



Trabajo Original

The association between high blood pressure, physical fitness and fatness in adolescents

Asociación entre presión arterial alta, aptitud física y obesidad en los adolescentes

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Abstract

Introduction: Hypertension is a health problem that is of national importance. It is a major risk factor for the occurrence of atherosclerosis and cardiovascular, cerebrovascular and renal diseases that are leading or among the leading causes of mortality and morbidity as in ours, as in the most developed and less developed countries.

Objective: The purpose of this study is to analyze the relation of cardiorespiratory fitness and obesity, blood pressure and hypertension for adolescents.

Material and methods: The research was realized on a sample of 4,051 boys and girls at the age of 11 to 14 years. Cardiorespiratory fitness was assessed by using a three minute step test, while the percentage of body fat was determined by bioelectrical impedance method. Blood pressure was measured three times at intervals of 60 seconds, and the result was the median value of the three measurements. The measurements were performed in a separate room with optimum ambient conditions. The relation between hypertension, cardiorespiratory fitness and fat was determined by correlation and multi-nominal logistic regressive analysis.

Results: Boys had higher systolic pressure and lower diastolic pressure compared to girls. The low level of cardiorespiratory fitness and high percentage of body fat were independently associated with an increased risk of blood pressure and hypertension for both boys and girls. The interaction was established between the percentage of body fat and fitness.

Conclusion: The results should be taken into account for building strategies and recommendations for improvement of lifestyle and health for adolescents.

Key words:

Blood pressure.
Physical fitness.
Fatness. Adolescent.

Resumen

Introducción: la hipertensión es un problema de la salud y es de importancia nacional. Es un factor de riesgo importante para la aparición de la aterosclerosis y enfermedades cardiovasculares, cerebrovasculares y enfermedades renales que están liderando o están entre las principales causas de mortalidad y la morbilidad como en la nuestra, también en los países más desarrollados y menos desarrollados.

Objetivo: el objetivo de este estudio es analizar la relación de la aptitud cardiorrespiratoria y la obesidad, la presión arterial y la hipertensión en los adolescentes.

Material y métodos: la investigación se realizó sobre una muestra de 4.501 niños y niñas de 11 a 14 años. La capacidad cardiorrespiratoria se evaluó con el uso de una prueba de paso que dura tres minutos, mientras que el porcentaje de grasa corporal se determinó con un método de impedancia bioeléctrica. La presión arterial se midió tres veces a intervalos de 60 segundos. El resultado fue el valor medio de las tres mediciones. Las mediciones se realizaron en una habitación separada con condiciones ambientales óptimas. La relación entre la hipertensión, la aptitud cardiorrespiratoria y la grasa se determina con un análisis de correlación y multinominal regresión logística.

Resultados: los niños tenían una mayor presión sistólica y diastólica que las niñas. El nivel bajo de aptitud cardiorrespiratoria y el porcentaje alto de grasa corporal se asociaron independientemente con un mayor riesgo de hipertensión arterial e hipertensión para niños y niñas. La interacción se establece entre el porcentaje de grasa corporal y la forma física.

Conclusión: los resultados obtenidos se deben tener en cuenta para la construcción de estrategias y recomendaciones para la mejora del estilo de vida y la salud de los adolescentes.

Palabras clave:

Presión arterial.
Aptitud física.
Obesidad.
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INTRODUCTION

Hypertension is a health problem that is of national importance. It is a major risk factor for the occurrence of atherosclerosis and cardiovascular, cerebrovascular and renal diseases that are leading or among the leading causes of mortality and morbidity as in ours, as in the most developed and less developed countries. Epidemiological studies show a correlation between low physical activity and/or low level of fitness and cardiovascular ailments (1). Biological risk factors for the occurrence of cardiovascular diseases track from childhood and adolescence into adulthood (2-4). The low level of fitness is associated with an increased risk of high blood pressure for middle-aged men and women (5,6). But there are many fewer researches which explain the etiological relationship between fitness and blood pressure for children and adolescents (7-9).

