, and 10 percent obese. Among girls, the average baseline BMI-for-age of 20.52 ± 2.87 did not increase significantly during the 4-year observational period, as it was 21.01 ± 3.05 at the end of the 12th grade ($p = 0.120$). Similarly, there was no significant change in the average BMI-for-age of the boys. It was 20.80 ± 3.75 in the autumn of 9th grade, and 22.01 ± 3.71 in the spring of 12th grade ($p = 0.100$).

Cardiorespiratory Performance of Boys and Girls during the four years

There was a statistically significant difference between the 4-year run–walk test results of genders (girls: $\chi2(2) = 52.32$, $p < 0.001$; boys: $\chi2(2) = 93.64$, $p < 0.001$). There were significant differences between the 9th grade autumn and 12th grade spring run-walk test results among boys ($Z = -4.726$, $p < 0.001$, $\eta2 = 11.99$) (Figure 2A). Among girls, only a seasonal variation could be observed (there was no significant difference between the 9th grade autumn and 12th grade autumn data in girls; $Z = -0.569$, $p = 0.569$, $\eta2 = 12.01$).

Muscle Performances of Boys and Girls during the four years

The lower limb dynamic, the strength and endurance of hip flexors and abdominal muscles, shoulder and arm muscle strength, significantly improved during the four years in both girls {1: $\chi2(2) = 67.147$, $p < 0.001$; 2: $\chi2(2) = 183.16$, $p < 0.001$; 3: $\chi2(2) = 148$, $p < 0.001$} and boys {1: $\chi2(2) = 336.395$, $p < 0.001$; 2: $\chi2(2) = 73.169$, $p < 0.001$; 3: $\chi2(2) = 210.542$, $p < 0.001$}. There were significant differences between the 9th grade autumn and 12th grade spring results of the standing long jump distance (boys $Z = -10.404$, $p < 0.001$, $\eta2 = 11.95$; girls $Z = -4.153$, $p < 0.001$, $\eta2 = 12.004$) (Figure 2B), sit-up test (boys $Z = -3.269$, $p < 0.001$, $\eta2 = 12.003$; girls $Z = -8.073$, $p < 0.001$, $\eta2 = 11.98$) (Figure 2C), and push-up test results (boys $Z = -6.946$, $p < 0.001$, $\eta2 = 11.98$; girls $Z = -5.746$, $p < 0.001$, $\eta2 = 11.99$) (Figure 2D).

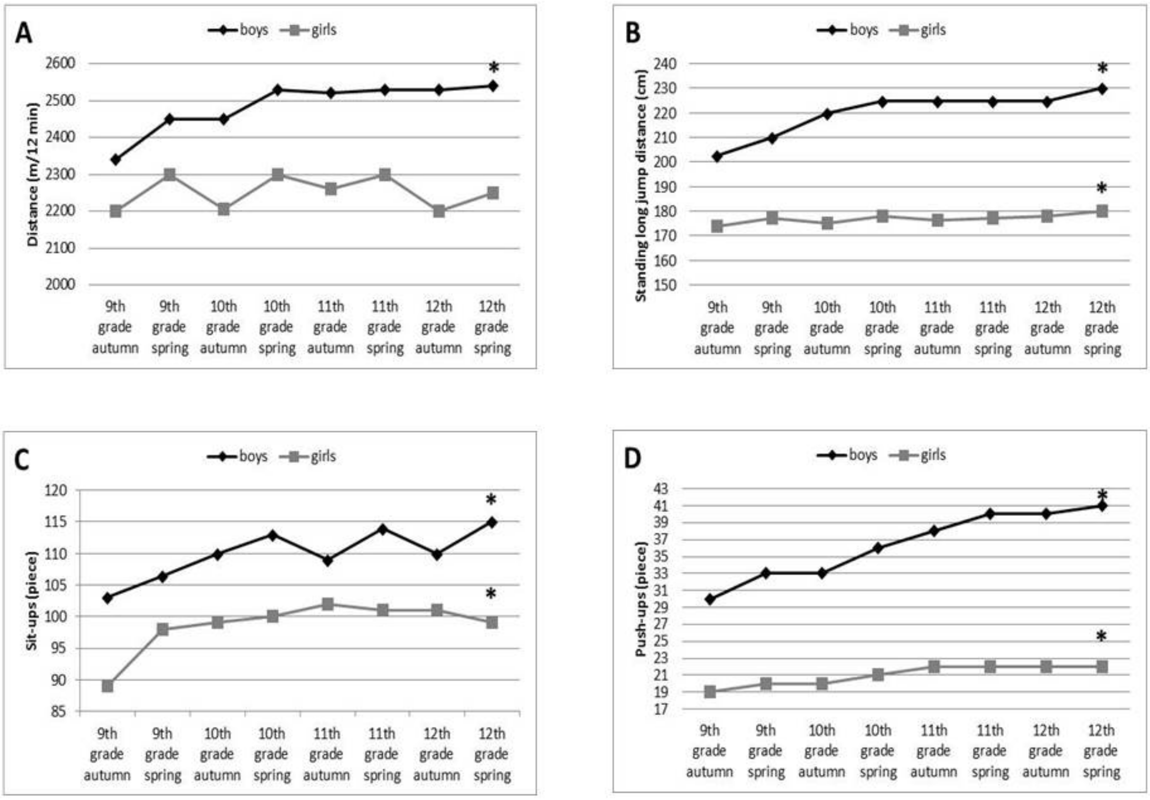


Figure 2. Changes in muscle strength and aerobic fitness between 9th and 12th grade in both genders. Significant improvement was detected in boys' aerobic capacity according to 9th grade autumn and 12th grade spring data (data are shown as median, * = $p < 0.05$). However, only a seasonal variation was revealed in girls' aerobic capacity during the 4 years (**A**). Significant improvement was detected in leg dynamic muscle strength (measured with long jump distance) (**B**), in the strength and endurance of abdominal muscles (measured by sit-up tests) (**C**), shoulder and arm muscles (measured by push-up tests) (**D**) in both genders during the 4-year observational period (data are shown as median, * = $p < 0.05$).

4.3.2. Results from Between-Weight-Groups Analyses

Association between obesity and overweight and cardiorespiratory performance

The Kruskal–Wallis H test showed a significant association between weight status and run-walk test results: the performance of overweight and obese girls was significantly lower than that of classmates with normal weight in the 9th grade ($\chi2(2) = 102.943$, $p < 0.001$, $\eta2 = 0.292$), and in the 12th grade ($\chi2(2) = 96.844$, $p < 0.001$, $\eta2 = 0.274$). Similar results were observed among boys in 9th grade ($\chi2(2) = 109.655$, $p < 0.001$, $\eta2 = 0.33$) and in 12th grade ($\chi2(2) = 86.406$, $p < 0.001$, $\eta2 = 0.258$) (Figure 3A). Mean rank values are shown in Table 1.

Table 1. Mean rank values by the Kruskal–Wallis test for between-weight-group analyses.

GIRLS						
performance type	9th grade			12th grade		
	obese	overweight	normal	obese	overweight	normal
run-walk	19.61	102.06	207.97	15.21	102.37	208.8
lower limb	65.77	150.18	193.78	28.66	169.88	191.42
hip flexor and abdominal muscle	37.45	140.99	198.26	29.21	153.57	194.29
shoulder and arm muscle	39.09	159.69	194.77	21.71	158.38	193.1
BOYS						
	9th grade			12th grade		
performance type	obese	overweight	normal	obese	overweight	normal
run-walk	22.97	129.59	200.5	27.37	165.21	195.11
lower limb	70.74	143.93	192.39	35.53	160.86	195.38
hip flexor and abdominal muscle	44.19	174.15	192.62	48.09	161.28	196.98
shoulder and arm muscle	75.28	159.66	188.1	54.29	159.66	192.52

Association between Obesity and Overweight and Lower Limb Performance

The performance of overweight and obese girls was significantly lower than that of normal weight girls in 9th grade ($\chi 2(2) = 37.85$, $p < 0.001$, $\eta 2 = 0.102$). In 12th grade, only obese girls provided significantly lower performance $\chi 2(2) = 44.341$, $p < 0.001$, $\eta 2 = 0.121$). Similar results were found among boys in 9th grade ($\chi 2(2) = 50.906$, $p < 0.001$, $\eta 2 = 0.148$), and in 12th grade ($\chi 2(2) = 82.886$, $p < 0.001$, $\eta 2 = 0.247$) (Figure 3B). Mean rank values are shown in Table 1.

Association between Obesity and Overweight and Hip Flexor and Abdominal Muscle Performance

Nonparametric analyses revealed an association between weight status and hip flexor and abdominal muscle strength in the adolescents. The median maximal performance of overweight and obese girls was significantly lower in 9th grade compared with normal weight girls ($\chi 2(2) = 58.752$, $p < 0.001$, $\eta 2 = 0.163$). In 12th grade, only the obese girls' performance was lower ($\chi 2(2) = 47.980$, $p < 0.001$, $\eta 2 = 0.132$). Among boys, only obesity was associated with worsened results of the sit-up tests, but no association between overweight and abdominal muscle performance could be observed ($\chi 2(2) = 65.282$, $p < 0.001$, $\eta 2 = 0.193$) neither in 9th nor in 12th grade ($\chi2(2) = 68.863$, $p < 0.001$, $\eta2 = 0.204$) (Figure 3C). Mean rank values are shown in Table 1.

Association between Obesity and Overweight and Shoulder and Arm Muscle Performance

The push-up data were inversely associated only with obesity in girls ($\chi2(2) = 48.853$, $p < 0.001$, $\eta2 = 0.134$ in 9th grade; $\chi2(2) = 51.102$, $p < 0.001$, $\eta2 = 0.141$ in 12th grade) and similarly in boys (in 9th grade $\chi2(2) = 41.229$, $p < 0.001$, $\eta2 = 0.118$; in 12th grade: $\chi2(2) = 57.717$, $p < 0.001$, $\eta2 = 0.169$). The performance of overweight boys and girls was similar to the normal weight peers also in 9th and 12th grade (Figure 3D) (Table 1).

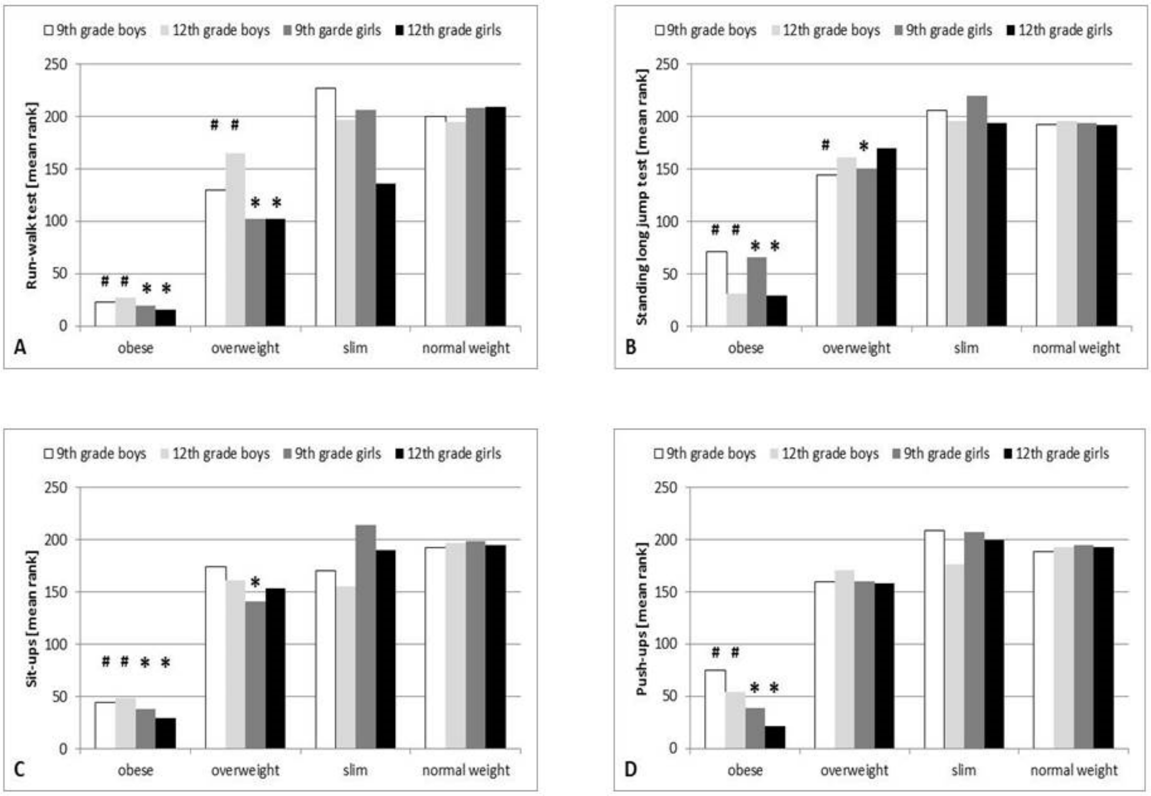


Figure 3. Association between body mass index (BMI)-for-age and aerobic and muscular fitness in adolescents. Run-walk test results are influenced by weight status in both genders (data are shown as mean rank, * = $p < 0.05$ for obese and overweight girls vs. normal weight girls; # = $p < 0.05$ for obese and overweight boys vs. normal weight boys) (**A**). Long jump test data were only influenced by obesity among 12th grade students (girls and boys, data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**B**). Sit-up test results were significantly associated with obesity, performance, and gender (data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**C**). Push-up test results were significantly influenced by obesity, but not by overweight in both genders (data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**D**).

4.3.3. Regression Analyses

Multivariate linear regression and stepwise analyses of the data from baseline BMI, sit-up and cardiorespiratory performance in 11th grade were performed to predict cardiorespiratory performance at the end of the observational period. These variables statistically significantly predicted changes in cardiorespiratory performance ($F(5, 342) = 9752.34$, $p < 0.0005$, $R2 = 0.993$).

4.4. Discussion

In our first study we have examined the association between the BMI-for-age and the cardiorespiratory and muscle performance of adolescents between 14 and 18 years of age. Our results show that cardiorespiratory performance increased significantly in boys during the 4 years, meanwhile in girls it only showed seasonal fluctuation. The strength of leg, shoulder and arm and abdominal muscles significantly increased both in boys and girls, but boys showed a more pronounced improvement. There was no significant change in the BMI-for-age during the examined period either in boys nor in girls. An inverse association between obesity and overweight and cardiorespiratory performance of the adolescents regardless of their age and gender was revealed. Worsening muscle performances were associated primarily with obesity. There was no association between overweight and shoulder and arm muscle performance in any age categories neither in girls nor in boys. Overweight was negatively correlated with lower limb strength in 9th grade girls and boys, and with abdominal muscle performance only in 9th grade girls.

The physical performance of adolescents in our study was similar to data of a recent survey examining children and adolescents in 30 European countries (88). This study showed that boys performed better than girls in muscular strength, power and endurance and physical fitness generally improved at a faster rate in boys than in girls, especially during the teenage years. In our study it was also found that the cardiorespiratory performance of adolescent girls showed a seasonal fluctuation, as the results of spring surveys were always better compared to the preceding autumn results, and no continuous development could be observed. Although we have not examined the reason of this phenomenon it might be due to the lower PA and increased weight gain during the summer holiday among adolescent girls as was suggested in a previous research (89). The strength and endurance of the lower limb, the abdominal, and the shoulder and arm muscles of both girls and boys significantly increased during the 4-year, but the improvement was significantly lower among girls, so the existing sex-differences further increased during this period (Figure 2B–D), which is also in accordance with previous data (88).

No significant change in the BMI-for-age was observed in our study neither in boys nor in girls during the 4-year. The proportion of normal weight girls remained the same (75%) and a slight decrease in the proportion of overweight (15% vs. 12%) and obese (6% vs. 5%) girls could be observed. With respect to the boys, a slight increase in the proportion of normal weight (69% vs. 72%), and a slight decrease in overweight (15% vs. 11%) boys could be measured, while the number of obese boys remained the same (10%) and was higher compared to that of girls'. In our sample of adolescents, the prevalence of obesity and overweight was lower than those reported in the literature (9, 10).

