RELATIONSHIP BETWEEN MAJOR CARDIOVASCULAR SYSTEM PARAMETERS AND BODY MASS INDEX IN ADOLESCENTS OF MAGADAN REGION

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Excess weight and obesity detected in adolescence are likely to be detected in adulthood, which increases the risk of cardiovascular disorders. The study was aimed to assess the features of cardiovascular system parameters in adolescent males considering their body mass index (BMI). For this purpose a total of 208 adolescent males aged 15–16 were surveyed. The major indicators of physical development and cardiovascular system function were evaluated by standard method. BMI was calculated, based on which three groups were distinguished: underweight adolescents, adolescents with normal and excess body weight. It was found that 23% of subjects were underweight, 62% had normal body weight, and excess body weight was reported in 15% of adolescents. It has been shown that the growth of strain on the cardiovascular system from the group of underweight adolescents to the group with excess weight is observed (4, 16, and 37%, respectively), which is confirmed by the correlation analysis results. The findings suggest the less effective cardiovascular system functioning mode in overweight adolescents compared to other assessed groups. The data obtained can be used to develop the guidelines on managing excess body weigth in the group of individuals being through the adolescent ontogeny period as a target group for health promotion and applying preventive measures.

Keywords: male adolescents, body mass index, cardiovascular system, North

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ЗАВИСИМОСТЬ ОСНОВНЫХ ПОКАЗАТЕЛЕЙ ДЕЯТЕЛЬНОСТИ СЕРДЕЧНО-СОСУДИСТОЙ СИСТЕМЫ ОТ ИНДЕКСА МАССЫ ТЕЛА У ПОДРОСТКОВ МАГАДАНСКОЙ ОБЛАСТИ

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Выявленные в подростковом возрасте избыточная масса тела и ожирение с большой вероятностью будут обнаружены и во взрослом возрасте, что повышает риск развития сердечно-сосудистых заболеваний. Целью исследования было изучить особенности показателей сердечно-сосудистой системы мальчиков-подростков с учетом величины индекса массы тела (ИМТ). Для этого были обследованы 208 подростков мужского пола в возрасте 15–16 лет. Оценка основных показателей физического развития и сердечно-сосудистой системы проведена стандартными методами. Выполнен расчет ИМТ, на основе которого выделены три группы: подростки с дефицитом массы тела, подростки с нормальной и избыточной массой тела. Установлено, что дефицит массы тела имел место у 23% обследованных, 62% имели нормальную массу тела, избыточная масса тела отмечена у 15% подростков. Выявлено, что от группы подростков с дефицитом массы тела к группе с избыточной массой тела наблюдается рост напряжения в работе сердечно-сосудистой системы (4, 16 и 37% соответственно), что подтверждают результаты корреляционного анализа. Результаты исследования свидетельствуют о менее эффективном режиме функционирования сердечно-сосудистой системы у подростков с избыточной массой тела по сравнению с другими обследованными группами. Полученные данные можно использовать для разработки рекомендаций по коррекции избыточной массы тела в группе лиц подросткового периода онтогенеза как целевой группе по укреплению здоровья и проведению профилактических мероприятий.

Ключевые слова: подростки мужского пола, индекс массы тела, сердечно-сосудистая система, Север

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Anthropometry is among methods most widely used to assess body composition in epidemiology studies due to its ease of use, low cost, and high reliability relative to other human morphology evaluation methods [1]. Indicators of physical development obtained during anthropometric measurements enable estimation of adolescent's development and health [2, 3]. It should be noted that the state and endurance of cardiovascular system also represent good predictors of health across the life-course that are inversely related to such morphological parameters, as body mass index (BMI), waist circumference, body weight (BW), body fat percentage, and skinfold thickness [4–7].

BMI is a synthetic direct indicator of the human body harmony and an indirect indicator of adequate diet and general health based on the ratio between BW and body length. BMI calculation is essential for detection of excess BW and obesity being important risk factors of a number of cardiometabolic disorders [8, 9].