One of the problems of the research is that the increased percentage of body fat (obesity) is associated with blood pressure and fitness. A high physical activity level may influence both fitness and body fatness. There is a consensus that aerobic training reduces blood pressure for adults, but a growing number of studies research the relation of fitness and obesity on blood pressure for children and adolescents, and there were no researches on the interaction of obesity and fitness in terms of blood pressure. Explaining the relationship between blood pressure, physical fitness and obesity is useful for building strategies and recommendations to improve the lifestyle and health of adolescents.

The purpose of this study was to analyze the relation of cardiorespiratory fitness and obesity, blood pressure, as the possible combined effects of cardiorespiratory fitness and body fat.

MATERIALS AND METHODS

SAMPLE OF RESPONDENTS

The research is realized on a sample of 4,051 adolescents with Macedonian nationality, 19 primary school in the central and eastern part of Macedonia, 8 of which are in rural and 11 in urban areas. The sample is divided into two subsamples according to gender and that is 2,078 male respondents and 1,973 female respondents. The average age of the respondents of both gender is 12.4 years. In the study were included all students whose parents gave consent to participate in the research that were psychologically and physically healthy, and who regularly attend classes in physical and health education. The respondents were acted in accordance with the Helsinki Declaration.

The measurements are realized in March, April and May 2013, in standard conditions of regular school classes of physical and health education. The measurements were realized by experts in the field of kinesiology and medicine, previously trained to perform functional tests and taking anthropometric measures.

ANTHROPOMETRIC MEASURES AND BODY COMPOSITION

The measurement of anthropometric measures were implemented by the recommendations of the IBP - International Biological Program (10). For assessment of morphological characteristics were applied the following anthropometric measures: height of the body in a standing position (cm), weight (kg), and body mass index (BMI).

The components of the body composition are determined by bioelectrical impedance method (measuring the electrical conductivity - Bioelectrical Impedance Analysis - BIA). The measurement is realized by Body Composition Monitor, model «OMRON - BF511», with whose help the body weight, body fat percentage, and muscle mass percentage is measured. Before starting the measurement in Body Composition Monitor were entered the parameters of gender, age and body height of the respondent. In order to ensure better accuracy of the results obtained from the assessment of body composition, before each measurement were fulfilled prerequisites recommended by ACSM (11) and Heyward (12).

BLOOD PRESSURE

The blood pressure measurement (systolic and diastolic) is realized by experts from the medicine, doctor-specialists pediatrician fields. The measurements were performed in a separate room with optimum ambient conditions in a relaxed state of the respondent, and the relaxation is conducted at least five minutes before the measuring. The measurements were realized on forearm above the wrist on the palm, with clinically tested electronic digital device for measuring blood pressure from the company «Omron». The measurement was conducted on the left hand and before measuring care was taken that the cuff was properly inserted, the hand is at the height of the heart, and the respondent sit properly, not to move or to talk. Blood pressure was measured three times at intervals of 60 seconds, and the result was the median value of the three measurements. In the age group studied, the High Blood Pressure (HBP) was regarded as the average (from three measurements) of systolic and/or diastolic pressure at the 95th percentile for age and gender, adjusted to height percentile. We adopted the methodological recommendations of the Update on the Task Force Report on High Blood Pressure in Children and Adolescent (13).

EVALUATION OF PHYSICAL FITNESS

3-minute step test. Aerobic capacity is calculated using the 3-minute step test. Respondent was tasked 3 minutes to climb up and climb down from bench on high of 30.5 cm, and that is in four cycles (up, up, down, down) with standardized rhythm of 96 beats per minute (bpm), which enjoyed the metronome. Before the beginning of the test the heart rate was measured, wherein

children who are in rest condition had submaximal value in terms of age, they were not subjected to loading. The respondents who did not have contraindications to perform step-test immediately after the test (on cue) should sit on the bench to measure heart rate immediately after the burden, and a minute later, the stage of recovery. If the respondent felt dizziness, shortness of breath, nausea, headache or other difficulties, the test is immediately interrupted. The heart rate was measured using a monitor Polar RS800 for registration of the hearth frequency. As a result was taken the heart frequency measured one minute after the test (Postexercise pulse rate) (14).