The cardiorespiratory performance showed an inverse correlation with the BMI-for-age of the adolescents. The running distances of both overweight and obese girls and boys were significantly shorter than those of normal weight children (Figure 3A), regardless of their age. The association between the weight status and cardiorespiratory and muscle performances has been examined previously among adolescents. All studies concluded that there was a strong and inverse association between BMI status and cardiorespiratory performance (81,82,90,91). However, the association between BMI and the muscle performance of adolescents shows greater variability. In a Finnish study it was found that both overweight and obesity significantly affected all aerobic and muscle tests (sit-ups, five-jump, back-and-forth jumping, ball skills, coordination, and endurance shuttle run tests), with the exception of the sit-and-reach test, and overweight and obesity had the most negative association with cardiorespiratory performance and muscle endurance tests (90). Examining 9 different muscular strength tests and the body weights of Spanish children (1513 boys and 1265 girls) aged 6 to 17.9 years it was found that normal weight children showed significantly higher performance than their overweight and obese counterparts in lower body explosive strength tests and in the push- up test in boys and bent arm hang test in both boys and girls, and boys had significantly better scores than girls in all the studied tests (92). Taiwanese youth aged 10 to 18 years showed decreased fitness levels for lower body explosive strength and cardiorespiratory endurance in both sexes for the obese and overweight children and adolescents (sit-up, flexibility and abdominal muscular strength/endurance) (91).

In our study, obesity showed negative association with the performance of all examined muscle groups (lower limb, shoulder and arm and abdominal), and this inverse association could be observed throughout the 4 years and no gender differences could be observed. However overweight had no such clear inverse association with the muscle performance of the adolescents. Only the lower limb muscle strength in 9th grade in boys and girls and the abdominal muscle strength and endurance in 9th grade girls were inversely associated with overweight. The shoulder and arm muscle performance were not affected by overweight neither in boys nor in girls in any age categories.

There are numerous studies in the literature to show that childhood obesity is strongly associated with increased risk of many chronic diseases in the short- and long- term (16,17,18). Additionally, cardiorespiratory and muscle performance is independently and inversely associated with CV and metabolic risk factors in adoles-cents (76,77). The Aerobics Center Longitudinal Study (93) and a Finnish cohort (94) also confirmed that better CV health in childhood promotes CV health in adulthood. Finally, we want to emphasize that physically active life in adolescence is associated with healthy weight, better cardio-metabolic health, increased bone mass, muscle strength and flexibility, improved academic performance, mental health, mood and sleep and social behavior (95).

Based on our data more attention is needed to maintain the normal weight status and physical performance of adolescents since increased BMI is negatively associated with most physical fitness parameters.

5. Examination of Self-Esteem, Body Image, Eating Attitudes and Cardiorespiratory Performance in Adolescents

5.1. Introduction

Adolescence represents a sensitive period in which significant physical and psychological changes occur. Psychological characteristics, such as self-esteem and positive well-being may play a pivotal role in physical health. Better mental health during adolescence predicts better general health and fewer risky health behaviors during young adulthood (96).

Self-esteem (SE) is generally defined as the overall evaluation of oneself, and interchangeably referred to as one's overall selfconcept or self-view. (97) SE also can be defined as “the positivity of the person’s self-evaluation (98). It influences the development of important life outcomes, such as satisfaction in relationships, education, job success, and mental and physical health (99). SE is tipically lower during adolescence, particularly among girls when compared with boys. This requires particular attention because a low SE in adolescence may induce health outcomes at this age, and may also have cumulative effects on subsequent life outcomes (100). Adolescents with low SE experience higher rates of crime and substance use, and lower life satisfaction (101). Youth with low SE also report higher levels of suicidal ideation, self-injury, depression, and anxiety (102). SE was also found to be associated with past and present smoking, smokers scoring lower for SE (98). The habit of smoking is often acquired already in late childhood or early adolescence. Higher SE and close parental relationship seem to protect young people against developing a smoking habit (103). SE is also associated with alcohol consumption in adolescence. In a recent study college students with higher alcohol consumption may have had either high or low self-esteem. Students with higher alcohol consumption and lower self-esteem had a pattern of poor mental health and higher impulsivity and could be therefore more prone to risky behaviors, including deliberated self-harm (104).

Self-esteem can be defined as a subjective self-assessment based on prior learning and experiences and reflects how an individual sees and evaluates oneself (105). Lower self-esteem can be a causal factor for depression, anxiety, eating disorders, high-risk behaviors, and social functioning (106). In adolescence, a decline in the level of self-esteem can be observed (107), especially among girls (108). Additionally, overweight and obese adolescents frequently experience low SE. Interestingly, authors in a large meta-analysis found no improvement in self-esteem in obese or overweight adolescents following significant weight loss (109). Good SE facilitates engaging in health-promoting behaviors and maintaining good health (110). Inversely, inadequate SE may result in risk behaviors (111) and has been related to undesirable eating behaviors, an inactive lifestyle, diminished performance in areas of academics and elevated risk in developing symptoms associated with depression (112).

Body image is determined by how individuals perceive or feel in relation to the size and outline of their own body (113). Body image is made up of two attitudes or dimensions. The first is self- evaluation, in which the emotional component prevails, focusing on pleasure / displeasure or satisfaction / dissatisfaction with the appearance. The effect of internalizing the ideal of beauty in society shares this attitude. A second component of body image is investing in an attitude to personal appearance (114). Body image disorders can cause severe and lasting changes in perception and attitude, such as dissatisfaction and distortion, which can lead to social, physical, and emotional suffering (113). Severe cases of body image disorders can lead to unhealthy behaviors, such as eating and body dysmorphic disorders (113). Adolescence is an important period of physical and social changes that can lead to a negative body image (114). Concerns about body image due to the succession of physical and cognitive changes are common in adolescence, leading to increased evaluation and focus on body and appearance (115). It is well known that girls are more dissatisfied with their body image than boys in adolescence (116).

Body image, another remarkable psychological factor in adolescence, was defined as ‘a person’s perceptions, thoughts, and feelings about his or her body’ by Grogan (117). Body dissatisfaction occurs when views of the body are deemed negative and the body image represents a discrepancy between the individual’s actual and ideal body (118). Previous research suggests that women and adolescent girls experience higher levels of body dissatisfaction and disturbed eating patterns than when compared with their male counterparts (119,120). Women are more likely than men to describe themselves as fat or weigh themselves more often and they are also generally more dissatisfied with their physical appearance than are men (121). The body dissatisfaction that is presented by adults can already be found in adolescents (122). It is estimated that nearly 50% of adolescent girls are dissatisfied with their bodies (123). Body dissatisfaction may lead to adverse physical and mental health consequences, including depression, anxiety (124), low self-esteem (125), and eating disorders (126,127).

Unhealthy eating attitudes and behaviors are quite common among young people, and overweight and obesity imply a particularly high risk of developing such behaviors (128,129). The three most frequently studied areas regarding eating attitudes are uncontrolled eating (UE), cognitive restraint (CR), and emotional eating (EE). UE refers to an inclination to overeat, including the feeling of losing control (130). CR suggests a tendency to consciously restrict food intake rather than using physiological cues (i.e., hunger and satiety) as regulators of eating (131). Finally, emotional eaters tend to eat in response to emotional triggers rather than real physiological needs (132). Emotional eating also implies or predicts weight gain (133) and difficulty of losing weight (134). Compared to non-emotional eaters, emotional eaters are more prone to consume sweet and high-fat foods (135) and are more likely to eat in response to stressors (136). Many eating disorders appear to start soon after puberty and persist through secondary school years (137). However, most of these studies focus on girls and women and less attention is paid to boys and men, albeit eating disorders in men are increasing (138). In the current study, we focus on disordered eating attitudes that do not reach clinical levels but might be predictive for developing an eating disorder.

Improvement in cardiorespiratory fitness has a positive effect in combating depression, anxiety, mood status, self-esteem, and is seemingly associated with higher performance in education (76). In a recent clinical trial, cardiorespiratory fitness was independently and positively associated with self-related health in children (8–11.9 years age) and adolescents (12–17.9 years age) at baseline, including a two-year follow-up (139).

5. 2. Materials and Methods

5.2.1. Study Participants

A total of 374 students from fourth-grade high school classes were enrolled in our prospective study (209 girls with an average age of 16.4 ± 1.08 years, and 165 boys with an average age of 16.5 ± 1.03 years). Written informed consent was obtained from all the participating adolescents for the measurements and the anonymous use of data purely for scientific purposes. Parents were also asked to sign the form authorizing the measurements and data handling. The study was approved by the Regional Ethics Committee of the University of Pecs (7522-PTE 2018) and was performed in 2018.

5.2.2. Measurements

Bodyweight was measured to the nearest 0.1 kg using an electronic digital body weighing scale, and height was measured to the nearest 0.1 cm using a manual height board. To screen for overweight and obesity, BMI and sex- and age-specific BMI-for-age were calculated using the BMI-for-age CDC growth charts (84). Adolescents with a BMI-for-age ≥ 95th percentile were considered obese, between the 85th and 95th percentiles were classified as overweight, and with a BMI-for-age of <85th percentile were considered normal. The cut-off value for underweight was less than the 5th percentile of the BMI-for-age.

In consideration of the assessment regarding the cardiorespiratory performance of the adolescents, a 20 m shuttle run test was used. The 20 m shuttle run test is the most widely used field-based assessment of cardiorespiratory fitness (140). This test involves continuously running between two lines, 20 m apart, in time, to recorded beeps. The participants are first positioned behind one of the lines facing the second line and begin running when instructed by the recording. The participant continues running between the two lines, turning when signaled by the recorded beeps. A sound indicates an increase in speed in minute intervals. A participant is ushered a warning the first time he or she fails to reach the line (within 2 m) and is eliminated following the second warning. Each participant's score was tallied including the level and number of shuttles (20 m) reached before they were unable to keep up with the recording. The 20 m shuttle run test was conducted by the doctoral student with the help of a gym teacher and it was performed in the gym under standardized conditions.

5.2.3. Questionnaires

Questionnaires were completed by all study participants. Prior to completion students were instructed to read the questions carefully and to devote sufficient time to answer the questions.

Rosenberg Self-Esteem Scale

We used the Hungarian version of the Rosenberg Self-esteem Scale to measure students' global self-worth by measuring both negative and positive feelings regarding the inner self. The 10-item scale is uni-dimensional. All items are answered using a 4-point Likert scale ranging from strongly agree to strongly disagree. Higher scores refer to higher self-esteem (141).

EAT-26

The Eating Attitudes Test measures three aspects of eating behaviors. Cognitive restraint (CR) is a conscious effort by individuals to control what they eat to maintain or lose weight. Uncontrolled eating (UE) defines excessive eating in response to a loss of control over the food. Emotional eating (EE) is the need to overeat when an individual is unable to cope with emotionally negative situations and moods. The total value consists of tallying the scores regarding the three factors. Higher scores in the respective scales are indicative of greater cognitive restraint, uncontrolled, or emotional eating (130).

BAT

The Body Attitude Test (BAT) is a self-report questionnaire including 20 items, scored on a 6-point Likert-scale. The test measures the subjective body experience and the attitudes toward the individual's body, such as dissatisfaction with their own body, depersonalization of the body, complex feelings regarding overweight, lack of trust in one's own body, hyperactivity and restlessness (142). The cut-off score is 36. Higher scores reflect diminished levels regarding attitudes toward one's own body.

The descriptives of the psychological variables are depicted in Table 2. The internal reliability of each scale reached a good level: Rosenberg Self-esteem Scale (Cronbach's α = 0.88), The BAT (Cronbach's α = 0.83), The Eating Attitudes Test (Cronbach's α = 0.81).

Table 2. Descriptives regarding the psychological variables. Mean refers to the average scores of each psychological scale and SD is the standard deviation. The Minimum and Maximum values show what were the lowest and highest scores the subjects circled. Skewness is a measure of symmetry, or more precisely, the lack of symmetry of the data, while Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution.

Psychological Variable	Mean	SD	Minimum	Maximum	Skewness/Kurtosis
Self-esteem (RSES)	28.91	6.32	12	40	−0.251/−0.471
Body attitudes (BAT)	24.02	7.70	13.13	55	0.865/0.960
Uncontrolled eating (EAT-UE)	19.29	5.18	9	33	0.339/−0.391
Cognitive restraints (EAT-CR)	14.92	3.74	6	26	0.080/−0.352
Emotional eating (EAT-EE)	10.24	4.98	6	24	0.598/0.725

5.2.4. Data Analysis

Sample size and power analysis were performed for the overall population grouped by gender and BMI-for-age using power and sample size calculation program version 3.1.2 (143,144). The sample size of $n = 9$ per group needed to detect a true difference of d = 6.017 in Rosenberg self-esteem with 95% power, where type I error probability is $\alpha = 0.05$. Effect size analysis showed d = 0.631 (according to Cohen).

To analyze the psychological and physical variables we used Independent Samples *t*-tests, one-way ANOVA, Correlation analysis and Multivariate linear regressions after using the

Kolmogorov–Smirnov test to check the normality of the data distribution. The normality test revealed a not significant result in all parameters ($p > 0.05$).

The Independent Samples *t*-tests were used to check the gender differences of the psychological variables.

Differences of BMI and shuttle run test (grouped by gender and BMI-for-age) as well as the psychological variables were evaluated by a one-way repeated ANOVA statistical test using Tamhane posthoc test.

Bivariate correlation analysis was performed calculating Spearman's correlation coefficient (rho). Multiple regression analysis with various models considering the principle of multicollinearity was performed to reveal which factors could predict Self-esteem, BAT, Uncontrolled eating, Cognitive restraints, Emotional eating and shuttle run test. The correlation analysis showed significant associations of the psychological variables and some of the physical ones, more precisely: objective body shape (percentile zones) and subjective body shape (How do I see my body? This question refers to how somebody perceives his body shape, ranging from overweight/fat to skinny through a 5 point Likert-scale.).

The first regression model was performed to predict Self-esteem, BAT, Uncontrolled eating, Cognitive restraints, Emotional eating as the dependent variables regarding age, gender, Subjective body shape, BMI-for-age as independent variables.

The second linear regression and stepwise analyses of the data were performed to predict shuttle run test as the dependent variable regarding the Rosenberg Self-esteem Scale and BAT values. According to the BAT results, we have divided the two gender groups into two groups: those who had worse attitudes toward their body (BAT-W), having more than 36 points, and those with better attitudes toward their body (BAT-B), having less than 36 points. Differences in these psychological variables between these girls and boys subgroups were evaluated by a one-way ANOVA statistical test.

5. 3. Results

5.3.1. BMI-for-Age

With respect to the boys, 10 percent were underweight, 63 percent normal weight, 19 percent overweight, and 8 percent obese (Figure 4A).

At the time of measurement 4 percent of the girls were underweight, 74 percent normal weight, 16 percent overweight, and 6 percent obese (Figure 4B).