It should be noted that adolescent obesity is strongly associated with multiple comorbidities [10], especially with cardiovascular and metabolic disorders [11, 12]. There is evidence that the increase in BW being a multifaceted process also affects the child's body growth and development, as well as psychoemotional state [13]. Consequently, careful monitoring of BW and BMI throughout childhood and adolescence ontogeny periods can represent not only a method to detect excess weight and obesity, but also a simple and powerful method to prevent the disorders associated with the above, including reducing the risk of cardiovascular disorders in adults [9]. This subject is becoming particularly important due to the spread of obesity in this age group observed in the past decade [14]. Thus, according to global forecast, 268 and 124 million children and adolescents will be overweight or obese by 2025 [15]. It should be noted that a pronounced increase in the prevalence of these conditions in adolescents observed in the 20th century was followed by the increase in the prevalence of arterial hypertension (AH) and prehypertension [16].

Based on the foregoing, the study was aimed to evaluate and analyze the main cardiovascular system characteristics in the group of adolescent males living in the North considering their BMI.

METHODS

A total of 208 male Caucasian adolescents aged 15–16, who had comparable living conditions and were permanent residents of the Magadan Region, were assessed. Inclusion criteria: age 15–16 years, availability of the informed consent, health group 1–2. Exclusion criteria: history of chronic disease, being outside the age range, no informed consent. Assessment was performed in fall/winter 2022.

Basic somatometric characteristics were determined in the subjects: body length (cm) and BW (kg) that were used to calculate BMI (kg/m^2) according to the following formula:

$$BMI = BW/BL^2,$$

where BL was body length (cm), BW was body weight (kg). Differentiation of adolescents based on BMI involved taking into account the percentile ranges in accordance with the guidelines issued by the World Health Organization (WHO) [17].

The assessed sample was divided into three groups according to the WHO criteria: group 1 — underweight adolescents (n = 48, 23%) with the average age of 16.2 ± 0.0 years; group 2 — subjects with normal weight (n = 128, 62%) with the average age of 16.2 ± 0.1 years; group 3 included overweight adolescents (n = 32, 15%) with the average age of 16.2 ± 0.1 years.

The Nessei DS-1862 blood pressure monitor (Nissei; Japan) was used to measure systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), heart rate (HR, bpm) three times and calculate mean values. The following indicators were calculated based on the data obtained: rate-pressure product (RPP, AU), stroke volume (SV, mL), cardiac output (CO, mL/min), systemic vascular resistance (SVR, dyn · s · cm^{-5}) [18].

Statistical processing of the results was performed using the Statistica 7.0 software package (StatSoft; USA). The distribution of measured variables was tested for normality using the Shapiro–Wilk test. The results of applying parametric methods were presented as mean (M) and error of the mean (± m). No preliminary calculation of the sample size was performed. Significance of differences was determined using the Student's t-test. The critical significance level (p) was set as 0.05.

RESULTS

The Table provides the main cardiovascular system parameters and their values calculated in adolescent males living in the North based on their BMI. The results obtained show that 23% of subjects were underweight, 62% of adolescents had normal weight, and 15% were overweight. There were no significant differences in body length between the studied groups, which suggested that the samples were comparable.

The data provided show that overweight adolescent boys are characterized by significantly higher SBP, HR, SV, and CO values, as well as RPP, along with no significant intergroup differences in SVR. Optimal cardiovascular system characteristics in the form of the lowest HR and DBP values have been revealed in the group of individuals with normal weight. Underweight adolescents have significantly lower SBP, RPP, SV, and CO values. However, it should be noted that no differences in DBP and HR between groups with the weight deficit and normal weight have been revealed. When differentiating the studied groups based on the share of individuals with the high-normal blood pressure (HNBP) and AH based on SBP and SBP, it has been determined that such cardiovascular system abnormalities are most common in overweight adolescents.

DISCUSSION

The findings suggest that the lowest SBP values are typical for underweight adolescent boys, and the corresponding indicator grows in each subsequent group. The lowest DBP values are reported in the group with normal BW, while the highest values are observed in overweight individuals. It is well-known that excess BW and obesity detected in early childhood are likely to be found in adolescence and adulthood [19, 20], which increases the risk of cardiovascular disorders [21], type 2 diabetes mellitus and musculoskeletal disorders [22].

Differentiation of the assessed group by BP [23] showed that the share of individuals with HNBP and AH along with underweight based on SBP was 0% and 4%, while no similar deviations were revealed based on DBP. No individuals with HNBP based on SBP were found among adolescents with normal weight, the share of individuals with HNBP based on DBP was 5%, AH based on SBP was reported in 8% of adolescents, and AH based on DBP was found in 3%.