STATISTICAL ANALYSIS

The data are presented as frequencies (percentage) for categorical variables and mean (SD) for continuous variables. Gender differences in fitness, blood pressure and anthropometric characteristics were analyzed by one-way analysis of variance (ANOVA). Categorical data (weight status and proportion of hypertension) were analyzed using the Chi-square test. Pearson correlation was used to analyse the relationship between blood pressure, anthropometric characteristics and fitness. The univariant and multivariant relation between hypertension, cardiorespiratory fitness and fat tissue is determined by logistic regression analysis, for the needs of the multi-nominal logistic regressive analyze the sample was divided into five categories of postexercise pulse rate and body fat, according to quintile. All the analyses were performed using the Statistical Package for Social Sciences software (SPSS, v. 22.0 for WINDOWS; SPSS Inc., Chicago, IL, USA), and values of $p < 0.05$ were considered statistically significant.

RESULTS

The research was realized on a sample of 4.091 respondents of which 2.116 (51.7%) boys and 1975 (48.3%) girls at the age of 11 to 14 years. The average age of the respondents was 12.4 ± 1.1 years.

In table I are shown the characteristics of a sample. From the review of the table I in which are shown the values of the arithmetical means, standard deviations and the level of statistical significance can be seen that there are statistically significant differences between the male and female gender in the variables Height, Weight, Body fat (%), SBP (mmHg), DBP (mmHg) and Postexercise pulse rate. From the review of the obtained results, can be seen that boys are taller, heavier, have a lower percentage of body fat, higher systolic pressure, and lower diastolic pressure compared to girls. Statistically significant differences were found in the age and BMI variables.

The distribution of the excessive weight/obesity assessed by BMI and hypertension for adolescents in terms of gender are shown in table I. The table I analysis and summary of the Chi-square test (Chi-square = 20.000, $p = 0.000$) indicate that there are statistically significant differences in the nutrition level among boys and girls. The percentage values show that a higher percentage of boys are overweight/obese. Also, the statistically significant differences were established in the hypertension between boys and girls (Chi-square = 9.449, $p = 0.002$). The percentage values show that higher percentage of girls (16.5%) have hypertension compared to boys (14.7%).

In the table II are shown the correlation coefficients between the assessment of blood pressure and anthropometric indicators variables and measures to assess cardiorespiratory fitness in the

Table I. Description of the study population means and standard deviation (SD)

| | Boys (n = 2,116) | | Girls (n = 1,975) | | Total (n = 4,091) | | p-value |
|--|------------------|-------|-------------------|-------|-------------------|-------|---------|
| | Mean | SD | Mean | SD | Mean | SD | |
| Age (years) | 12.35 | 1.10 | 12.37 | 1.10 | 12.36 | 1.10 | 0.530 |
| Height (cm) | 157.74 | 10.94 | 156.13 | 8.08 | 156.96 | 9.70 | 0.000 |
| Weight (kg) | 52.76 | 14.71 | 51.12 | 12.07 | 51.96 | 13.52 | 0.000 |
| BMI | 20.95 | 4.17 | 20.84 | 4.07 | 20.90 | 4.12 | 0.414 |
| Body fat (%) | 20.60 | 8.47 | 25.04 | 7.73 | 22.76 | 8.41 | 0.000 |
| SBP (mmHg) | 115.04 | 10.87 | 113.87 | 10.15 | 114.47 | 10.54 | 0.000 |
| DBP (mmHg) | 71.02 | 8.81 | 72.22 | 8.20 | 71.60 | 8.54 | 0.000 |
| Postexercise pulse rate | 112.19 | 18.57 | 130.03 | 18.64 | 120.88 | 20.63 | 0.000 |
| Proportion with systolic hypertension n (%) | 207 | 10.1% | 194 | 10.0% | 401 | 10.1% | 0.958 |
| Proportion with diastolic hypertension n (%) | 169 | 8.1% | 205 | 10.5% | 374 | 9.3% | 0.009 |
| Systolic or/and diastolic hypertension n (%) | 302 | 14.7% | 355 | 18.4% | 657 | 16.5% | 0.002 |
| Proportion with overweight and obesity n (%) | 386 | 39.6% | 267 | 29.7% | 653 | 34.9% | 0.000 |