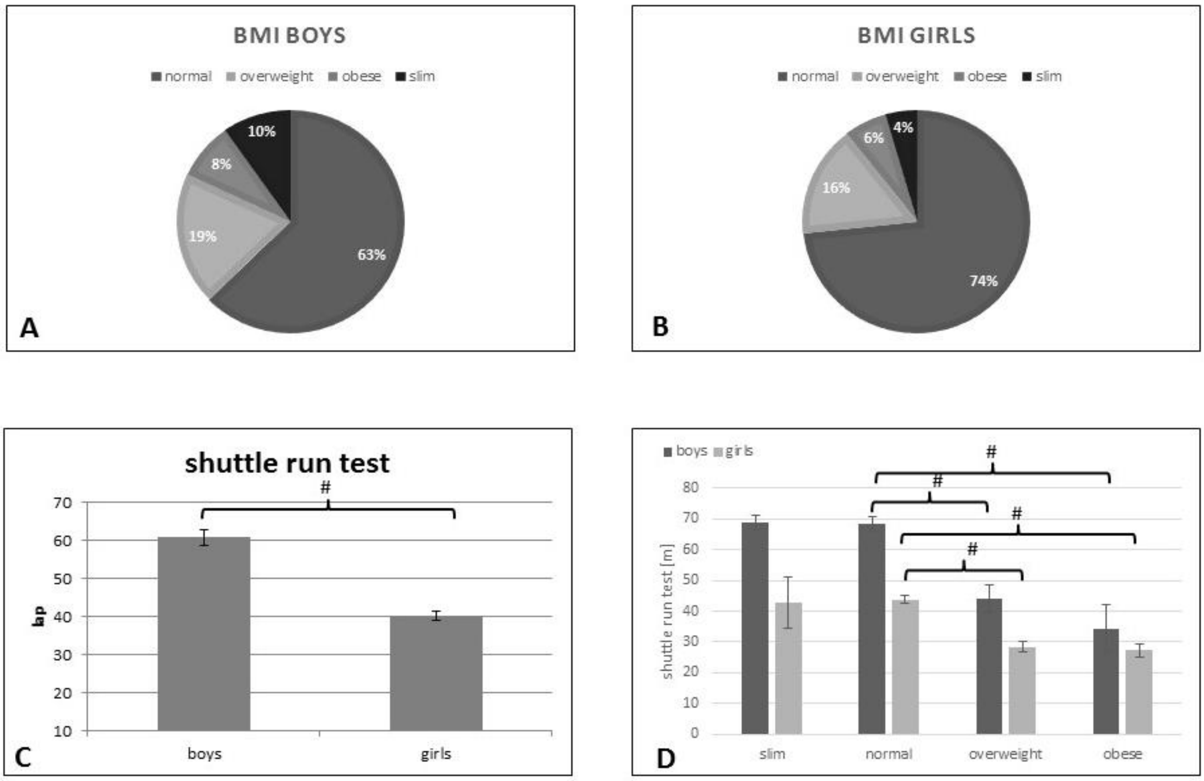


Figure 4. BMI-for-age in boys (A) and girls (B). Our results depicted significant differences in gender specific (C) and BMI-for-age specific shuttle run test (D) (data are shown as mean ± S.E.M, # = p < 0.001).

5.3.2. The 20 m Shuttle Run Test Results

According to the 20 m shuttle run test data, 65% of boys (54 lap≥) and 59% of girls (38 lap≥) were in the Healthy Fitness Zone (HFZ). 35% of boys (≤45 lap) and 41% of girls (≤28 lap) were in the Needs Improvement zone (NIZ). The boys completed an average of 60.83 ± 25.79 laps. The girls accomplished 40.22 ± 16.34 laps. Students who meet the standards are classified as being in the Healthy Fitness Zone (HFZ), whereas students who fall below the standards are classified as being in Needs Improvement Zone (NIZ).

The analysis of the gender differences detected significantly lower shuttle run test results among girls than when compared with boys (40.2 ± 1.13 vs. 60.8 ± 2.0; $p < 0.001$) (Figure 4C).

We observed no significant differences in shuttle run test results between slim and normal (68.81 ± 2.35 vs. 68.32 ± 2.46), as well as between overweight and obese boys (44.09 ± 4.65 vs. 34.4 ± 7.94), however, we discovered significantly lower performance in the obese and overweight boys than when compared with their classmates with normal BMI-for-age (Figure 4D).

The study results exhibited quite similar consequences in studying girls weight groups: there were no significant differences in shuttle run test outcomes between slim and normal nor between overweight and obese, however, we found significant differences between normal and overweight or obese girls' aerobic capacity (42.78 ± 8.5 slim; 43.8 ± 1.28 normal; 28.44 ± 1.57 overweight; 27.23 ± 2.02 obese) (Figure 4C).

5.3.3. Psychological Tests Results

The study revealed a significant difference in self-esteem: Girls showed lower self-esteem than when compared with boys (t (374) = 6.62; p = 0.05). Girls also reported significantly negative body attitudes (t (374) = −9.12; p < 0.001) than when compared with boys and reached higher scores on each of the Eating attitudes subscales. Girls showed signs of uncontrolled eating (t (374) = −3.47; p = 0.01), cognitive restraint (t (374) = −5.56; p < 0.001) and emotional eating (t (374) = −4.78; p < 0.001) more often than when compared with secondary school-aged boys (Figure 5).

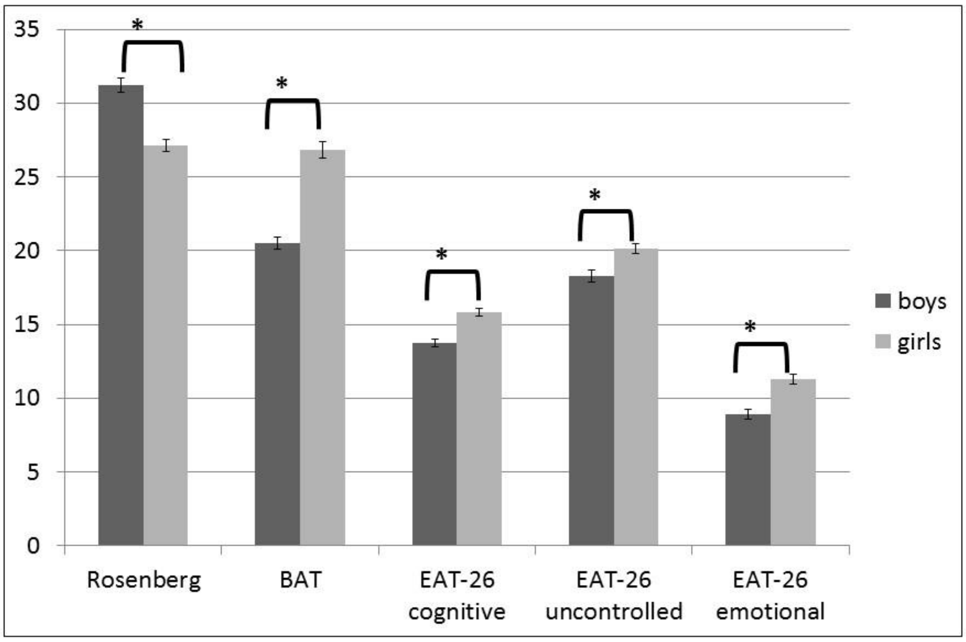
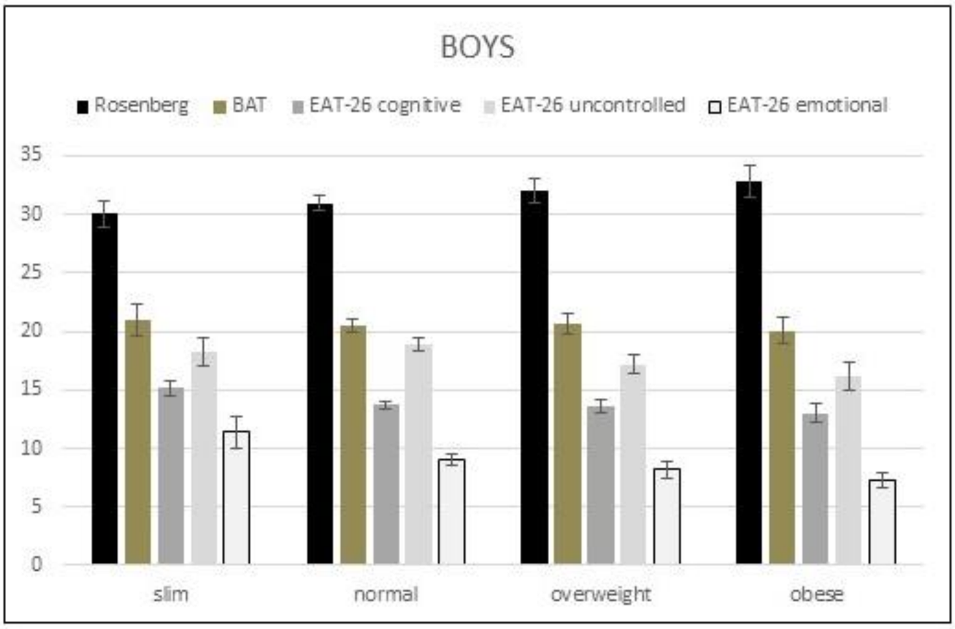


Figure 5. Our results showed significant differences in gender on the psychological tests (data are shown as mean ± S.E.M, * = p < 0.001). (Rosenberg = Rosenberg Self-esteem Scale; BAT = Body Attitude Test; EAT-26 = Eating Attitudes test: cognitive restraint, uncontrolled eating, emotional eating).

Psychological tests did not reveal any significant differences in the comprehensive analyses of the weight groups in both boys and girls (Figure 6).



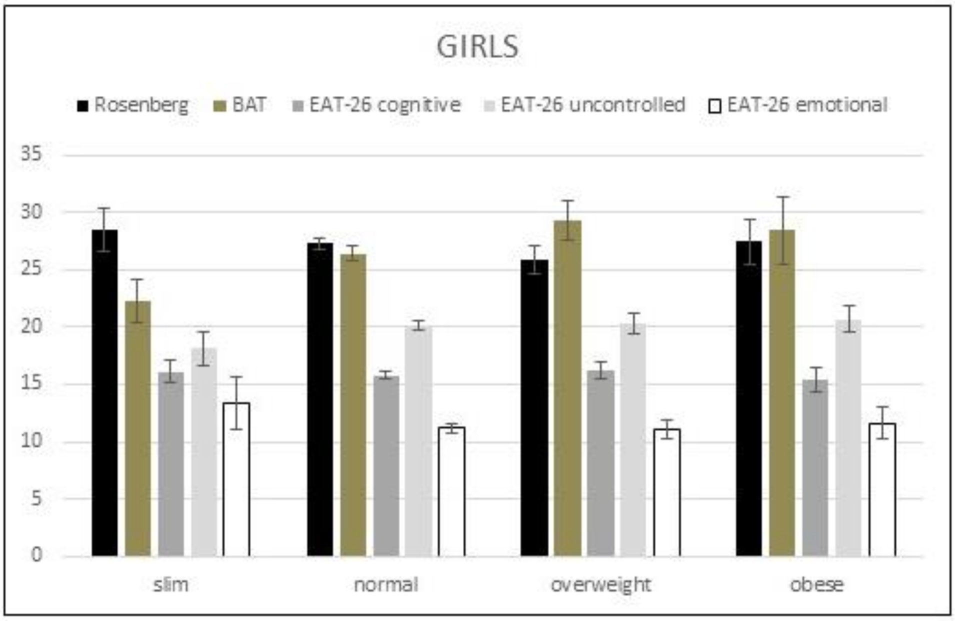


Figure 6. Psychological results in boys and girls showed no significant differences in the weight groups (data are shown as mean ± S.E.M, $p < 0.05$). (Rosenberg = Rosenberg Self-esteem Scale; BAT = Body Attitude Test; EAT-26 = Eating Attitudes test: cognitive restraint, uncontrolled eating, emotional eating).

The ANOVA analysis detected significant differences between girls BAT-W and BAT-B subgroups in Rosenberg Self-esteem Scale (21.7 ± 0.95 vs. 27.97 ± 0.42; $p < 0.001$) and in the eating attitudes, such as cognitive restraints (17.8 ± 0.69 vs. 15.5 ± 0.27; $p = 0.003$) and emotional eating (13.5 ± 1.04 vs. 10.9 ± 0.37; $p = 0.011$). The results showed significant differences between boys BAT-W and BAT-B subgroups in eating attitudes cognitive restraints subscale (19.0 ± 1.0 vs. 13.7 ± 0.27; $p = 0.03$) (Figure 7).

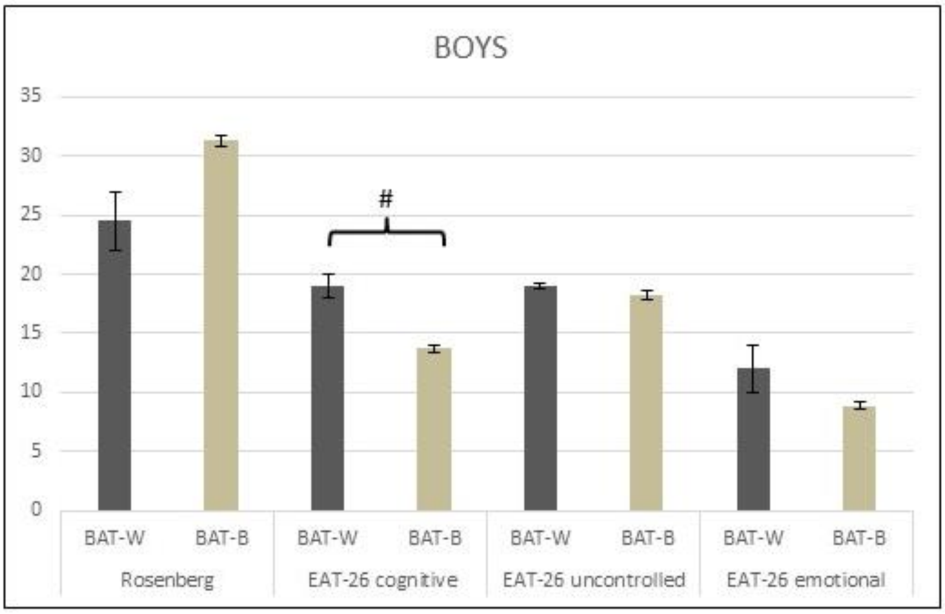
The first multilinear regression analysis revealed that gender (b = −0.31, $t = -6.41$, $p < 0.001$) and subjective body shape predicted self-esteem (b = 0.16, $t = 3.23$, $p = 0.001$).

Body attitudes were also influenced by gender (b = 0.39, $t = 8.71$, $p < 0.001$) and subjective body shape (b = −0.32, $t = -7.09$, $p < 0.001$).

The Uncontrolled eating subscale of the Eating attitudes was only affected by gender (b = 0.18, $t = 3.53$, $p < 0.001$), just as the Emotional eating subscale (b = 0.23, $t = 4.57$, $p < 0.001$). In this case, however, BMI also played a weaker role (b = −0.12, $t = -2.25$, $p < 0.05$).

Cognitive restraint, similarly to self-esteem, showed strong associations with subjective body shape (b = −0.22, $t = -4.32$, $p < 0.001$) and gender (b = 0.26, $t = 5.27$, $p < 0.001$) (Table 3).

Second multivariate linear regression and stepwise analyses were performed to predict shuttle run test as the dependent variable regarding Rosenberg Self-esteem Scale and BAT values. We revealed that both variables added statistically significantly to the prediction in boys $F(2, 163) = 3.189$, $p = 0.044$, R2 = 0.038.