Table. Main cardiovascular system parameters of adolescents living in the North based on BMI, significance of differences (M ± *m*)

Studied parameters	Assessed groups			Significance of differences		
	Underweight (1)	Normal weight (2)	Overweight (3)	1–2	2–3	1–3
Body length, cm	179.6 ± 0.7	179.0 ± 0.8	178.0 ± 0.7	$p = 0.58$	$p = 0.35$	$p = 0.11$
BW, kg	55.6 ± 0.5	65.4 ± 0.8	86.9 ± 1.3	$p < 0.001$	$p < 0.001$	$p < 0.001$
BMI, kg/m^2	17.2 ± 0.1	20.3 ± 0.8	27.4 ± 0.4	$p < 0.001$	$p < 0.001$	$p < 0.001$
SBP, mmHg	114.9 ± 1.4	118.3 ± 1.1	123.6 ± 1.1	$p < 0.05$	$p < 0.001$	$p < 0.001$
DBP, mmHg	70.4 ± 0.7	68.4 ± 0.9	71.3 ± 0.8	$p = 0.08$	$p < 0.05$	$p = 0.39$
HR, bpm	71.0 ± 1.0	70.8 ± 1.3	75.6 ± 1.1	$p = 0.91$	$p < 0.01$	$p < 0.01$
RPP, AU	81.6 ± 1.4	83.7 ± 1.6	93.7 ± 1.8	$p < 0.05$	$p < 0.001$	$p < 0.001$
SV, mL	71.3 ± 0.7	75.2 ± 0.9	74.6 ± 0.8	$p < 0.001$	$p = 0.62$	$p < 0.01$
CO, mL/min	5025.8 ± 58.0	5286.5 ± 93.5	5654.3 ± 112.1	$p < 0.05$	$p < 0.01$	$p < 0.001$
SVR, dyn · s · cm^{-5}	1433.0±18.9	1403.7 ± 31.4	1372.6 ± 31.6	$p = 0.42$	$p = 0.48$	$p = 0.11$

Among overweight adolescents, HNBP based on DBP was found in 6%, this group had the largest share of subjects with AH (25% based on SBP, 6% based on DBP).

Due to high prevalence, both arterial hypertension and obesity are considered to be a non-communicable pandemic [24]. We have interpreted the total rate of individuals with HNBP and AH based on SBP and DBP as strain on the cardiovascular system, it was 4% in the group of underweight adolescents, 16% in the group with the weight within normal range, 37% in the sample characterized by excess BW.

SV reflects the amount of blood ejected by the ventricles with each contraction and depends on the body's functional state [25]. Our findings show that the highest average SV values are typical for individuals with normal BW and the lowest values have been revealed in underweight individuals.

CO is the most important parameter determining blood flow. Adequate CO values suggest optimal oxygen supply to tissues and organs, which, in turn, is equivalent to cardiovascular health [26]. The highest CO values, being indirect indicators of energy metabolism, are typical for overweight adolescents. In this group high CO values result from higher HR and SV agaist the background of higher SBP relative to other assessed groups. High values of these parameters reflect the consumptive and energy-draining level of the cardiovascular system functioning [27]. The lowest CO values are typical for underweight adolescents.

SVR is a stationary component of cardiovascular system that ensures resistance to permanent blood flow and regulates the pressure gradient between the venous and arterial systems [28, 29]. The data obtained show that there are no intergroup differences in SVR.

RPP characterizes the cardiovascular system functional status and reflects the processes underlying its mechanical activity. It should be noted that RPP ≥ 100 AU is indicative of high heart energy production [30]. The RPP value close to the upper limit of normal range has been revealed in overweight adolescents, which reflect the increased need for myocardium in oxygen. At the same time, significantly lower RPP values have been revealed in the group of underweight individuals, which is indicative of the more energy-conserving and effective cardiovascular system functioning in this group.

Thus, all the assessed samples show the values of cardiovascular system parameters that correspond to normal ranges for these parameters, however, overweight individuals are characterized by strain on the cardiovascular system reflected in significantly higher SBP, HR, CO values. The correlation analysis results provided in Figure are also indicative of strain on the cardiovascular system.

The data obtained by correlation analysis show that BMI has no effect on the cardiovascular system characteristics in the groups of underweight adolescents and adolescents with normal weight. Correlations have been revealed in overweight individuals: DBP and SV increase with increasing BMI. Furthermore, there is a weak negative correlation between BMI and SVR.