Data are shown as mean (SD) unless otherwise indicated. Sex differences were analysed by one-way analysis of variance, with sex group as fixed factors, and anthropometric or physical fitness measurements as dependent variables. The respondents were categorized according to the international gender and age-specific BMI (kg/m^2) cut-off points (Cole et al. 2000, 2007) (15, 16). $p < 0.010$ for difference between boys and girls (Chi-Square Tests).

Table II. Relationship of systolic and diastolic blood pressure with age, height, weight, body mass index, body fat and physical fitness in Pearson correlation analysis

| | Boys | | Girls | | Total | |
|-------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | SBP (mm Hg) | DBP (mm Hg) | SBP (mm Hg) | DBP (mm Hg) | SBP (mm Hg) | DBP (mm Hg) |
| Age (years) | 0.310** | 0.094* | 0.182** | 0.144** | 0.249** | 0.118** |
| Height (cm) | 0.440** | 0.196** | 0.314** | 0.244** | 0.390** | 0.206** |
| Weight (kg) | 0.477** | 0.274** | 0.403** | 0.294** | 0.447** | 0.276** |
| BMI | 0.366** | 0.257** | 0.327** | 0.232** | 0.348** | 0.244** |
| Body fat (%) | 0.144** | 0.186** | 0.311** | 0.233** | 0.197** | 0.218** |
| Postexercise pulse rate | 0.223** | 0.268** | 0.256** | 0.297** | 0.189** | 0.282** |

* $p < 0.05$. ** $p < 0.01$.

total sample and separately for boys and girls. From the review of table II can be seen that the total sample there is statistically significant correlation between systolic blood pressure, age, body weight, body height, BMI, fat percentage and post-exercise pulse rate. The highest correlation with systolic pressure show the weight, BMI and body height variables. When analyzing the variables separately for boys and girls can be seen that for both gender the statistically significant correlation between systolic pressure, age, body weight, body height, BMI, fat percentage and post-exercise pulse rate. The highest correlation for both gender show again the variables weight, BMI and body height.

In the total sample low statistically significant correlation with diastolic pressure show the age, weight, body height, body weight, BMI, fat percentage and post-exercise pulse rate variables. The highest correlation with diastolic pressure shows the post-exercise pulse rate, and weight variables. When analyzing the variables separately for boys and girls can be seen that these variables are statistically correlated with the low diastolic pressure. The highest correlation with the diastolic pressure for both gender shows the post-exercise pulse variable, which estimate the cardiorespiratory fitness.

The relation between hypertension, cardiorespiratory fitness and fat tissue is determined by the multi-nominal logistic regressive analysis, and the results are show in the table III. For the purposes of the multi-nominal logistic regressive analysis the sample was divided into five categories of postexercise pulse rate and body fat, according to quintile. For boys and girls odds ratio (OR) for hypertension is calculated the univariant and multivariant between quintiles of the cardiorespiratory fitness (reference group was the highest quintile) and quintile of body fat compared with respondents who have the smallest percentage of fat (lowest quintile) (Table III).

On the univariant level the independent OR for the lowest quintile of fitness compared to the highest quintile was 3.13 in boys ($p = 0.00$) and 4.44 in girls ($p = 0.00$), respectively. The independent OR for the highest quintile of body fat compared to the lowest quintile was 3.89 ($p = 0.00$) in boys and 2.83 ($p = 0.00$) in girls, respectively.