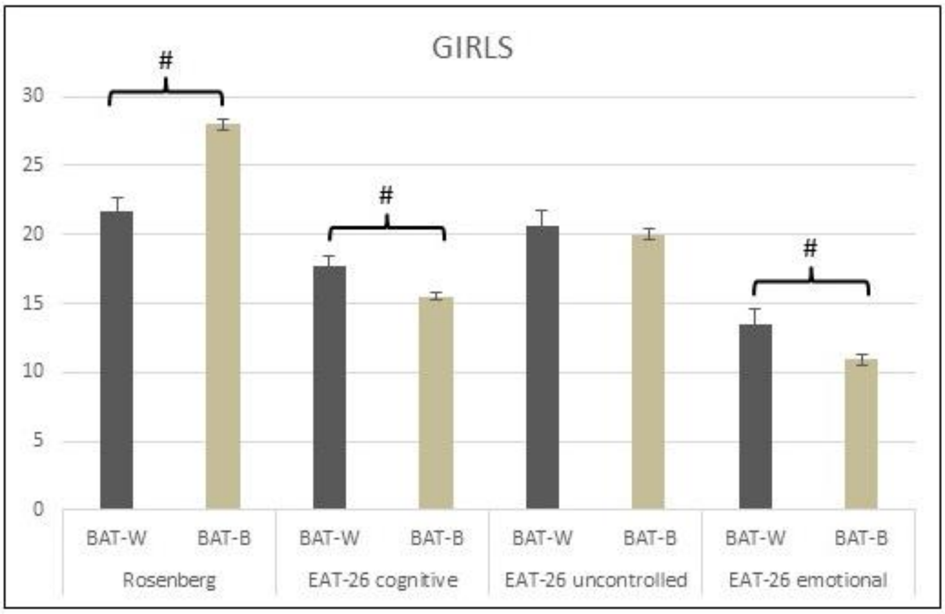


Figure 7. The analysis revealed significant differences between girls BAT-W (those with worse attitudes toward their body) and BAT-B (those with better attitudes toward their body) subgroups in Rosenberg Self-Esteem Scale and Eating attitudes cognitive restraints and emotional eating subscales. Additionally, our data showed significant differences between boys BAT-W and BAT-B subgroups in the cognitive restraints subscale of eating attitudes. (BAT-W: those with worse attitudes toward their body, BAT-B: those with better attitudes toward their body). #: significant difference, $p<0.05$

Table 3. Results of the regression analysis: standardized β and R2 values. (SBSH: Subjective body shape). *p<.05, **p<.001

Dependent Variables	Predictors				
	Age	**Gender**	**SBSH**	**BMI for Age**	R^2
Self-esteem (RSES)	0.09	−0.31 **	**0.16 ****	0.07	**0.16 ****
Body attitudes (BAT)	0.00	**0.39 ****	**−0.32 ****	0.01	**0.28 ****
Uncontrolled eating (UE)	−0.06	0.18	0.06	−0.02	0.04 *
Cognitive restraints (CR)	0.02	**0.26 ****	**−0.22 ****	−0.09	**0.12 ****
Emotional eating (EE)	−0.01	**0.23 ****	−0.07	−0.12*	0.07 **

5.4. Discussion

In our second work we investigated different psychological characteristics among adolescent boys and girls and examined gender differences and correlations with the BMI-for-age and cardiorespiratory performance. According to our results lower self-esteem and higher scores for BAT and each scale of eating attitudes, such as Uncontrolled Eating (UE), Cognitive Restraints (CR) and Emotional Eat-ing (EE) were measured among adolescent girls compared to boys. Interestingly, not objective body weight but subjective body shape and gender predicted self-esteem and BAT scores and the cognitive restraints in the eating attitudes. Uncontrolled and emotional eating subscales were primarily influenced by gender, while BMI played only a weaker role. Additionally, self-esteem and body image were positively associated with cardiorespiratory performance in the boys, but not among girls.

The proportion of overweight and obese adolescents in our study group (Figure 4A, B) is slightly higher when compared to international data. A total of 107.7 million children were obese in 2015 worldwide (142), thus, obesity prevalence was as high as 5% among children, while overweight and obesity prevalence combined was as high as 23% (10,145). Furthermore, overweight and obesity were more common in boys when compared to girls in our study (Figure 4A, B) which corresponds with international data (146).

In consideration of cardiorespiratory performance, measured by the shuttle run test, boys performed better than when compared with girls (Figure 4C) as it was anticipated, consistent with data in the literature (88). Thin and normal weight adolescents performed significantly better on the cardiorespiratory test than when compared with their overweight or obese peers, among both genders (Figure 4D), of which findings are also congruent with previous studies (147,148). Additionally, more girls have fallen into the Needs Improvement Zone than boys (41 vs. 35 %).

Cardiorespiratory performance and its association with different psychological variables have been previously investigated in children and adolescents. For instance, Morales et al. in a Spanish study examining 1596 children, aged 8–11 years, found that cardiorespiratory fitness in girls and muscular fitness in boys closely associated with most of the dimensions of health related quality of life, including physical and psychological well-being, moods and emotions, self-perception, parent relation, home life and social acceptance (149). In a study conducted in Australia, examining 821 elementary-school children, higher levels of cardiovascular fitness were found as a protective factor to body image concerns, regardless of the child's body composition (150). Interestingly, in accordance with our findings, cardiorespiratory performance was positively associated with self-esteem and body attitudes test results in our age-group (16.5 years) regarding adolescent boys, however, not in girls.

A relationship focusing on overweight, obesity and low self-esteem has been investigated several times and the results varied. In our findings, self-esteem was predicted by subjective body shape instead of objective bodyweight. Several studies depict lower self esteem among obese adolescents (106,151), while others found associations only among subgroups based on age or race (152,153) or for a specific domain of self-esteem (154). A literature review indicated it was unclear whether self-esteem was consistently related to obesity (155). There may be some other factors that mediate the relationship between obesity and psychological problems. According to earlier studies, body-image satisfaction may be the intermediate factor between obesity and self-esteem (156).

Assessing body image satisfaction, the Body Attitude Test (BAT) was used, which was originally designed for patients, primarily women suffering from eating disorders (142). In the current study, girls scored higher scores on BAT than boys that could mean that boys have more positive attitudes toward their bodies, but it is also possible that the questionnaire does not measure enough aspects of male body attitudes. Later, Probst et al. evaluated the psychometric properties of body image questionnaires including BAT among non-clinical female and male subjects and found that these tests can reliably differentiate between the two sexes and those individuals who are and who are not suffering from body image concerns (157).

In our study, no significant correlation was found among the actual weight status and body image satisfaction, neither the eating attitude subscales (Figure 6). According to the literature, there are many factors influencing body image and eating attitudes. Studies have shown that social media consistently and overly represent idealized body types which potentially contribute to poor body image and disordered eating behaviors which may be underpinned by the beauty and diet industries (158–160). Adolescent body image is also heavily influenced by family and social relationships. Adolescents who are exposed to negative body and diet conversations with friends and family members have higher levels of body dissatisfaction and higher BMIs and are manifested in unhealthy eating behaviors later in life (161,162).

In our study, positive body image was associated with higher self-esteem and lower cognitive restraints and emotional eating in the eating attitude subscales in girls and with lower cognitive restraints in boys (Figure 7). Previous studies indicated that positive body image has been associated with lower concerns regarding appearance, healthier BMI, increased physical activity and better general health habits in adolescents (163–166). On the other hand, body dissatisfaction may trigger emotional eating (167) which has been associated with greater adiposity and higher BMI (168,169). Furthermore, emotional eaters tend to turn to high-energy and low-nutrient foods in response to their emotional feelings (170). Restrained eaters take control over what they eat and when they eat, however, paradoxically, under certain conditions they lose control, for example during negative mood states (171).

Additionally, in our study, all aspects regarding eating attitudes were affected by gender. Girls were more prone to emotional and uncontrolled eating and cognitive restraints, when compared to boys and BMI, had only a weaker role in emotional and uncontrolled eating. It is well-known that eating disorders are more common in women than in men and adolescent girls are at high risk. Girls experience more food-related conflicts than when compared with boys and they also experience more dissatisfaction with their body that may affect weight regulation (172).

Finally, there may be some gender relevant analysis issues with the use of the EAT-26 questionnaire which was originally validated and used in female populations (130). However, in a recent study, Schaefer et al. have demonstrated that no items of EAT-26 met the criteria for statistically significant differential item functioning suggesting that the EAT-26 questionnaire operates similarly among males and females (173). Although EAT-26 seems to be an appropriate measure to assess thinness-oriented eating disorder symptoms in non- clinical samples of men, it may not evaluate symptoms that are more specific in the male population (e.g., muscularity-oriented concerns) (174).

Based on our results we want to emphasize that attention must be focused on both psychological and physical health during adolescence.

6. Future perspectives

6.1. Prevention of Obesity among Children and Adolescents

Family-based programmes that involve parents, may help children and adolescents to lose weight. There is some evidence that family-based behaviour modification programmes may help children and adolescents to lose weight. Educating parents on proper nutrition and dietary caloric intake requirements for their children is at the forefront for the prevention of obesity. Furthermore, parents who themselves eat healthy foods and do regular physical activity set a good example for their children (12).

Health-care providers and policymakers should increasingly invest in prevention strategies to lower childhood and adolescent obesity. There are number of school programs designed to promote physical activity, a healthy diet, and a reduction in sedentary lifestyles that can help reduce obesity in school children and adolescents. In the last decades, the Hungarian government has taken several significant measures to improve the eating habits of the population. In 2008, a law was introduced banning advertising that promotes empty calories in educational institutions. A decree has also been introduced to promote a healthy lifestyle, which provides free fruit for educational institutions participating in the program (175). A public health product tax was introduced in 2011 to curb the consumption of unhealthy foods. In 2013, a law on the restriction of trans- fatty acids in food was adopted. The regulation set maximum levels for trans-fatty acids, revised the conditions for marketing and introduced monitoring of the population's intake of trans- fatty acids, a measure that was uniquely stringent in Europe. In 2015, new, stricter dietary rules were introduced in public catering. The aim is to provide children with adequate energy and nutrition, with a stronger emphasis on healthy eating (176).

6.2. Increasing physical activity, decreasing sedentary time

Improving cardiorespiratory fitness could be a strategy of particular interest for improving the health-related quality of life of children and adolescents (149).

To prevent cardiovascular disease risk factors, physical activity levels should be higher than the current international guidelines of at least 1 hour per day of physical activity of at least moderate intensity. According to the The European Youth Heart Study achieving 90 min of daily activity might be necessary for children to prevent insulin resistance, which seems to be the central feature for cardiovascular disease risk (16).

A well-designed and implemented school health and physical activity program can have a positive effect on increasing the level of physical activity and reducing sedentary activity. We can encourage families to walk to school or work or take at least part of the way on foot.
Going to school includes a “dose” of physical activity in daily routine. This provides the first steps towards an active lifestyle from which they can move on to moderate and intense physical activities such as cycling, swimming and team sports. It is recommended to take active breaks at schools to reduce uninterrupted sitting time. Encourage children and adolescents to use the stairs instead of the elevators (95). Understanding the relationships between weight status and physical fitness and physical activity may help to increase physical activity (90).

6.3. Improving mental health and eating behavior in children and adolescents

Treating children's and adolescents' anxiety and depression can be an important effort to prevent obesity. Physicians, parents, and teachers need to be informed about specific comorbidities associated with childhood obesity so that they can take targeted interventions that can improve well-being (106). Interventions should recognize individual differences in setting motivational goals to achieve weight control. Pediatricians can improve self-esteem by advising parents and teens on the importance of limiting television time and recommending physical activity and participation in team sports (109).

Paying more attention to the pressure felt by adolescents and to being thin or muscular can help determine what makes some adolescents more vulnerable than their peers, improving our ability to detect and prevent eating disorders among them (119). Given that a positive body image has a significant impact on health and well-being, this can be an important area of intervention. In interventions program positive body image can be used to focus people on the positive instead of curing the negative. For example, adolescents need to be taught to focus on what they love and value about their bodies and how to take care of them, rather than how to stop their body's dislike (166).

Increasing body image and self-esteem can be one way to combat bad eating behaviors. The interrelationship between body appreciation and diet suggests that encouraging girls to take a balanced and non-restrictive approach to eating can help them appreciate their bodies. Increasing girls 'body appreciation can help them participate in exercise more during adolescence (165).

7. Summary of new findings

7.1. Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents

1. The cardiorespiratory performance of adolescent girls and boys was inversely associated with both overweight and obesity, and this association could be observed throughout the 4 years of our study.
2. Obesity has shown an inverse relation with muscle performance regardless of the age and gender of the adolescents.
3. A lower correlation between overweight and the strength of different muscle groups was found and depended on age and gender.

7.2. Examination of Self-Esteem, Body Image, Eating Attitudes and Cardiorespiratory Performance in Adolescents

1. Although overweight and obesity were more commonly seen in adolescent boys, girls were more prone to have lower levels of self-esteem, poorer body images and experienced increased problems regarding eating behaviors such as uncontrolled eating, cognitive restraints and emotional eating compared to boys.
2. No significant correlation was found between BMI and psychological test results in either boys or girls.
3. Cardiorespiratory performance was positively associated with self-esteem and body image among boys, and it had a negative correlation with body weight in both genders.
4. Interestingly, not objective body weight but subjective body shape satisfaction and gender predicted self-esteem, body attitude and the cognitive restraints in the eating attitudes.
5. Uncontrolled and emotional eating were primarily influenced by gender, while BMI played only a weaker role.

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10. Publications of the author

10.1. Topic related journal articles

Petrovics, P.; Sandor, B.; Palfi, A.; Szekeres, Z.; Atlasz, T.; Toth, K.; Szabados, E**.** Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents. Int. J. Environ. Res. Public Health. 2020, 18, 134. doi:10.3390/ijerph18010134.

Quartile Ranking: Q2 Impact Factor: 3.390 (2020)

Petrovics, P.; Nagy, A.; Sandor, B.; Palfi, A.; Szekeres, Z.; Toth, K.; Szabados, E. Examination of Self-Esteem, Body Image, Eating Attitudes and Cardiorespiratory Performance in Adolescents. Int. J. Environ. Res. Public Health. 2021 Dec 14;18(24):13172. doi: 10.3390/ijerph182413172.

Quartile Ranking: Q2 Impact Factor: 3.390 (2020)

10.2. Other articles

1. Praksch, D**.;** Kovacs, D.; Sandor, B.; **Petrovics, P**.; Kovacs, K.; Toth, K.; Szabados, E. Impact of home- and center- based physical training program on cardio-metabolic health and IGF-1 level in elderly women. European Journal Aging and Physical Activity.

Quartile Ranking: Q2 Impact Factor: 2.65 (2017/2018)

10.3. Published abstracts

1. Praksch, D.; Kovacs, D.; Sandor, B.; Totsimon, K.; Mezey, B.; **Petrovics, P.;** Wilhelm, M.; Kesmarky, G.; Toth, K.; Szabados, E. Ambuláns és otthoni fizikai tréning hatásának vizsgálata magas kardiovaszkulárisrizikójú nőbetegek körében. Magyar Haemorheologiai Társaság XXIII. MagyarMikrocirkulációs és Vaszkuláris Biológiai Társaság Magyar Szabadgyök-Kutató Társaság V. Közös Kongresszusa, Balatonkenese, 2016. április 22-23. Érbetegségek. 2016; 23 p. 30. (2016)

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4. **Petrovics, P.;** Nagy, A.; Palfi, A.; Krizsan, A. Praksch D, Toth K, Szabados E. Életmódi szokások, tápláltsági állapot és pszichés jóllét felmérése 14-18 éves diákoknál. A Magyar Kardiológusok Társasága 2018. évi Tudományos Kongresszusa. Balatonfüred Cardiologia Hungarica 2018;48: Suppl. C, p 89. (2018)

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Article

Association between Obesity and Overweight and Cardiorespiratory and Muscle Performance in Adolescents

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Abstract: The high prevalence of obesity in childhood and adolescence has major public health consequences, since it is associated with various chronic diseases in the short- and long-term. The goal of our study was to examine the possible association between obesity and overweight and cardiorespiratory and muscle performance during a 4-year follow up period in adolescents. The body mass index (BMI) and physical performance of adolescents (360 girls and 348 boys) between 14–18 years of age was measured twice a year, and the possible correlation between overweight and obesity and cardiorespiratory and muscle performances were investigated. Our results revealed that cardiorespiratory performance increased significantly in boys during the 4 years ($p < 0.001$), but the aerobic performance of girls only showed seasonal fluctuation. Muscle performance significantly increased both in boys and girls ($p < 0.001$). Inverse association between obesity and cardiorespiratory and muscle performance was proved. Overweight was also inversely correlated with cardiorespiratory performance, but it demonstrated no correlation with muscle strength. Avoiding increased BMI and decreased physical fitness is essential for adolescents' health to prevent short- and long-term adverse effects.

Keywords: cardiorespiratory performance; muscle performance; adolescents; obesity; overweight

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1. Introduction

The worldwide prevalence of obesity among adults as well as in children and adolescents has markedly increased over the past three decades leading to the so-called obesity epidemic. According to the latest data in the literature, childhood and adolescent obesity is as high as 18.5% in the USA [1], and 15% in Europe [2]. The prevalence of obesity in adolescence has stabilized at a high level in developed countries [3–5] but is still increasing in developing countries [5–7]. Besides many short-term effects of obesity such as cardio-metabolic, respiratory, musculoskeletal, endocrine, psychosocial, increased cancer risk, etc. [8–11], a high percentage of children and adolescents track their obesity into adulthood [12] resulting in several chronic diseases [13] and even premature death [14].