CONCLUSIONS

Thus, the findings show strain on the cardiovascular system in the group of overweight adolescents. The increase in strain on the cardiovascular system has been revealed, which is 4% in the group of underweight adolescents, 16% in the group with BW within normal range, 37% in the sample characterized by excess BW. It has been shown that the cardiovascular system of overweight adolescents functions more effectively, which is reflected in significantly higher SBP, HR, SV, and CO values observed against the background of enhanced

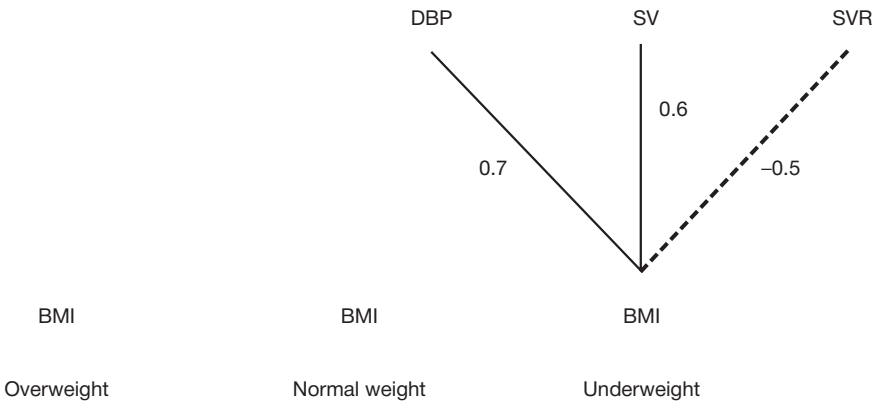

Fig. Correlation analysis of the relationship between body mass index and the major cardiovascular system characteristics

processes underlying mechanical activity of the heart. This is well correlated to the correlation analysis results. The findings can be used to produce the guidelines aimed at managing excess BW in the group of individuals being through the adolescent ontogeny period as a target group for health promotion and applying preventive measures.