In order to analyze the independent association of both the cardiorespiratory fitness and the percentage of body fat with the hypertension firstly was done a neutralization of age and body fat and then neutralization of age and cardiorespiratory fitness. The independent OR for the lowest quintile of fitness compared to the highest quintile was 2.18 in boys ($p = 0.00$) and 3.54 in girls ($p = 0.00$), respectively, after adjustment for body fat and age. The independent OR for the highest quintile of body fat compared to the lowest quintile was 3.04 ($p = 0.00$) in boys and 2.28 ($p = 0.00$) girls, respectively, after adjustment for fitness and age.

DISCUSSION

The aim of this study was to determine the relation between the cardiorespiratory fitness and obesity (fatness), blood pressure and hypertension for adolescents. The advantage of this study is the relatively large number of respondents who passed the cardiorespiratory test, and they were measured as well as the body composition and the blood pressure. The study results show that there is a connection between the cardiorespiratory fitness and blood pressure/hypertension on the one hand and body fats and blood pressure on the other hand.

On some previous research is it found that the relation between the cardiorespiratory fitness and blood pressure is not linear (17). In this sample for girls and boys it is determined almost linear relation between the blood pressure and the cardiorespiratory fitness. The respondents who belong to the first and second-fifth of the lowest cardiorespiratory fitness have significantly higher blood pressure compared to the remaining three-fifths. The mechanism of the relation between the blood pressure, obesity and fitness are not yet sufficiently explained and it is unknown whether these relations exist a causative relation. It is reasonable to be believed that there is a causative-consequence relation between low levels of physical activity on the one hand and the increased percentage of body fat on the other hand. But also, it is known that both properties have a strong genetic component, and on the other side the nutrition plays an important role at least in

Table III. Odds ratios and 95% confidence intervals for the relationship between hypertension and fitness as well as body fat

| Hypertension | Boys OR | 95% lower | 95% upper | p value | Girls OR | 95% lower | 95% upper | p value |
|---|---------|-----------|-----------|---------|----------|-----------|-----------|---------|
| <i>Crude analyses^a</i> | | | | | | | | |
| Lowest quintile CRF | 3.13 | 2.08 | 4.71 | 0.00 | 4.44 | 2.91 | 6.79 | 0.00 |
| 2 nd quintile of CRF | 1.74 | 1.13 | 2.68 | 0.01 | 3.11 | 2.01 | 4.80 | 0.00 |
| 3 rd quintile of CRF | 1.21 | 0.76 | 1.93 | 0.41 | 1.73 | 1.09 | 2.74 | 0.02 |
| 4 th quintile of CRF | 1.05 | 0.65 | 1.69 | 0.85 | 1.75 | 1.09 | 2.79 | 0.02 |
| Highest quintile of CRF | 1 | - | - | - | 1 | - | - | - |
| Highest quintile body fat | 3.89 | 2.58 | 5.86 | 0.00 | 2.83 | 1.95 | 4.10 | 0.00 |
| 2 nd highest quintile body fat | 1.75 | 1.12 | 2.73 | 0.01 | 1.69 | 1.15 | 2.50 | 0.01 |
| 3 rd highest quintile body fat | 1.39 | 0.88 | 2.21 | 0.16 | 1.22 | 0.81 | 1.84 | 0.34 |
| 4 th highest quintile body fat | 1.39 | 0.88 | 2.21 | 0.16 | 1.15 | 0.76 | 1.75 | 0.50 |
| Lowest quintile body fat | 1 | - | - | - | 1 | - | - | - |
| <i>Multiple analyses^b</i> | | | | | | | | |
| Lowest quintile CRF | 2.18 | 1.42 | 3.36 | 0.00 | 3.54 | 2.28 | 5.49 | 0.00 |
| 2 nd quintile of CRF | 1.37 | 0.88 | 2.14 | 0.16 | 2.71 | 1.74 | 4.22 | 0.00 |
| 3 rd quintile of CRF | 1.02 | 0.63 | 1.63 | 0.95 | 1.52 | 0.95 | 2.42 | 0.08 |
| 4 th quintile of CRF | 0.97 | 0.60 | 1.58 | 0.91 | 1.66 | 1.03 | 2.66 | 0.04 |
| Highest quintile of CRF | 1 | - | - | - | 1 | - | - | - |
| Highest quintile body fat | 3.04 | 1.96 | 4.70 | 0.00 | 2.28 | 1.53 | 3.38 | 0.00 |
| 2 nd highest quintile body fat | 1.53 | 0.96 | 2.44 | 0.07 | 1.53 | 1.01 | 2.30 | 0.04 |
| 3 rd highest quintile body fat | 1.40 | 0.87 | 2.25 | 0.16 | 1.18 | 0.77 | 1.81 | 0.45 |
| 4 th highest quintile body fat | 1.26 | 0.78 | 2.05 | 0.35 | 1.17 | 0.76 | 1.81 | 0.47 |
| Lowest quintile body fat | 1 | - | - | - | 1 | - | - | - |