It is recommended that children and adolescents aged 6–17 years do 60 min or more of physical activity each day [15]. Despite guidelines and recommendations [3,6,15,16], a decline in physical activity (PA) and cardiorespiratory and muscular fitness levels [17,18] has been reported worldwide among children and adolescents [19,20]. Cardiorespiratory fitness is defined as the overall capacity of the cardiovascular and respiratory systems to provide adequate amount of oxygen to the body during prolonged or strenuous exercise.

Low cardiorespiratory fitness in children and adolescents has been associated with increased body fatness [20,21], hypertension, [20,22] increased risk of metabolic syndrome [9,18,23], and worse academic performance [24,25]. Besides cardiorespiratory fitness, muscular fitness is independently and inversely associated with clustered metabolic risk during adolescence [26]. The main health-related muscular fitness components are maximal (isometric and dynamic), explosive, endurance and isokinetic strength [25]. Muscular endurance is the ability of a muscle or muscle group to perform repeated contractions. A large meta-analysis revealed negative association between muscular fitness in childhood and adolescence and adiposity and cardiometabolic parameters in adulthood. The effects of endurance (push-ups, sit-ups, bent arm hang, etc.) and strength tests (handgrip, standing long jump, vertical jump, etc.) were similar. [27]. Furthermore, a negative association between standing long jump test, which assesses lower-limb maximal dynamic contraction, and total cholesterol in overweight and obese male adolescents was observed [28].

Previous studies have shown a strong correlation between increased body mass index (BMI) and reduced cardiorespiratory fitness in children and adolescents [4,29]. The association between increased body weight and decreased cardiorespiratory fitness is unequivocal in most of the studies [30–32] but its interaction with muscle performance is more ambiguous [9,26]. Furthermore, most of the studies examining the association between childhood and adolescence physical fitness and BMI are cross-sectional. In our study, we have measured the cardiorespiratory and muscle performance of adolescents between 14 and 18 years of age twice a year and investigated the possible association between overweight and obesity and cardiorespiratory and muscle performance and observed age and gender differences. Our aim was to investigate whether overweight shows the same relationship to cardiorespiratory and muscle performance as obesity.

2. Materials and Methods

2.1. Subjects

A total of 708 students from four-grade high school classes were enrolled in the study (360 girls with an average age of 14.2 ± 0.4 years, and 348 boys with an average age of 14.1 ± 0.4 years) at the beginning of high school (9th grade) in Baranya county, Hungary. Measurements (body weight and height, cardiorespiratory and muscle performance) were performed twice a year (autumn and spring) for 4 years, until the end of high school (12th grade). The inclusion criteria were as follows: students who had just started high school and agreed to participate in the study. Exclusion criteria were any medical conditions that prevented student attending physical exercise classes or did not agree to participate in the study. A written informed consent was obtained from the adolescents for the measurements and the anonymous use of data for scientific purposes. Parents were also asked to sign the form to allow the measurements and data handling. The study was approved by the Regional Ethics Committee of the University of Pecs.

2.2. Body Weight, BMI, and Obesity Measurements

Body weight was measured to the nearest 0.1 kg using an electronic digital body weight weighing scale, and height was measured to the nearest 0.1 cm with a manual height board. To screen for overweight and obesity, body mass index (BMI) and sex- and age-specific BMI-for-age were calculated using the BMI-for-age BMI growth charts [19]. Adolescents with a BMI-for-age ≥95th percentile were considered obese, between the 85th and 95th percentiles were classified as overweight, and with a BMI-for-age of <85th percentile were considered normal. The cut-off value for underweight was less than the 5th percentile of the BMI-for-age [7,19].

2.3. Measurements of Cardiorespiratory Performance

For the assessment of the cardiorespiratory performance of the adolescents, the 12-min run–walk test was used. The students ran, jogged, or walked on a flat course as far as they could in 12 min, and the distance covered was recorded in meters [33].

2.4. Measurements of Muscle Performance

Muscle performance was assessed using three motor tests. Standing long jump test: To assess leg dynamic muscle strength, standing long jump tests were performed. Children stood behind a line marked on the ground and attempted to jump as far as they could, landing on both feet without falling backwards. The measurement was taken by a tape measure from the take-off line to the nearest point of contact, with 1 cm accuracy, on the landing (back of the heels). A maximum of three attempts were allowed, and the best result was recorded in centimeters [34]. Push-up test: The endurance and dynamic strength of shoulder and arm muscles were measured by push-up tests. Students bent and stretched the arms in a push-up position with only the hands and the toes touching the floor, while their torso remained straight. They performed as many repetitions as they could until exhaustion, and the number of push-ups was recorded [35]. Sit-up test from supine position: To measure the endurance and dynamic strength of abdominal muscles, sit-up tests were performed. Students lied on a mat on their back while bending both knees at 90-degree angles, keeping their feet on the mat, pointing the elbows forwards, putting the fingers behind the ears, and flattening the stomach. They raised the torso off the floor, touching their thighs with the elbows, then descended back and returned to the starting position with quick steady tempo/space until exhaustion or for a maximum of 4 min. The test ended when the students were no longer able to continue the sit-ups or until the end of the 4th minute. The number of sit-ups was recorded [35].

2.5. Statistical Analysis

The significance level was defined as $p < 0.05$. IBM SPSS statistical software (New York, NY, USA), version 11.0.1 was used to conduct descriptive analyses and to describe the sample. According to the Kolmogorov–Smirnov normality test, data collection revealed a significant deviation from the normal distribution. Therefore, the nonparametric Friedman test together with the post-hoc analysis through Wilcoxon signed-rank tests were conducted with a Bonferroni correction to analyze potential changes between gender groups, and the nonparametric Kruskal–Wallis test was performed to describe potential changes between the different weight subgroups.

A gender specific sample size and power analysis was performed for the investigated population using PS program version 3.1.2. For the sample size of $n = 254$ boys needed to detect a true difference of $\delta = 10.25$ in sit-up test values with 90.08% power, where type I error probability is $\alpha = 0.05$. For the sample size of $n = 255$ girls needed to detect a true difference of $\delta = 8.28$ in sit-up test values with 93.52% power, where type I error probability is $\alpha = 0.05$.

3. Results from Gender Within-Groups Analyses

3.1. Changes in the BMI-for-Age during the 4 Years

At the beginning of our study, 4 percent of the girls were underweight, 75 percent normal weight, 15 percent overweight, and 6 percent obese. With respect to the boys, 6 percent were underweight, 69 percent normal weight, 15 percent overweight, and 10 percent obese. In the spring of 12th grade, 8 percent of the girls were underweight, 75 percent normal weight, 12 percent overweight and 5 percent obese. With respect to the boys, 7 percent were underweight, 72 percent normal weight, 11 percent overweight, and 10 percent obese. Among girls, the average baseline BMI-for-age of 20.52 ± 2.87 did not increase significantly during the 4-year observational period, as it was 21.01 ± 3.05 at the end of the 12th grade ($p = 0.120$). Similarly, there was no significant change in the average BMI-for-age of the boys. It was 20.80 ± 3.75 in the autumn of 9th grade, and 22.01 ± 3.71 in the spring of 12th grade ($p = 0.100$).

3.1.1. Cardiorespiratory Performance of Boys and Girls during the 4 Years

There was a statistically significant difference between the 4-year run–walk test results of genders (girls: $\chi^2(2) = 52.32$, $p < 0.001$; boys: $\chi^2(2) = 93.64$, $p < 0.001$). There were significant differences between the 9th grade autumn and 12th grade spring run-walk test results among boys ($Z = -4.726$, $p < 0.001$, $\eta^2 = 11.99$) (Figure 1A). Among girls, only a seasonal variation could be observed (there was no significant difference between the 9th grade autumn and 12th grade autumn data in girls; $Z = -0.569$, $p = 0.569$, $\eta^2 = 12.01$).

3.1.2. Muscle Performances of Boys and Girls during the Four Years

The lower limb dynamic, the strength and endurance of hip flexors and abdominal muscles, shoulder and arm muscle strength, significantly improved during the four years in both girls {1: $\chi^2(2) = 67.147$, $p < 0.001$; 2: $\chi^2(2) = 183.16$, $p < 0.001$; 3: $\chi^2(2) = 148$, $p < 0.001$} and boys {1: $\chi^2(2) = 336.395$, $p < 0.001$; 2: $\chi^2(2) = 73.169$, $p < 0.001$; 3: $\chi^2(2) = 210.542$, $p < 0.001$}. There were significant differences between the 9th grade autumn and 12th grade spring results of the standing long jump distance (boys $Z = -10.404$, $p < 0.001$, $\eta^2 = 11.95$; girls $Z = -4.153$, $p < 0.001$, $\eta^2 = 12.004$) (Figure 1B), sit-up test (boys $Z = -3.269$, $p < 0.001$, $\eta^2 = 12.003$; girls $Z = -8.073$, $p < 0.001$, $\eta^2 = 11.98$) (Figure 1C), and push-up test results (boys $Z = -6.946$, $p < 0.001$, $\eta^2 = 11.98$; girls $Z = -5.746$, $p < 0.001$, $\eta^2 = 11.99$) (Figure 1D).

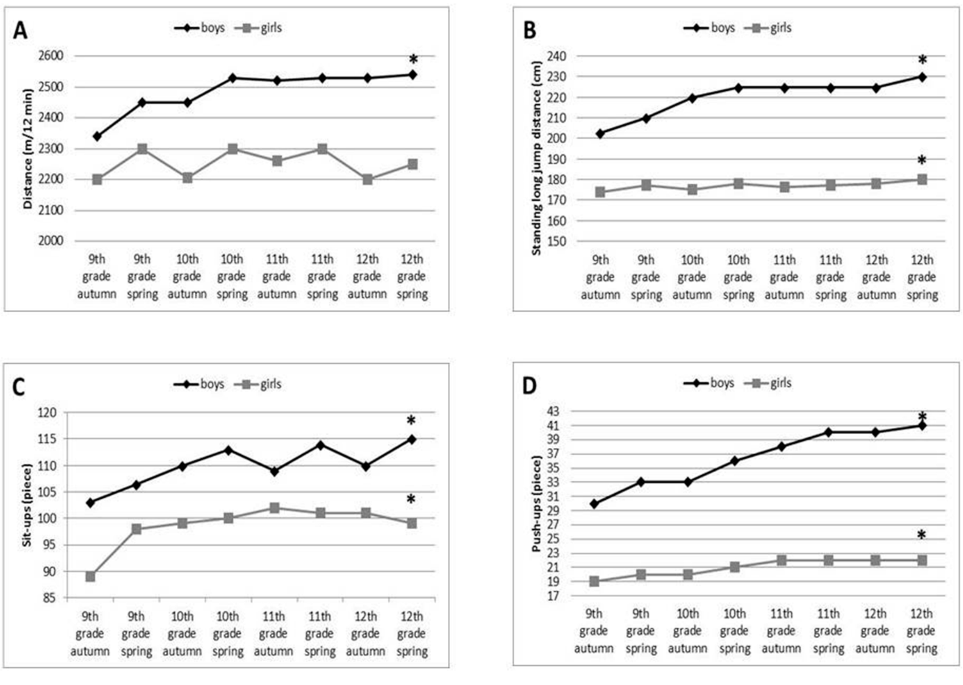

Figure 1. Changes in muscle strength and aerobic fitness between 9th and 12th grade in both genders. Significant improvement was detected in boys' aerobic capacity according to 9th grade autumn and 12th grade spring data (data are shown as median, * = $p < 0.05$). However, only a seasonal variation was revealed in girls' aerobic capacity during the 4 years (**A**). Significant improvement was detected in leg dynamic muscle strength (measured with long jump distance) (**B**), in the strength and endurance of abdominal muscles (measured by sit-up tests) (**C**), shoulder and arm muscles (measured by push-up tests) (**D**) in both genders during the 4-year observational period (data are shown as median, * = $p < 0.05$).

3.2. Results from Between-Weight-Groups Analyses

Association between obesity and overweight and cardiorespiratory performance.

The Kruskal–Wallis H test showed a significant association between weight status and run-walk test results: the performance of overweight and obese girls was significantly lower than that of classmates with normal weight in the 9th grade ($\chi^2(2) = 102.943$, $p < 0.001$, $\eta^2 = 0.292$), and in the 12th grade ($\chi^2(2) = 96.844$, $p < 0.001$, $\eta^2 = 0.274$). Similar results were observed among boys in 9th grade ($\chi^2(2) = 109.655$, $p < 0.001$, $\eta^2 = 0.33$) and in 12th grade ($\chi^2(2) = 86.406$, $p < 0.001$, $\eta^2 = 0.258$) (Figure 2A) (Table 1).

Table 1. Mean rank values by the Kruskal–Wallis test for between weight-group analyses.

GIRLS.						
performance type	9th grade			12th grade		
	obese	overweight	normal	obese	overweight	normal
run-walk	19.61	102.06	207.97	15.21	102.37	208.8
lower limb	65.77	150.18	193.78	28.66	169.88	191.42
hip flexor and abdominal muscle	37.45	140.99	198.26	29.21	153.57	194.29
shoulder and arm muscle	39.09	159.69	194.77	21.71	158.38	193.1
BOYS						
	9th grade			12th grade		
performance type	obese	overweight	normal	obese	overweight	normal
run-walk	22.97	129.59	200.5	27.37	165.21	195.11
lower limb	70.74	143.93	192.39	35.53	160.86	195.38
hip flexor and abdominal muscle	44.19	174.15	192.62	48.09	161.28	196.98
shoulder and arm muscle	75.28	159.66	188.1	54.29	159.66	192.52

3.2.1. Association between Obesity and Overweight and Lower Limb Performance

The performance of overweight and obese girls was significantly lower than that of normal weight girls in 9th grade ($\chi^2(2) = 37.85$, $p < 0.001$, $\eta^2 = 0.102$). In 12th grade, only obese girls provided significantly lower performance $\chi^2(2) = 44.341$, $p < 0.001$, $\eta^2 = 0.121$). Similar results were found among boys in 9th grade ($\chi^2(2) = 50.906$, $p < 0.001$, $\eta^2 = 0.148$), and in 12th grade ($\chi^2(2) = 82.886$, $p < 0.001$, $\eta^2 = 0.247$) (Figure 2B) (Table 1).

3.2.2. Association between Obesity and Overweight and Hip Flexor and Abdominal Muscle Performance

Nonparametric analyses revealed an association between weight status and hip flexor and abdominal muscle strength in the adolescents. The median maximal performance of overweight and obese girls was significantly lower in 9th grade compared with normal weight girls ($\chi^2(2) = 58.752$, $p < 0.001$, $\eta^2 = 0.163$). In 12th grade, only the obese girls' performance was lower ($\chi^2(2) = 47.980$, $p < 0.001$, $\eta^2 = 0.132$). Among boys, only obesity was associated with worsened results of the sit-up tests, but no association between overweight and abdominal muscle performance could be observed ($\chi^2(2) = 65.282$, $p < 0.001$, $\eta^2 = 0.193$) neither in 9th nor in 12th grade ($\chi^2(2) = 68.863$, $p < 0.001$, $\eta^2 = 0.204$) (Figure 2C) (Table 1).

3.2.3. Association between Obesity and Overweight and Shoulder and Arm Muscle Performance

The push-up data were inversely associated only with obesity in girls ($\chi^2(2) = 48.853$, $p < 0.001$, $\eta^2 = 0.134$ in 9th grade; $\chi^2(2) = 51.102$, $p < 0.001$, $\eta^2 = 0.141$ in 12th grade) and similarly in boys (in 9th grade $\chi^2(2) = 41.229$, $p < 0.001$, $\eta^2 = 0.118$; in 12th grade: $\chi^2(2) = 57.717$, $p < 0.001$, $\eta^2 = 0.169$). The performance of overweight boys and girls was similar to the normal weight peers also in 9th and 12th grade (Figure 2D) (Table 1).