References

1. Rice E, Mashford-Pringle A, Maclean T, Belmore D. Needing indigenous biometrics for health in Canada. Preventive Medicine Reports. 2023; (31): 102115. DOI:10.1016/j.pmedr.2023.102115.
2. Drazner MH. The progression of hypertensive heart disease. Circulation. 2011; 123 (3): 327–34. DOI:10.1161/circulationaha.108.845792.
3. Henriksson P, Cadenas-Sanchez C, Leppänen MH, Nyström CD, Ortega FB, Pomeroy J, et al. Associations of fat mass and fat-free masswith physical fitness in 4-year-old children: results from the MINISTOP trial. Nutrients. 2016; 8 (8): 473. DOI:10.3390/nu8080473.
4. Cicek B, Ozturk A, Unalan D, Bayat M, Mazicioglu MM, Kurtoglu S. Foursite skinfolds and bodyfat percentage references in6-to-17-year old Turkish children and adolescents. The Journal of the Pakistan Medical Association. 2014; 64 (10): 1154–61. DOI:10.1515/jpem-2013-0467.
5. Ferrari GL, Bracco M, Matsudo VKR, Fisberget M. Cardiorespiratory fitness and nutritional status of schoolchildren: 30-year evolution. Jornal de Pediatria (Versão Em Português). 2013; 89 (4); 366–73. DOI:10.1016/j.jped.2012.12.006.
6. Gonçalves ECA, Nunes HEG, Silva DAS. Which body fat anthropometric indicators are most strongly associated with maximum oxygen uptake in adolescents. Asian Journal of Sports Medicine. 2017; 8 (3): 812. DOI:10.5812/asjsm.13812.
7. Awotidebe A, Monyeki MA, Moss SJ, Strydom GL, Amstrong M, Kemper HCG. Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of south African adolescents: the PAHL study. Journal oh Human Hypertension. 2015; 30 (4): 245–51. DOI:10.1038/jhh.2015.81.
8. Chernozemov VG, Afanasenkova NV, Varencova IA. Metody fiziologicheskogo issledovanija cheloveka. Severnyj (Arkticheskij) federal'nyj universitet im. M.V. Lomonosova, 2017; 159 p. (in Rus.).
9. Oliveira-Santos J, Santos R, Moreira C, Abreu S, Lopes L, Agostinis-Sobrinhoet C, et al. Associations between anthropometric indicators in early life and low-grade inflammation, insulin resistance and lipid profile in adolescence. Nutrition, Metabolism and Cardiovascular Diseases. 2019; 29 (8): 783–92. DOI: 10.1016/j.numecd.2019.05.052.
10. Kumar S, Kelly AS. Review of childhood obesity: from epidemiology, etiology, and comorbidities to clinical assessment and treatment. Mayo Clinic Proc. 2017; 92 (2): 251–65. DOI:10.1016/j.mayocp.2016.09.017.
11. Geserick M, Vogel M, Gausche R, Lipek T, Spielau U, Kelleret E, et al. Acceleration of BMI in early childhood and risk of sustained obesity. New England Journal of Medicine. 2018; (379): 1303–12. DOI: 10.1056/NEJMoa1803527.
12. Madias JE. “Obesity paradox” and takotsubo syndrome. International Journal of Cardiology Cardiovascular Risk and Prevention. 2022; (15): 200152. DOI:10.1016/j.ijcrp.2022.200152.
13. Juliaty A, Mutmainnah, Daud D, Lisal JS. Correlation between vitamin D deficiency and fasting blood glucose levels in obese children. Clinical Nutrition ESPEN. 2021; (44): 200–3. DOI:10.1016/j.clnesp.2021.06.022.
14. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128 · 9 million children, adolescents, and adults. Lancet. 2017; 390 (10113): 2627–42. DOI: 10.1016/S0140-6736(17)32129-3.