^aUnivariate age-adjusted OR. ^bAge-adjusted OR for body fat and fitness in the same model.

the etiology of obesity. It is often argued that the physical activity protects against obesity, due to the higher calorific consumption (18), but it can be very simplified explanation. Theoretically it is possible as a result of decreased calorie intake to reduce weight, but maintaining it for a longer time of period without increased physical activity is rarely possible. One of the reasons for this may be the function of the enzymes in the metabolism of fats and sensitivity of metabolic hormones, especially insulin which affects the regulation of the appetite, and are not recoverable by a diet. Neither physical activity by itself is not proved successful in reducing body weight but has other benefits provided by exercise, except weight loss (19,20).

It is known that insulin sensitivity increases with aerobic. The training effect is from local character only for the trained muscles. In the study of Acts and al. it is applied an experiment which was loaded only one leg, it showed greater sensitivity on insulin, while for the untrained leg there were no changes (21). Insulin is a hormone with many functions, and the post-serum level of the insulin is increased for people with low level of fitness as well as people with a large percentage of body fat. Besides its impact

on the transport of glucose it has anabolic effect in the storage of fat in fat cells. Insulin influences the regulation of the appetite by changes in substrate levels in the blood, and the Ferranini indicates the impact on blood pressure (22). The sensitivity to insulin can be one of the key mechanisms that cause the relation between blood pressure, body fat and cardiorespiratory fitness.

The relation between obesity and blood pressure is consistent with the previous researches (23-28). Farah and the collaborators (29) have made systematic review of randomized clinical trials in which the physical training effects of blood pressure in obese adolescents were researched. In two studies were applied exercises for strength in combination with aerobic exercises, while in six studies only aerobic exercises. Five studies used complementary intervention, especially nutritional. In four studies is determined the reduction of the systolic pressure for experimental group, and at the same time by reducing the percentage of body fat. In all studies in which was determined reduction of the systolic blood pressure were applied aerobic (cardiorespiratory) exercises from 12 to 24 weeks with a frequency of three to six times a week, with a duration of 50 to 90 minutes and intensity of burden between 55 to 75% of

the maximum heart rate. Our research also confirmed the results of these studies in which the cardiorespiratory fitness and blood pressure in preadolescents and adolescents were researched. The results of our study indicate that the change in cardiorespiratory fitness is associated with the changes in blood pressure adds to the existing evidence in adults of an association between physical fitness and blood pressure. To confirm the results, further research is needed, especially through experimental and interventional studies. In short, the results indicate that there is a relation between the level of cardiorespiratory fitness and blood pressure and probably the change in cardiorespiratory fitness and reducing body fat is associated with blood pressure for adolescents.

CONCLUSION

On the basis of the obtained results it can be concluded that a higher percentage of boys are overweight/obese, have a higher systolic pressure, and lower diastolic pressure compared to girls. The low level of cardiorespiratory fitness and high percentage of body fat are independently associated with an increased risk of blood pressure and hypertension for both boys and girls. The interaction is established between the percentage of body fat and fitness. The results should be taken into account in building strategies and recommendations to improve the lifestyle and health for adolescents.

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