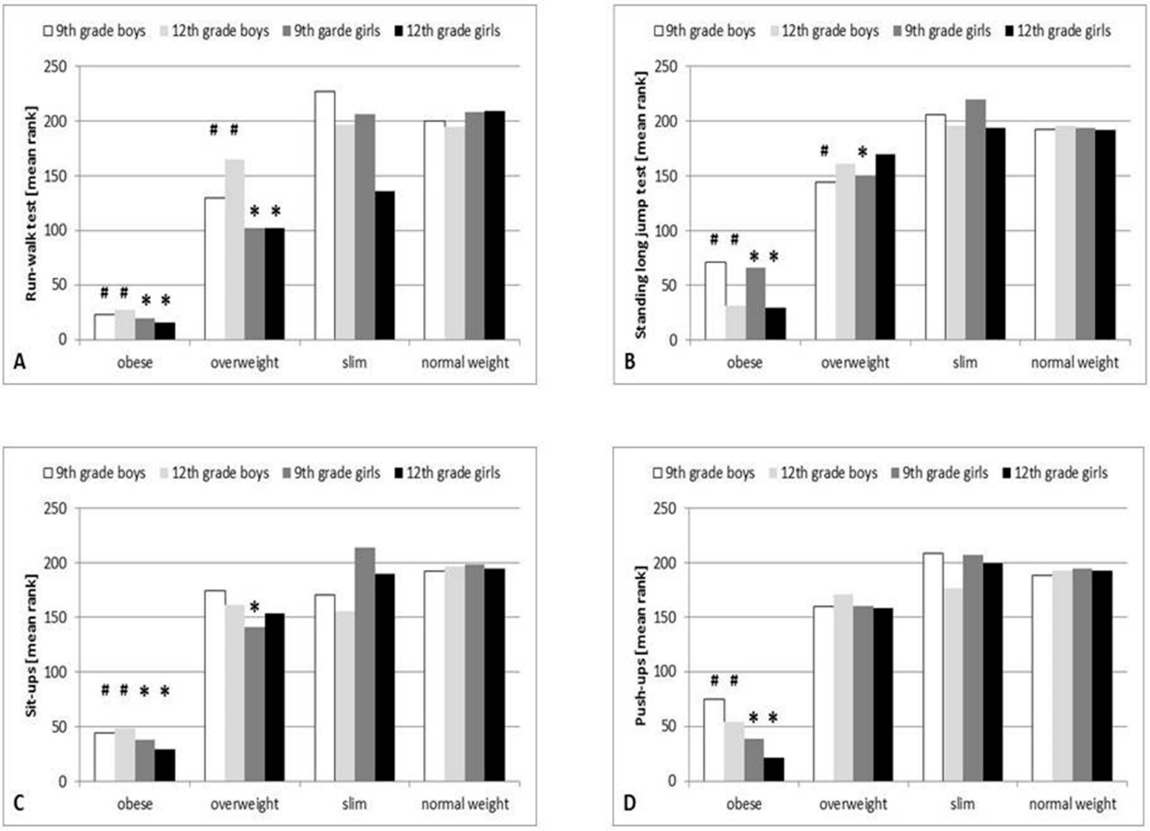

Figure 2. Association between body mass index (BMI)-for-age and aerobic and muscular fitness in adolescents. Run-walk test results are influenced by weight status in both genders (data are shown as mean rank, * = $p < 0.05$ for obese and overweight girls vs. normal weight girls; # = $p < 0.05$ for obese and overweight boys vs. normal weight boys) (**A**). Long jump test data were only influenced by obesity among 12th grade students (girls and boys, data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**B**). Sit-up test results were significantly associated with obesity, performance and gender (data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**C**). Push-up test results were significantly influenced by obesity, but not by overweight in both genders (data are shown as mean rank, * = $p < 0.05$ for obese girls vs. normal weight girls; # = $p < 0.05$ for obese boys vs. normal weight boys) (**D**).

3.3. Regression Analyses:

Multivariate linear regression and stepwise analyses of the data from baseline BMI, sit-up and cardiorespiratory performance in 11th grade were performed to predict cardiorespiratory performance at the end of the observational period. These variables statistically significantly predicted changes in end cardiorespiratory performance (F (5, 342) = 9752.34, $p < 0.0005$, $R^2 = 0.993$).

4. Discussion

We have examined the association between the BMI-for-age and the cardiorespiratory and muscle performance of adolescents between 14 and 18 years of age. Our results show that cardiorespiratory performance increased significantly in boys during the 4 years, meanwhile in girls it only showed seasonal fluctuation. The strength of leg, shoulder and arm and abdominal muscles significantly increased both in boys and girls, but boys showed a more pronounced improvement. There was no significant change in the BMI-for-age during the examined period either in boys nor in girls. An inverse association between obesity and overweight and cardiorespiratory performance of the adolescents regardless of their age and gender was revealed. Worsening muscle performances were associated primarily with obesity. There was no association between overweight and shoulder and arm muscle performance in any age categories neither in girls nor in boys. Overweight was negatively correlated with lower limb strength in 9th grade girls and boys, and with abdominal muscle performance only in 9th grade girls.

The physical performance of adolescents in our study was similar to data of a recent survey examining children and adolescents in 30 European countries [36]. This study showed that boys performed better than girls in muscular strength, power and endurance and physical fitness generally improved at a faster rate in boys than in girls, especially during the teenage years. In our study it was also found that the cardiorespiratory performance of adolescent girls showed a seasonal fluctuation, as the results of spring surveys were always better compared to the preceding autumn results, and no continuous development could be observed. Although we have not examined the reason of this phenomenon it might be due to the lower physical activity and increased weight gain during the summer holiday among adolescent girls as was suggested in a previous research [37]. The strength and endurance of the lower limb, the abdominal, and the shoulder and arm muscles of both girls and boys significantly increased during the 4-year, but the improvement was significantly lower among girls, so the existing sex-differences further increased during this period (Figure 1B–D), which is also in accordance with previous data [36].

No significant change in the BMI-for-age was observed in our study neither in boys nor in girls during the 4-year. The proportion of normal weight girls remained the same (75%) and a slight decrease in the proportion of overweight (15% vs. 12%) and obese (6% vs. 5%) girls could be observed. With respect to the boys, a slight increase in the proportion of normal weight (69% vs. 72%), and a slight decrease in overweight (15% vs. 11%) boys could be measured, while the number of obese boys remained the same (10%) and was higher compared to that of girls'. In our sample of adolescents, the prevalence of obesity and overweight was lower than those reported in the literature [1,2].

The cardiorespiratory performance showed an inverse correlation with the BMI-for-age of the adolescents. The running distances of both overweight and obese girls and boys were significantly shorter than those of normal weight children (Figure 2A), regardless of their age. The association between the weight status and cardiorespiratory and muscle performances has been examined previously among adolescents. All studies concluded that there was a strong and inverse association between BMI status and cardiorespiratory performance [30,31,38,39]. However, the association between BMI and the muscle performance of adolescents shows greater variability. In a Finnish study it was found that both overweight and obesity significantly affected all aerobic and muscle tests (sit-ups, five-jump, back-and-forth jumping, ball skills, coordination, and endurance shuttle run tests), with the exception of the sit-and-reach test, and overweight and obesity had the most negative association with cardiorespiratory performance and muscle endurance tests [38]. Examining 9 different muscular strength tests and the body weights of Spanish children (1513 boys and 1265 girls) aged 6 to 17.9 years it was found that normal weight children showed significantly higher performance than their overweight and obese counterparts in lower body explosive strength tests and in the push- up test in boys and bent arm hang test in both boys and girls, and boys had significantly better scores than girls in all the studied tests [40]. Taiwanese youth aged 10 to 18 years showed decreased fitness levels for lower body explosive strength and cardiorespiratory endurance in both sexes for the obese and overweight children and adolescents (sit-up, flexibility and abdominal muscular strength/endurance) [39].

In our study, obesity showed negative association with the performance of all examined muscle groups (lower limb, shoulder and arm and abdominal), and this inverse association could be observed throughout the 4 years and no gender differences could be observed. However overweight had no such clear inverse association with the muscle performance of the adolescents. Only the lower limb muscle strength in 9th grade in boys and girls and the abdominal muscle strength and endurance in 9th grade girls were inversely associated with overweight. The shoulder and arm muscle performance were not affected by overweight neither in boys nor in girls in any age categories.

There are numerous studies in the literature to show that childhood obesity is strongly associated with increased risk of many chronic diseases in the short- and long-term [7–13]. Additionally, cardiorespiratory and muscle performance is independently and inversely associated with cardiovascular (CV) and metabolic risk factors in adolescents [7,9,25,26]. The Aerobics Center Longitudinal Study [41] and a Finnish cohort [42] also confirmed that better CV health in childhood promotes CV health in adulthood. Finally, we want to emphasize that physically active life in adolescence is associated with healthy weight, better cardio-metabolic health, increased bone mass, muscle strength and flexibility, improved academic performance, mental health, mood and sleep and social behavior [43].

Limitations

Although we have obtained new data on the association of the BMI-for-age and physical performance of adolescents over a 4-year period, our study has also some limitations such as using only the BMI-for-age determining obesity and overweight, and body composition was not measured. Furthermore, the percentage of obese and overweight adolescents was relatively small in our sample, therefore further investigations are needed to establish our findings.

5. Conclusions

In our study the cardiorespiratory performance of adolescent girls and boys was inversely associated with both overweight and obesity, and this association could be observed throughout the 4 years. In addition, obesity also showed an inverse relation with muscle performance regardless of the age and gender of the adolescents. In contrast, the association between overweight and the strength of different muscle groups showed age and gender differences. Based on our data more attention is needed to maintain the normal weight status and physical performance of adolescents since increased BMI is negatively associated with most physical fitness parameters.

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Article

Examination of Self-Esteem, Body Image, Eating Attitudes and Cardiorespiratory Performance in Adolescents

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Abstract: Self-esteem, body image and eating attitudes are important characteristics regarding adolescent mental health. In our present work, we aimed to investigate these psychological items in adolescent boys and girls examining gender differences and correlations with the BMI-for-age and cardiorespiratory performance. 374 students (209 girls with an average age of 16.4 ± 1.08 years, and 165 boys with an average age of 16.5 ± 1.03 years) underwent investigation using the Rosenberg self-esteem scale, EAT-26 and BAT questionnaires. The BMI-for-age was calculated with BMI growth charts and the cardiorespiratory performance was measured with the 20 m shuttle run test. Our results showed that adolescent girls scored lower self-esteem and higher values for BAT and each scale of eating behaviors, such as uncontrolled eating, cognitive restraints and emotional eating compared to boys despite the fact, that obesity and overweight were more common among boys. No significant correlation was found between BMI and psychological test results in either boys or girls, however, subjective body shape and gender predicted self-esteem and BAT scores and the cognitive restraints in the eating attitudes. Uncontrolled and emotional eating were primarily influenced by gender, in which BMI played only a weaker role. Cardiorespiratory performance was positively associated with self-esteem and body image among boys, and it had a negative correlation regarding BMI in both genders.

Keywords: adolescent; self-esteem; body image; eating attitudes; cardiorespiratory performance

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1. Introduction

Adolescence represents a sensitive period in which significant physical and psychological changes occur. Psychological characteristics, such as self-esteem and positive well-being may play a pivotal role in physical health. Better mental health during adolescence predicts better general health and fewer risky health behaviors during young adulthood [1]. Self-esteem can be defined as a subjective self-assessment based on prior learning and experiences and reflects how an individual sees and evaluates oneself [2]. Lower self-esteem can be a causal factor for depression, anxiety, eating disorders, high-risk behaviors, and social functioning [3]. In adolescence, a decline in the level of self-esteem can be observed [4], especially among girls [5]. Additionally, overweight and obese adolescents frequently experience low self-esteem. Interestingly, authors in a large meta-analysis found no improvement in self-esteem in obese or overweight adolescents following significant weight loss [6]. Good self-esteem facilitates engaging in health-promoting behaviors and maintaining good health [7]. Inversely, inadequate self-esteem may result in risk behaviors [8] and has been related to undesirable eating behaviors, an inactive lifestyle, diminished performance in areas of academics and elevated risk in developing symptoms associated with depression [9].

Body image, another remarkable psychological factor in adolescence, was defined as 'a person's perceptions, thoughts, and feelings about his or her body' by Grogan [10]. Body dissatisfaction occurs when views of the body are deemed negative and the body image represents a discrepancy between the individual's actual and ideal body [11]. Previous research suggests that women and adolescent girls experience higher levels of body dissatisfaction and disturbed eating patterns than when compared with their male counterparts [12,13]. Women are more likely than men to describe themselves as fat or weigh themselves more often and they are also generally more dissatisfied with their physical appearance than are men [14]. The body dissatisfaction that is presented by adults can already be found in adolescents [15]. It is estimated that nearly 50% of adolescent girls are dissatisfied with their bodies [16]. Body dissatisfaction may lead to adverse physical and mental health consequences, including depression, anxiety [17], low self-esteem [18], and eating disorders [19,20].

Unhealthy eating attitudes and behaviors are quite common among young people, and overweight and obesity imply a particularly high risk of developing such behaviors [21,22]. The three most frequently studied areas regarding eating attitudes are uncontrolled eating (UE), cognitive restraint (CR), and emotional eating (EE). UE refers to an inclination to overeat, including the feeling of losing control [23]. CR suggests a tendency to consciously restrict food intake rather than using physiological cues (i.e., hunger and satiety) as regulators of eating [24]. Finally, emotional eaters tend to eat in response to emotional triggers rather than real physiological needs [25]. Emotional eating also implies or predicts weight gain [26] and difficulty of losing weight [27]. Compared to non-emotional eaters, emotional eaters are more prone to consume sweet and high-fat foods [28] and are more likely to eat in response to stressors [29]. Many eating disorders appear to start soon after puberty and persist through secondary school years [30]. However, most of these studies focus on girls and women and less attention is paid to boys and men, albeit eating disorders in men are increasing [31]. In the current study, we focus on disordered eating attitudes that do not reach clinical levels but might be predictive for developing an eating disorder.

Cardiorespiratory performance, which is a good indicator of overall physical health, can be defined as the capacity of the cardiovascular and respiratory systems to provide an adequate amount of oxygen during prolonged or strenuous exercise. Low cardiorespiratory fitness in children and adolescents has been associated with increased body fatness [32,33], hypertension [32,34] increased risk of metabolic syndrome [35,36] and depression [37]. Improvement in cardiorespiratory fitness has a positive effect in combating depression, anxiety, mood status, self-esteem, and is seemingly associated with higher performance in education [38]. In a recent clinical trial, cardiorespiratory fitness was independently and positively associated with self-related health in children (8–11.9 years age) and adolescents (12–17.9 years age) at baseline, including a two-year follow-up [39].

In our present work, we aimed to investigate the correlations depicted in areas of self-esteem, body image, eating attitudes and BMI-for-age and cardiorespiratory performance among adolescent boys and girls, since the correlations between these psychological and physical items have not been unequivocally described in previous studies. Furthermore, in the current study, we attempted to compare whether there is a difference in gender concerning our physical and psychological variables.

2. Materials and Methods

2.1. Study Participants

A total of 374 students from fourth-grade high school classes were enrolled in our prospective study (209 girls with an average age of 16.4 ± 1.08 years, and 165 boys with an average age of 16.5 ± 1.03 years). Written informed consent was obtained from all the participating adolescents for the measurements and the anonymous use of data purely for scientific purposes. Parents were also asked to sign the form authorizing the measurements and data handling. The study was approved by the Regional Ethics Committee of the University of Pecs (7522-PTE 2018) and was performed in 2018.

2.2. Measurements

Bodyweight was measured to the nearest 0.1 kg using an electronic digital body weighing scale, and height was measured to the nearest 0.1 cm using a manual height board. To screen for overweight and obesity, body mass index (BMI) and sex- and age-specific BMI-for-age were calculated using the BMI-for-age CDC growth charts [40]. Adolescents with a BMI-for-age $\geq$ 95th percentile were considered obese, between the 85th and 95th percentiles were classified as overweight, and with a BMI-for-age of <85th percentile were considered normal. The cut-off value for underweight was less than the 5th percentile of the BMI-for-age.