15. Swinburn BA, Kraak VI, Allender S, Atkins VJ, Baker PI, Bogard JR, et al. The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. Lancet. 2019; 393 (10173): 791–846. DOI: 10.1016/S0140-6736(19)30384-8.
16. Mustafayeva AG. Mechanisms for the development of arterial hypertension in overweight adolescents and young adults. Problems of Endocrinology. 2019; 65 (3): 191–6 (in Rus.).
17. WHO [Internet]. BMI-for-age (5-19 years) [cited 2022 Nov 30]. Available from: https://cdn.who.int/media/docs/default-source/child-growth/growth-reference-5-19-years/bmi-for-age-(5-19-years)/sft-bmifa-girls-perc-5-19years-(1)_411a8497-4364-45b5-9c55-a1d96a623869.pdf?sfvrsn=fad3e8ce_6.
18. Jurev VV, Simahodskij AS, Voronovich NN. Rost i razvitie rebenka. SPb.: Piter, 2007; 272 p. (in Rus.).
19. Calder PC, Ahluwalia N, Albers R, Bosco N, Bourdet-Sicard R, Haller D, et al. A consideration of biomarkers to be used for evaluation of inflammation in human nutritional studies. British Journal of Nutrition. 2013; (109): 1–34. DOI: 10.1017/S0007114512005119.
20. Tyson N, Frank M. Childhood and adolescent obesity definitions as related to BMI, evaluation and management options. Best Pract Res Clin Obstet Gynaecol. 2018; 48: 158–64. DOI: 10.1016/j.bpobgyn.2017.06.003.
21. Tai P, Yang S, Liu W, Wang S, Chen K, Jia W, et al. Association of anthropometric and nutrition status indicators with cognitive functions in centenarians. Clinical Nutrition. 2021; 40 (4): 2252–58. DOI:10.1016/j.clnu.2020.10.004.
22. Kirkpatrick BM, Yuhas M, Zoellner JM. Exploring differences in adolescent BMI and obesity-related behaviors by urban, suburban, and rural status. Preventive Medicine Reports. 2022; (29): 101960. DOI: 10.1016/j.pmedr.2022.101960.
23. Aleksandrov AA, Kisliak OA, Leontyeva IV. Clinical guidelines on arterial hypertension diagnosis, treatment and prevention in children and adolescents. Systemic Hypertension. 2020; 17 (2): 7–35 (in Rus.). DOI: 10.26442/2075082X.2020.2.200126.
24. Chukaeva II, Klepikova MV, Orlova NV, Agaeva LM. Role of obesity in development of hypertension and efficiency of anorectic therapy. Medical alphabet. 2018; 1 (12): 37–9 (in Rus.).
25. Antonov AA. No-loads assessment of functional state of athlete’s body. Lechebnaja fizkul'tura i sportivnaja medicina. 2011; 10 (94): 39–46 (in Rus.).
26. Antonov AA. Universal technology for diagnosis of functional state of organism of sportsmen based on the integral indices of cardiovascular system. Vestnik vosstanovitel'noj mediciny. 2017; 5 (81): 38–44 (in Rus.).
27. Solodkov AS, Sologub EB. Fiziologija cheloveka. Obshhaja. Sportivnaja. Vozrastnaja. M.: Sport, 2015.; 620 p. (in Rus.).
28. Aronow WS. Heart disease and aging. Med Clin North Am. 2006; 90 (5): 849–62. DOI: 10.1016/j.mcna.2006.05.009.
29. Barannik IA, Lavinskaja NN, Svjatov DI, Leonteva MN. Klasternyj analiz sistemnogo krovoobrashhenija u prakticheski zdorovyh muzhchin molodogo-srednego vozrasta. Vestnik Sankt-Peterburgskoj Gosudarstvennoj medicinskoj akademii imeni I.I. Mechnikova. 2007; 1: 184–6 (in Rus.).
30. Baevskij RM, Kirillov OI, Kleckin SZ. Matematicheskij analiz izmenenij serdechnogo ritma pri stresse. M.: Nauka, 1984; 225 p. (in Rus.).