In consideration of the assessment regarding the cardiorespiratory performance of the adolescents, a 20 m shuttle run test was used. The 20 m shuttle run test is the most widely used field-based assessment of cardiorespiratory fitness [41].

This test involves continuously running between two lines, 20 m apart, in time, to recorded beeps. The participants are first positioned behind one of the lines facing the second line and begin running when instructed by the recording. The participant continues running between the two lines, turning when signaled by the recorded beeps. A sound indicates an increase in speed in minute intervals. A participant is ushered a warning the first time he or she fails to reach the line (within 2 m) and is eliminated following the second warning. Each participant's score was tallied including the level and number of shuttles (20 m) reached before they were unable to keep up with the recording.

The 20 m shuttle run test was conducted by the doctoral student with the help of a gym teacher and it was performed in the gym under standardized conditions.

2.3. Questionnaires

Questionnaires were completed by all study participants. Prior to completion students were instructed to read the questions carefully and to devote sufficient time to answer the questions.

2.3.1. Rosenberg Self-Esteem Scale

We used the Hungarian version of the Rosenberg Self-esteem Scale to measure students' global self-worth by measuring both negative and positive feelings regarding the inner self. The 10-item scale is uni-dimensional. All items are answered using a 4-point Likert scale ranging from strongly agree to strongly disagree. Higher scores refer to higher self-esteem [42].

2.3.2. EAT-26

The Eating Attitudes Test measures three aspects of eating behaviors. Cognitive restraint (CR) is a conscious effort by individuals to control what they eat to maintain or lose weight. Uncontrolled eating (UE) defines excessive eating in response to a loss of control over the food. Emotional eating (EE) is the need to overeat when an individual is unable to cope with emotionally negative situations and moods. The total value consists of tallying the scores regarding the three factors. Higher scores in the respective scales are indicative of greater cognitive restraint, uncontrolled, or emotional eating [23].

2.3.3. BAT

The Body Attitude Test (BAT) is a self-report questionnaire including 20 items, scored on a 6-point Likert-scale. The test measures the subjective body experience and the attitudes toward the individual's body, such as dissatisfaction with their own body, depersonalization of the body, complex feelings regarding overweight, lack of trust in one's own body, hyperactivity and restlessness [43]. The cut-off score is 36. Higher scores reflect diminished levels regarding attitudes toward one's own body.

The descriptives of the psychological variables are depicted in Table 1. The internal reliability of each scale reached a good level: Rosenberg Self-esteem Scale (Cronbach's $\alpha = 0.88$), The Body Attitude Test (Cronbach's $\alpha = 0.83$), The Eating Attitudes Test (Cronbach's $\alpha = 0.81$).

Table 1. Descriptives regarding the psychological variables.

Psychological Variable	Mean	SD	Minimum	Maximum	Skewness/Kurtosis
Self-esteem (RSES)	28.91	6.32	12	40	−0.251/−0.471
Body attitudes (BAT)	24.02	7.70	13.13	55	0.865/0.960
Uncontrolled eating (EAT-UE)	19.29	5.18	9	33	0.339/−0.391
Cognitive restraints (EAT-CR)	14.92	3.74	6	26	0.080/−0.352
Emotional eating (EAT-EE)	10.24	4.98	6	24	0.598/0.725

2.4. Data Analysis

Sample size and power analysis were performed for the overall population grouped by gender and BMI-for-age using power and sample size calculation program version 3.1.2 [44,45]. The sample size of $n = 9$ per group needed to detect a true difference of d = 6.017 in Rosenberg self-esteem with 95% power, where type I error probability is $\alpha = 0.05$. Effect size analysis showed d = 0.631 (according to Cohen).

To analyze the psychological and physical variables we used Independent Samples *t*-tests, one-way ANOVA, Correlation analysis and Multivariate linear regressions after using the Kolmogorov–Smirnov test to check the normality of the data distribution. The normality test revealed a not significant result in all parameters ($p > 0.05$).

The Independent Samples *t*-tests were used to check the gender differences of the psychological variables.

Differences of BMI and shuttle run test (grouped by gender and BMI-for-age) as well as the psychological variables were evaluated by a one-way repeated ANOVA statistical test using Tamhane posthoc test.

Bivariate correlation analysis was performed calculating Spearman's correlation coefficient (rho). Multiple regression analysis with various models considering the principle of multicollinearity was performed to reveal which factors could predict Self-esteem, BAT, Uncontrolled eating, Cognitive restraints, Emotional eating and shuttle run test. The correlation analysis showed significant associations of the psychological variables and some of the physical ones, more precisely: objective body shape (percentile zones) and subjective body shape (How do I see my body? This question refers to how somebody perceives his body shape, ranging from overweight/fat to skinny through a 5 point Likert-scale.).

The first regression model was performed to predict Self-esteem, BAT, Uncontrolled eating, Cognitive restraints, Emotional eating as the dependent variables regarding age, gender, Subjective body shape, BMI-for-age as independent variables.

The second linear regression and stepwise analyses of the data were performed to predict shuttle run test as the dependent variable regarding the Rosenberg Self-esteem Scale and Body Attitude Test values.

According to the Body Attitude Test results, we have divided the two gender groups into two groups: those who had worse attitudes toward their body (BAT-W), having more than 36 points, and those with better attitudes toward their body (BAT-B), having less than 36 points. Differences in these psychological variables between these girls and boys subgroups were evaluated by a one-way ANOVA statistical test.

3. Results

3.1. BMI-for-Age

With respect to the boys, 10 percent were underweight, 63 percent normal weight, 19 percent overweight, and 8 percent obese (Figure 1A).

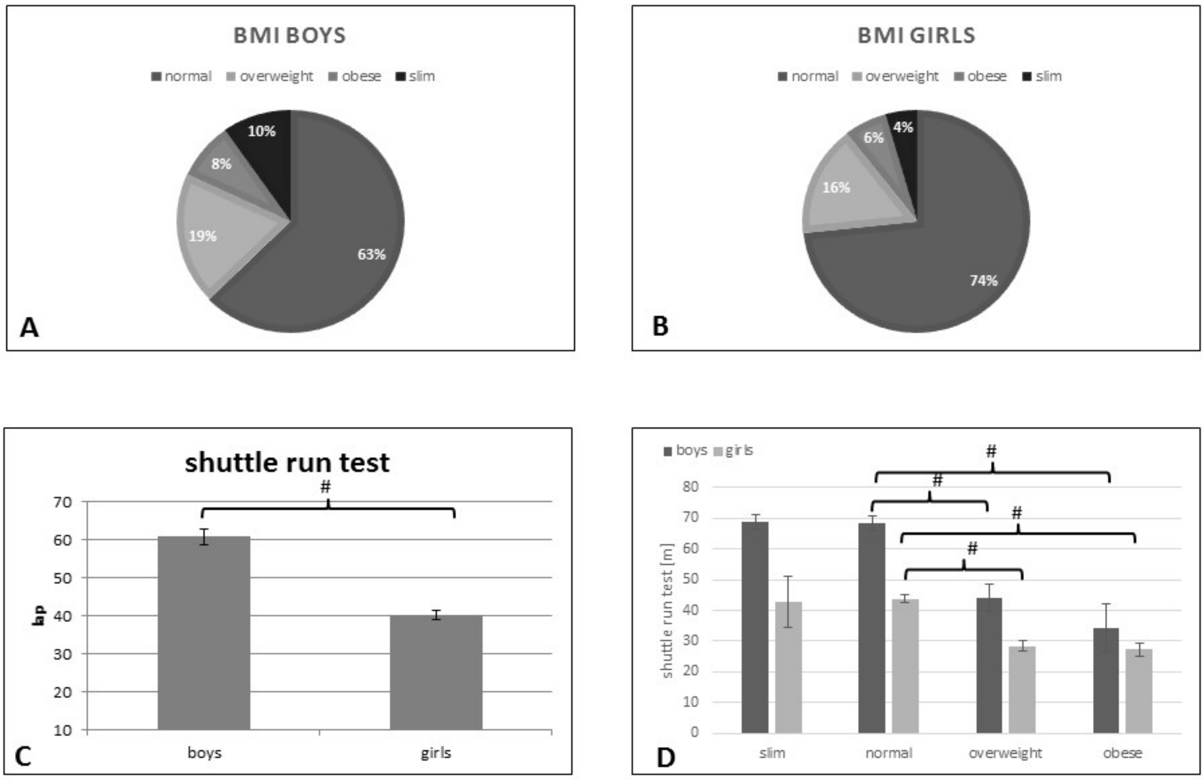


Figure 1. BMI-for-age in boys (**A**) and girls (**B**). Our results depicted significant differences in gender specific (**C**) and BMI-for-age specific shuttle run test (**D**) (data are shown as mean ± S.E.M, # = $p < 0.001$).

At the time of measurement 4 percent of the girls were underweight, 74 percent normal weight, 16 percent overweight, and 6 percent obese (Figure 1B).

3.2. The 20 m Shuttle Run Test

According to the 20 m shuttle run test data, 65% of boys (54 lap≥) and 59% of girls (38 lap≥) were in the Healthy Fitness Zone (HFZ). 35% of boys (≤45 lap) and 41% of girls (≤28 lap) were in the Needs Improvement zone (NIZ). The boys completed an average of 60.83 ± 25.79 laps. The girls accomplished 40.22 ± 16.34 laps. Students who meet the standards are classified as being in the Healthy Fitness Zone (HFZ), whereas students who fall below the standards are classified as being in Needs Improvement Zone (NIZ).

The analysis of the gender differences detected significantly lower shuttle-run test results among girls than when compared with boys (40.2 ± 1.13 vs. 60.8 ± 2.0; $p < 0.001$) (Figure 1C).

We observed no significant differences in shuttle run test results between slim and normal (68.81 ± 2.35 vs. 68.32 ± 2.46), as well as between overweight and obese boys (44.09 ± 4.65 vs. 34.4 ± 7.94), however, we discovered significantly lower performance in the obese and overweight boys than when compared with their classmates with normal BMI-for-age (Figure 1D).

The study results exhibited quite similar consequences in studying girls weight groups: there were no significant differences in shuttle run test outcomes between slim and normal nor between overweight and obese, however, we found significant differences between normal and overweight or obese girls' aerobic capacity (42.78 ± 8.5 slim; 43.8 ± 1.28 normal; 28.44 ± 1.57 overweight; 27.23 ± 2.02 obese) (Figure 1C).

3.3. Psychological Tests Results

The study revealed a significant difference in self-esteem: Girls showed lower self-esteem than when compared with boys (t (374) = 6.62; p = 0.05). Girls also reported significantly negative body attitudes (t (374) = −9.12; $p < 0.001$) than when compared with boys and reached higher scores on each of the Eating attitudes subscales. Girls showed signs of uncontrolled eating (t (374) = −3.47; p = 0.01), cognitive restraint (t (374) = −5.56; $p < 0.001$) and emotional eating (t (374) = −4.78; $p < 0.001$) more often than when compared with secondary school-aged boys (Figure 2).

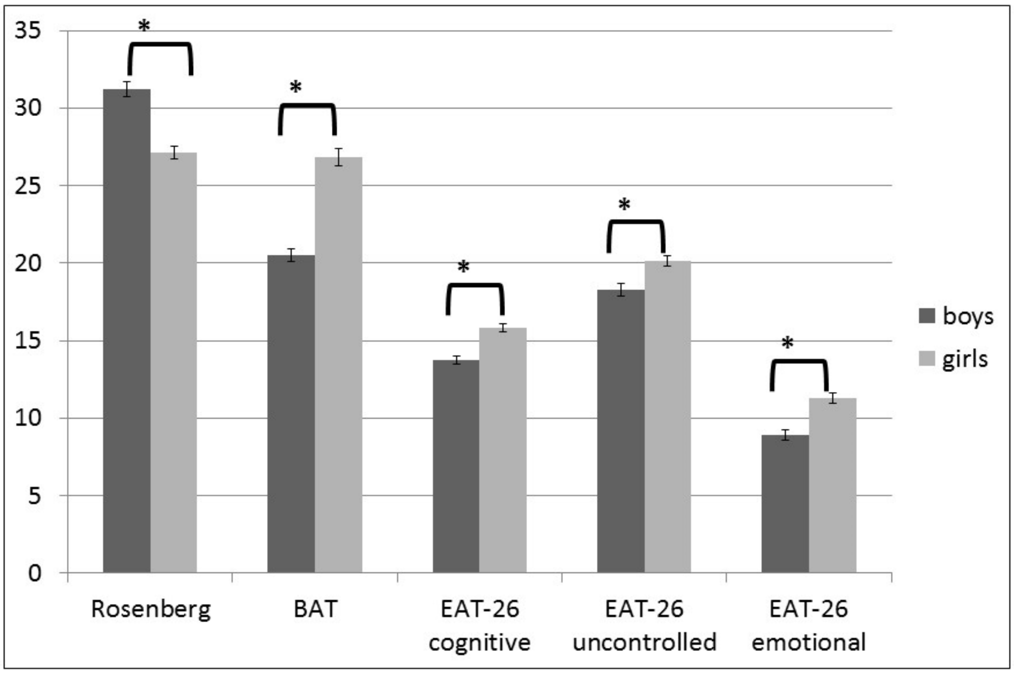


Figure 2. Our results showed significant differences in gender on the psychological tests (data are shown as mean ± S.E.M, * = $p < 0.001$). (Rosenberg = Rosenberg Self-esteem Scale; BAT = Body Attitude Test; EAT-26 = Eating Attitudes test: cognitive restraint, uncontrolled eating, emotional eating).

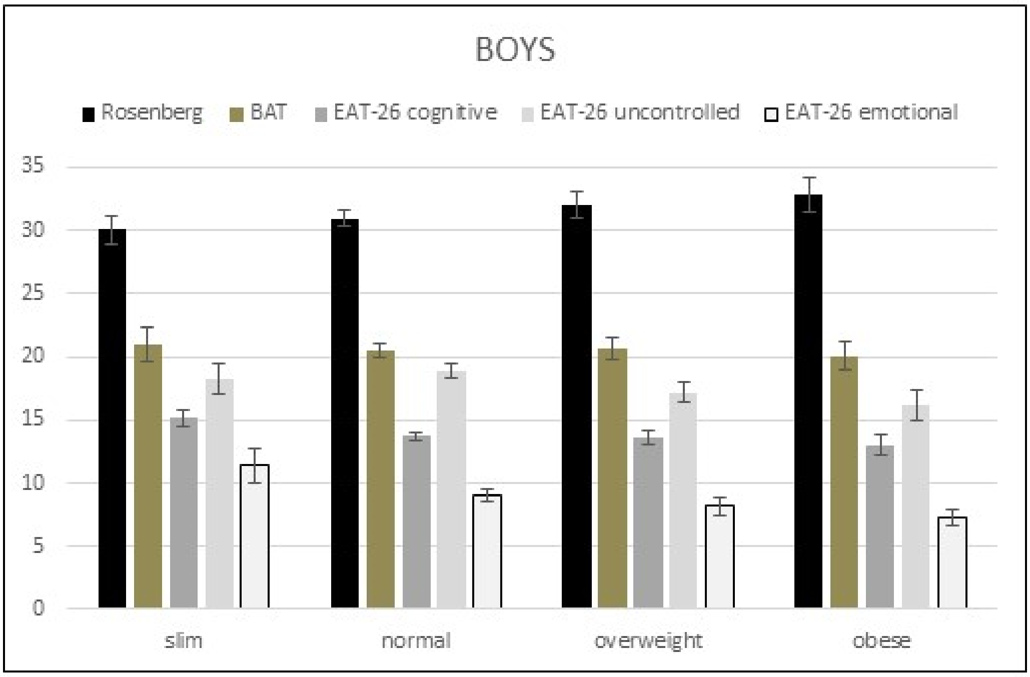
Psychological tests did not reveal any significant differences in the comprehensive analyses of the weight groups in both boys and girls (Figure 3).