Литература

1. Rice E, Mashford-Pringle A, Maclean T, Belmore D. Needing indigenous biometrics for health in Canada. Preventive Medicine Reports. 2023; (31): 102115. DOI:10.1016/j.pmedr.2023.102115.
2. Drazner MH. The progression of hypertensive heart disease. Circulation. 2011; 123 (3): 327–34. DOI:10.1161/circulationaha.108.845792.
3. Henriksson P, Cadenas-Sanchez C, Leppänen MH, Nyström CD, Ortega FB, Pomeroy J, et al. Associations of fat mass and fat-free masswith physical fitness in 4-year-old children: results from the MINISTOP trial. Nutrients. 2016; 8 (8): 473. DOI:10.3390/nu8080473.
4. Cicek B, Ozturk A, Unalan D, Bayat M, Mazicioglu MM, Kurtoglu S. Foursite skinfolds and bodyfat percentage references in6-to-17-year old Turkish children and adolescents. The Journal of the Pakistan Medical Association. 2014; 64 (10): 1154–61. DOI:10.1515/jpem-2013-0467.
5. Ferrari GL, Bracco M, Matsudo VKR, Fisberget M. Cardiorespiratory fitness and nutritional status of schoolchildren: 30-year evolution. Jornal de Pediatria (Versão Em Português). 2013; 89 (4); 366–73. DOI:10.1016/j.jped.2012.12.006.
6. Gonçalves ECA, Nunes HEG, Silva DAS. Which body fat anthropometric indicators are most strongly associated with maximum oxygen uptake in adolescents. Asian Journal of Sports Medicine. 2017; 8 (3): 812. DOI:10.5812/asjsm.13812.
7. Awotidebe A, Monyeki MA, Moss SJ, Strydom GL, Amstrong M, Kemper HCG. Relationship of adiposity and cardiorespiratory fitness with resting blood pressure of south African adolescents: the PAHL study. Journal oh Human Hypertension. 2015; 30 (4): 245–51. DOI:10.1038/jhh.2015.81.
8. Черноземов В. Г. Афанасенкова Н. В., Варенцова И. А. Методы физиологического исследования человека. Северный (Арктический) федеральный университет им. М. В. Ломоносова, 2017; 159 с.
9. Oliveira-Santos J, Santos R, Moreira C, Abreu S, Lopes L, Agostinis-Sobrinhoet C, et al. Associations between anthropometric indicators in early life and low-grade inflammation, insulin resistance and lipid profile in adolescence. Nutrition, Metabolism and Cardiovascular Diseases. 2019; 29 (8): 783–92. DOI: 10.1016/j.numecd.2019.05.052.
10. Kumar S, Kelly AS. Review of childhood obesity: from epidemiology, etiology, and comorbidities to clinical assessment and treatment. Mayo Clinic Proc. 2017; 92 (2): 251–65. DOI:10.1016/j.mayocp.2016.09.017.
11. Geserick M, Vogel M, Gausche R, Lipek T, Spielau U, Kelleret E, et al. Acceleration of BMI in early childhood and risk of sustained obesity. New England Journal of Medicine. 2018; (379): 1303–12. DOI: 10.1056/NEJMoa1803527.
12. Madias JE. “Obesity paradox” and takotsubo syndrome. International Journal of Cardiology Cardiovascular Risk and Prevention. 2022; (15): 200152. DOI:10.1016/j.ijcrp.2022.200152.
13. Juliaty A, Mutmainnah, Daud D, Lisal JS. Correlation between vitamin D deficiency and fasting blood glucose levels in obese children. Clinical Nutrition ESPEN. 2021; (44): 200–3. DOI:10.1016/j.clnesp.2021.06.022.
14. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128 · 9 million children, adolescents, and adults. Lancet. 2017; 390 (10113): 2627–42. DOI: 10.1016/S0140-6736(17)32129-3.
15. Swinburn BA, Kraak VI, Allender S, Atkins VJ, Baker PI, Bogard JR, et al. The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. Lancet. 2019; 393 (10173): 791–846. DOI: 10.1016/S0140-6736(19)30384-8.
16. Мустафаева А. Г. Механизмы развития артериальной гипертензии у лиц молодого возраста с избыточным весом. Проблемы эндокринологии. 2019; 65 (3): 191–6. DOI: https://doi.org/10.14341/probl9651.
17. WHO [Интернет]. BMI-for-age (5–19 years) [дата обращения 30.11.2022]. URL: https://cdn.who.int/media/docs/default-source/child-growth/growth-reference-5-19-years/bmi-for-age-(5-19-years)/sft-bmifa-girls-perc-5-19years-(1)_411a8497-4364-45b5-9c55-a1d96a623869.pdf?sfvrsn=fad3e8ce_6.
18. Юрьев В. В., Симаходский А. С., Воронович Н. Н. Рост и развитие ребенка. СПб.: Питер, 2007; 272 с.
19. Calder PC, Ahluwalia N, Albers R, Bosco N, Bourdet-Sicard R, Haller D, et al. A consideration of biomarkers to be used for evaluation of inflammation in human nutritional studies. British Journal of Nutrition. 2013; (109): 1–34. DOI: 10.1017/S0007114512005119
20. Tyson N, Frank M. Childhood and adolescent obesity definitions as related to BMI, evaluation and management options. Best Pract Res Clin Obstet Gynaecol. 2018; 48: 158–64. DOI: 10.1016/j.bpobgyn.2017.06.003.
21. Tai P, Yang S, Liu W, Wang S, Chen K, Jia W, et al. Association of anthropometric and nutrition status indicators with cognitive functions in centenarians. Clinical Nutrition. 2021; 40 (4): 2252–58. DOI:10.1016/j.clnu.2020.10.004.
22. Kirkpatrick BM, Yuhas M, Zoellner JM. Exploring differences in adolescent BMI and obesity-related behaviors by urban, suburban, and rural status. Preventive Medicine Reports. 2022; (29): 101960. DOI: 10.1016/j.pmedr.2022.101960.
23. Александров А. А., Кисляк О. А., Леонтьева И. В. Диагностика, лечение и профилактика артериальной гипертензии у детей и подростков. Системные гипертензии. 2020; 17 (2): 7–35. DOI: 10.26442/2075082X.2020.2.200126.
24. Чукаева И. И., Клепикова М. В., Орлова Н. В., Агаева Л. М. Роль ожирения в развитии артериальной гипертонии и эффективность анорексигенной терапии. Медицинский алфавит. 2018; 1 (12): 37–9.
25. Антонов А. А. Безнагрузочная оценка функционального состояния организма спортсменов. Лечебная физкультура и спортивная медицина. 2011; 10 (94): 39–46.
26. Антонов А. А. Универсальная технология диагностики функционального состояния организма спортсменов на основе интегральных показателей сердечно-сосудистой системы. Вестник восстановительной медицины. 2017; 5 (81): 38–44.
27. Солодков А. С., Сологуб Е. Б. Физиология человека. Общая. Спортивная. Возрастная. М.: Спорт, 2015; 620 с.
28. Aronow WS. Heart disease and aging. Med Clin North Am. 2006; 90 (5): 849–62. DOI: 10.1016/j.mcna.2006.05.009.
29. Баранник И. А., Лавинская Н. Н., Святов Д. И., Леонтьева М. Н. Кластерный анализ системного кровообращения у практически здоровых мужчин молодого-среднего возраста. Вестник Санкт-Петербургской Государственной медицинской академии имени И. И. Мечникова. 2007; 1: 184–6.
30. Баевский Р. М., Кириллов О. И., Клецкин С. З. Математический анализ изменений сердечного ритма при стрессе. М.: Наука, 1984; 225 с.