The ANOVA analysis detected significant differences between girls BAT-W and BAT-B subgroups in Rosenberg Self-esteem Scale (21.7 ± 0.95 vs. 27.97 ± 0.42; $p < 0.001$) and in the eating attitudes, such as cognitive restraints (17.8 ± 0.69 vs. 15.5 ± 0.27; p = 0.003) and emotional eating (13.5 ± 1.04 vs. 10.9 ± 0.37; p = 0.011). The results showed significant differences between boys BAT-W and BAT-B subgroups in eating attitudes cognitive restraints subscale (19.0 ± 1.0 vs. 13.7 ± 0.27; p = 0.03) (Figure 4).

The first multilinear regression analysis revealed that gender (b = −0.31, t = −6.41, $p < 0.001$) and subjective body shape predicted self-esteem (b = 0.16, t = 3.23, p = 0.001).

Body attitudes were also influenced by gender (b = 0.39, t = 8.71, $p < 0.001$) and subjective body shape (b = −0.32, t = −7.09, $p < 0.001$).

The Uncontrolled eating subscale of the Eating attitudes was only affected by gender (b = 0.18, t = 3.53, $p < 0.001$), just as the Emotional eating subscale (b = 0.23, t = 4.57, $p < 0.001$). In this case, however, BMI also played a weaker role (b = −0.12, t = −2.25, $p < 0.05$).



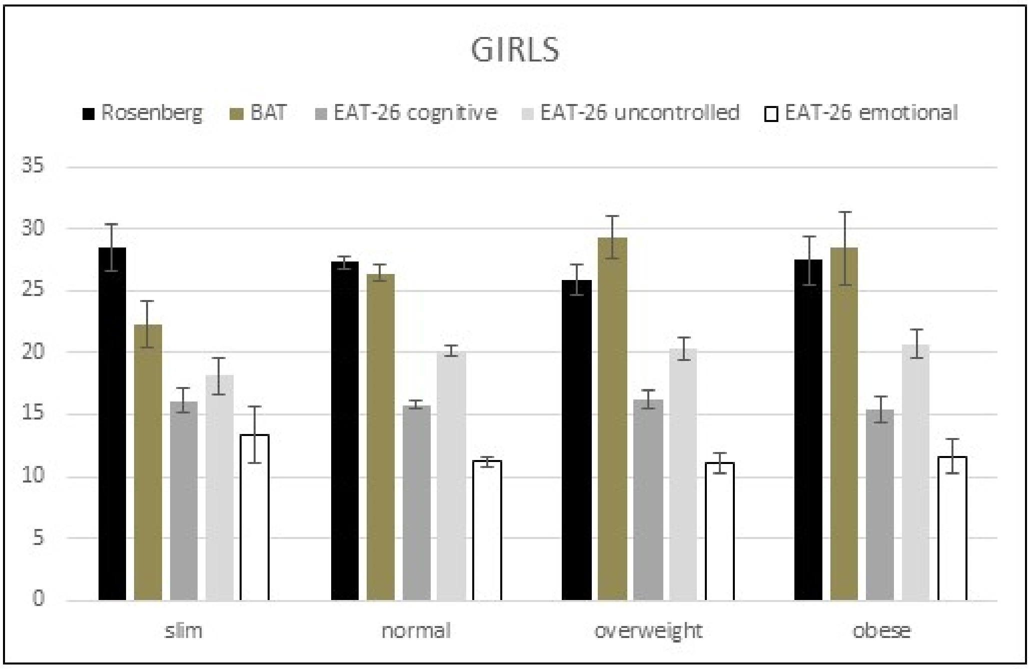


Figure 3. Psychological results in boys and girls showed no significant differences in the weight groups (data are shown as mean ± S.E.M, $p < 0.05$). (Rosenberg = Rosenberg Self-esteem Scale; BAT = Body Attitude Test; EAT-26 = Eating Attitudes test: cognitive restraint, uncontrolled eating, emotional eating).

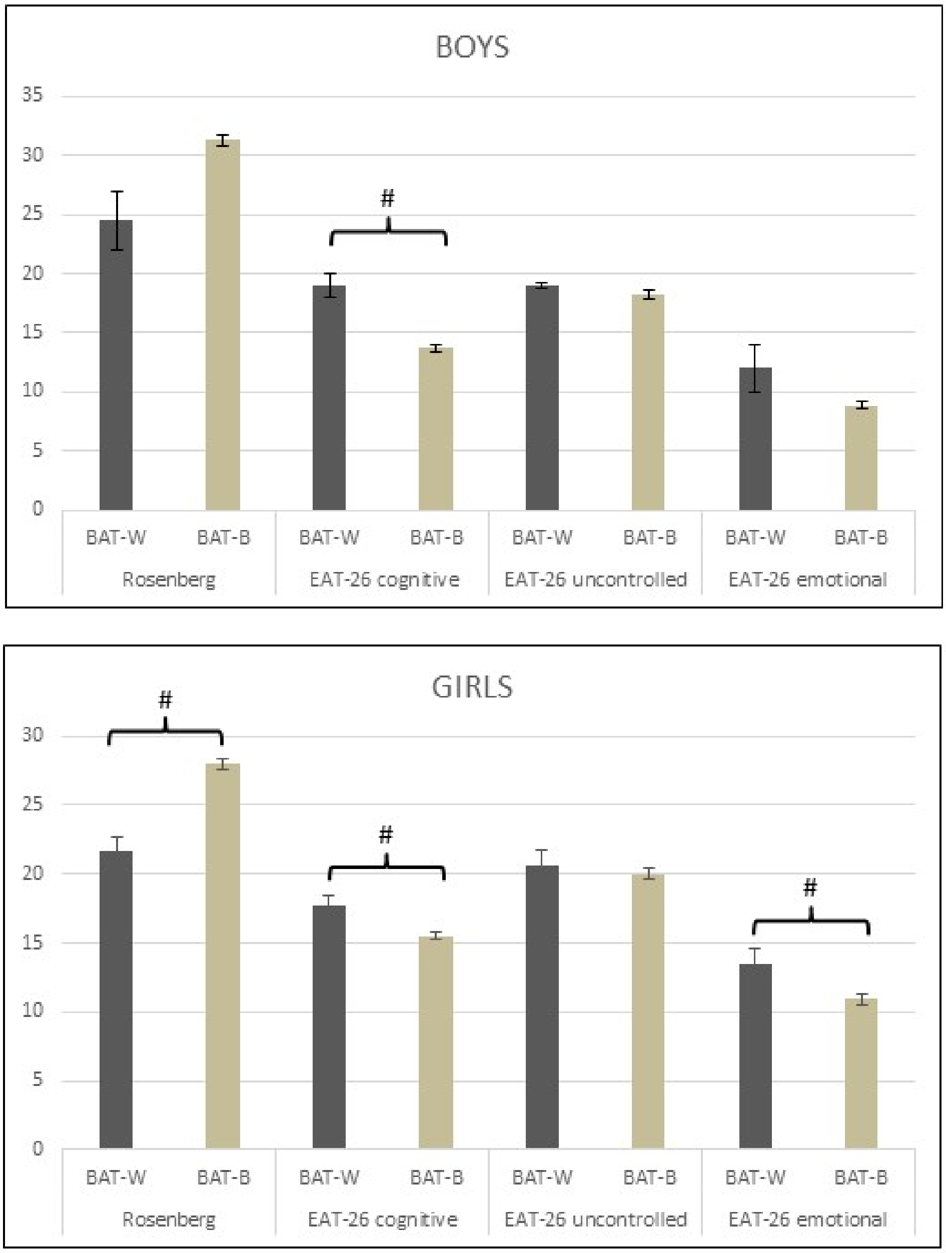


Figure 4. The analysis revealed significant differences between girls BAT-W (those with worse attitudes toward their body) and BAT-B (those with better attitudes toward their body) subgroups in Rosenberg Self-Esteem Scale and Eating attitudes cognitive restraints and emotional eating subscales. Additionally, our data showed significant differences between boys BAT-W and BAT-B subgroups in the cognitive restraints subscale of eating attitudes. (BAT-W: those with worse attitudes toward their body, BAT-B: those with better attitudes toward their body). #: significant difference, $p < 0.05$.

Cognitive restraint, similarly to self-esteem, showed strong associations with subjective body shape (b = −0.22, $t = -4.32$, $p < 0.001$) and gender (b = 0.26, $t = 5.27$, $p < 0.001$) (Table 2).

Second multivariate linear regression and stepwise analyses were performed to predict shuttle run test as the dependent variable regarding Rosenberg Self-esteem Scale and Body Attitude Test values. We revealed that both variables added statistically significantly to the prediction in boys $F(2, 163) = 3.189$, $p = 0.044$, $R^2 = 0.038$.

Table 2. Results of the regression analysis: standardized β and R^2 values. (SBSH: Subjective body shape). * $p < 0.05$, ** $p < 0.001$.

Dependent Variables	Predictors				
	Age	Gender	SBSH	BMI for Age	R^2
Self-esteem (RSES)	0.09	−0.31 **	0.16 **	0.07	0.16 **
Body attitudes (BAT)	0.00	0.39 **	−0.32 **	0.01	0.28 **
Uncontrolled eating (UE)	−0.06	0.18	0.06	−0.02	0.04 *
Cognitive restraints (CR)	0.02	0.26 **	−0.22 **	−0.09	0.12 **
Emotional eating (EE)	−0.01	0.23 **	−0.07	−0.12*	0.07 **

4. Discussion

In our study lower self-esteem and higher scores for BAT and each scale of eating attitudes, such as Uncontrolled Eating (UE), Cognitive Restraints (CR) and Emotional Eat-ing (EE) were measured among adolescent girls compared to boys. Interestingly, not objective bodyweight but subjective body shape and gender predicted self-esteem and BAT scores and the cognitive restraints in the eating attitudes. Uncontrolled and emotional eating subscales were primarily influenced by gender, while BMI played only a weaker role. Additionally, self-esteem and body image were positively associated with cardiorespiratory performance in the boys, but not among girls.

The proportion of overweight and obese adolescents in our study group (Figure 1A,B) is slightly higher when compared to international data. A total of 107.7 million children were obese in 2015 worldwide [43], thus, obesity prevalence was as high as 5% among children, while overweight and obesity prevalence combined was as high as 23% [46,47]. Furthermore, overweight and obesity were more common in boys when compared to girls in our study (Figure 1A,B) which corresponds with international data [48].

In consideration of cardiorespiratory performance, measured by the shuttle run test, boys performed better than when compared with girls (Figure 1C) as it was anticipated, consistent with data in the literature [49]. Thin and normal weight adolescents performed significantly better on the cardiorespiratory test than when compared with their overweight or obese peers, among both genders (Figure 1D), of which findings are also congruent with previous studies [50,51]. Additionally, more girls have fallen into the Needs Improvement Zone than boys (41 vs. 35%).

Cardiorespiratory performance and its association with different psychological variables have been previously investigated in children and adolescents. For instance, Morales et al. in a Spanish study examining 1596 children, aged 8–11 years, found that cardiorespiratory fitness in girls and muscular fitness in boys closely associated with most of the dimensions of health related quality of life, including physical and psychological well-being, moods and emotions, self-perception, parent relation, home life and social acceptance [52]. In a study conducted in Australia, examining 821 elementary-school children, higher levels of cardiovascular fitness were found as a protective factor to body image concerns, regardless of the child's body composition [53]. Interestingly, in accordance with our findings, cardiorespiratory performance was positively associated with self-esteem and body attitudes test results in our age-group (16.5 years) regarding adolescent boys, however, not in girls.

A relationship focusing on overweight, obesity and low self-esteem has been investigated several times and the results varied. In our findings, self-esteem was predicted by subjective body shape instead of objective bodyweight. Several studies depict lower self esteem among obese adolescents [3,54], while others found associations only among subgroups based on age or race [55,56] or for a specific domain of self-esteem [57]. A literature review indicated it was unclear whether self-esteem was consistently related to obesity [58]. There may be some other factors that mediate the relationship between obesity and psychological problems. According to earlier studies, body-image satisfaction may be the intermediate factor between obesity and self-esteem [59].

Assessing body image satisfaction, the Body Attitude Test (BAT) was used, which was originally designed for patients, primarily women suffering from eating disorders [43]. In the current study, girls scored higher scores on BAT than boys that could mean that boys have more positive attitudes toward their bodies, but it is also possible that the questionnaire does not measure enough aspects of male body attitudes. Later, Probst et al. evaluated the psychometric properties of body image questionnaires including BAT among non-clinical female and male subjects and found that these tests can reliably differentiate between the two sexes and those individuals who are and who are not suffering from body image concerns [60].

In our study, no significant correlation was found among the actual weight status and body image satisfaction, neither the eating attitude subscales (Figure 3). According to the literature, there are many factors influencing body image and eating attitudes. Studies have shown that social media consistently and overly represent idealized body types which potentially contribute to poor body image and disordered eating behaviors which may be underpinned by the beauty and diet industries [61–63]. Adolescent body image is also heavily influenced by family and social relationships. Adolescents who are exposed to negative body and diet conversations with friends and family members have higher levels of body dissatisfaction and higher BMIs and are manifested in unhealthy eating behaviors later in life [64,65].

In our study, positive body image was associated with higher self-esteem and lower cognitive restraints and emotional eating in the eating attitude subscales in girls and with lower cognitive restraints in boys (Figure 4). Previous studies indicated that positive body image has been associated with lower concerns regarding appearance, healthier BMI, increased physical activity and better general health habits in adolescents [66–69]. On the other hand, body dissatisfaction may trigger emotional eating [70,71] which has been associated with greater adiposity and higher BMI [71,72]. Furthermore, emotional eaters tend to turn to high-energy and low-nutrient foods in response to their emotional feelings [73]. Restrained eaters take control over what they eat and when they eat, however, paradoxically, under certain conditions they lose control, for example during negative mood states [74].

Additionally, in our study, all aspects regarding eating attitudes were affected by gender. Girls were more prone to emotional and uncontrolled eating and cognitive restraints, when compared to boys and BMI, had only a weaker role in emotional and uncontrolled eating. It is well-known that eating disorders are more common in women than in men and adolescent girls are at high risk. Girls experience more food-related conflicts than when compared with boys and they also experience more dissatisfaction with their body that may affect weight regulation [75].

Finally, there may be some gender relevant analysis issues with the use of the EAT-26 questionnaire which was originally validated and used in female populations [23]. However, in a recent study, Schaefer et al. have demonstrated that no items of EAT-26 met the criteria for statistically significant differential item functioning suggesting that the EAT-26 questionnaire operates similarly among males and females [76]. Although EAT-26 seems to be an appropriate measure to assess thinness-oriented eating disorder symptoms in non-clinical samples of men, it may not evaluate symptoms that are more specific in the male population (e.g., muscularity-oriented concerns) [77].

5. Limitations

There are some limitations of the current study that could be addressed in future research. First, the self-esteem of the study participants was measured by the Rosenberg Self-esteem Scale. However, the scale is widely used to measure global self-esteem, there are more theories that describe self-esteem as a more complex phenomenon. For further research, it would be interesting to compare the associations of different aspects of self-esteem to the variables used in the current study. Second, BAT and EAT-26 questionnaires were originally designed and validated for female subjects. Although these tests have already been used in male populations, they may not measure male specific items properly, and therefore, the results must be interpreted carefully. Third, the relatively small number of participants in the overweight and obese subgroups also warns us to interpret the associations with caution. These limitations should be taken into account and eliminated when planning future studies.

6. Conclusions

Based on our results we want to emphasize that attention must be focused on both psychological and physical health during adolescence. Although overweight and obesity were more commonly seen in adolescent boys, girls were more prone to have lower levels of self-esteem, poorer body images and experienced increased problems regarding eating behavior. Furthermore, no significant correlation was found between BMI and psychological test results in either boys or girls. However, cardiorespiratory performance was positively associated with self-esteem and body image among boys, and it had a negative correlation with body weight in both genders. Since adolescent health behaviors can predict adult health status [1,78], future research might require a longitudinal follow-up to track changes in attitudes of adolescents regarding their own body, self-esteem and eating habits and examine other potential mediators among physical and psychological variables, such as the role of social and family influence.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of University of Pecs (7522-PTE 2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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