PERIODICUM BIOLOGORUM
VOL. 119, No 2, 87–92, 2017
DOI: 10.18054/pb.v119i2.4498

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

original research article

Sex-related Differences in Correlation of Overweight/Obesity Markers to Blood Pressure in Prepubertal Children in Osijek-Baranja County – a Cross-sectional Study

LIDIJA RAŠIĆ
DAJANA ZRINUŠIĆ
INES DRENJANČEVIĆ*

Department of Physiology and Immunology
Faculty of Medicine Osijek
Josip Juraj Strossmayer University of Osijek
Osijek, Croatia

***Correspondence:**
Ines Drenjancevic, MD, PhD
Email: ines.drenjancevic@mefos.hr

List of abbreviations:
BMI – body mass index
WC – waist circumference
SBP – systolic blood pressure
DBP – diastolic blood pressure
fBGC – fasting blood glucose concentration

Key words: children, obesity, risk factors, chronic diseases

Abstract

Background: *The aim was to assess prevalence of overweight/obesity and evaluate their relations to blood pressure and blood glucose concentrations in prepubertal school children.*

Design and method: *Third grade elementary school children were included (total 111-53 girls, 58 boys; 9±1 years). Height, weight, body mass index (BMI), waist circumference (WC), upper arm and thigh skin fold (ASF, TSF) and systolic (SBP) and diastolic blood pressure (DBP) and fasting blood glucose concentrations (fBGC) were measured.*

Results: *13.51% subjects were overweight (BMI>85th percentile; 3 girls and 12 boys) and 15.32% subjects were obese (BMI>95th percentile;7 girls and 10 boys). Boys had significantly higher SBP than girls. Overweight/obese boys had significantly thicker ASF and TSF, higher SB, higher DBP (and higher fBGC compared to normal-weight boys; 5 boys and 4 girls were hypertensive (SBP>95th percentile). In boys, there were significant positive correlations of BMI and WC with SBP, DBP, ASF and TSF. Overweight/obese girls had significantly thicker ASF and TSF and greater WC compared to normal-weight girls. SBP, DBP or fBGC were not significantly different between OW/OB and normal-weight girls. In girls, BMI and WC significantly positively correlated with ASF and TSF, but no correlations to BP were observed. WC positively correlated to fBGC in both, boys and girls.*

Conclusions: *Significant association of OW/OB to arterial BP levels in prepubertal boys and a lack of associations among OW/OB markers and arterial BP levels in girls suggest that OW/OB might not be as important risk factors in development of hypertension in adulthood in females as in males.*

Received September 12, 2016.
Revised March 31, 2017.
Accepted April 12, 2017.

INTRODUCTION

Overweight and obesity in children, young adults and adults becomes problem nationwide *(1)*. Many recent studies showed that the childhood obesity is a global issue: in 77% of the countries examined, at least 10% of youth were overweight and in 20% of the countries at least 3% of children were obese *(2)*. In these studies, adiposity status is assessed in the clinical setting using simple anthropometric measures such as the body mass index (BMI) and waist circumference (WC). While BMI is a common measure, nowadays criticized as not descriptive enough in children, waist circumference is showing its' utility in iden-

tifying overweight children. Waist circumference is a marker of total and abdominal fat in children and adolescents *(3)*. Both obese and overweight children have high expectancy in becoming overweight adults, which is related to appearance of certain chronic diseases in adulthood *(4)*. Childhood obesity is associated with significant health problems; while children rarely develop true cardiovascular events, early evidence of accelerated atherogenesis can be detected *(5)*. Those children who remain obese as adults have great risk for the development of type 2 diabetes, hypertension, dyslipidemia and atherosclerotic cardiovasular disease *(6,7)*. Some of risk factors in childhood' overweight are modifiable, such as lack of regular exercise, high frequency of TV watching, computer usage or usage of other screen media, low parental educational level, over-consumption of high-calorie food *(8,9,10)*. This gives the opportunity to prevent or alleviate risks of developing cardiovascular diseases in adulthood.

It is well known that sex hormones have influence on cardiovascular risk factors. Many studies have shown the protective role of estrogen considering cardiovascular system in women during reproductive age *(11,12)*, while lately there are many studies indicating that the testosterone deficiency is related to the outbreak of cardiovascular risk factors *(13)*. It is well known that sex hormones are involved in adipocyte metabolism and fat distribution *(14)*. Estrogen has anabolic effect on fat, especially subcutaneous fat. Decrease in estrogen levels in menopausal women is associated with the loss of subcutaneous fat and increase in abdominal fat *(15)*. On the other hand, androgens have lipolytic effect *(16)*, while testosterone deficiency is associated with increased body weight, adiposity and increased waist circumference *(17)*. However, there is a paucity of data in regard of childhood obesity before the sexual maturation and pubertal endocrine activation. At that time of life the energy metabolism is not affected by sex hormones because sex hormones are still idle *(18)*, and the influence of sex hormones on metabolic and anthropometric characteristics related to the risk factors for developing obesity and later cardiovascular diseases is minimized.

The aim of this study was to investigate prevalence of obesity and overweight and its relationship to arterial blood pressure and fasting glucose levels in pre-pubertal children of both sexes in Osijek, Croatia.

METHODS AND PROCEDURES

Population and sample

Cross-sectional study was performed on preadolescent pupils of randomly chosen primary schools in Osijek, Croatia. The pupils were 3rd grade of primary school, 9±1 years old. One hundred and eleven subjects were included in total (see Statistical analysis section). According to the Tanner's stages of sexual maturation, children did not have signs of puberty in this prepubertal phase *(19)*. The written informed consent was obtained from parents and schools agreed for study to be conducted. The study protocol and procedures conformed to the standards set by the latest revision of the *Declaration of Helsinki* and were approved by the Ethical Committee of the Faculty of Medicine, University of Osijek.

Arterial blood pressure, fasting glucose levels, skin fold, BMI and WC measurements

Anthropometric parameters included were height, weight, and waist circumference (WC). Thickness of skinfold of the upper arm and of the thigh was also measured and systolic and diastolic arterial blood pressure (SBP and DBP) and fasting blood glucose concentration (fBGC) were also assessed. Blood pressure was measured at the beginning of the visit after 15 minutes rest while sitting, using manual sphygmomanometer. The pediatric cuff was placed smoothly and snugly around an upper arm, at roughly the same vertical height as the heart. The final values of arterial blood pressure and heart rate were the mean of three repeated measurements.

BMI was calculated for each subject scaled toward percentiles to determine normal weight, overweight and obese children. Categories according to BMI were based on National center for Health Statistics guidelines *(20)*: normal weight males (≤18.6), overweight males (18.6–21), obese males (≥21); normal weight females (≤19), overweight females (19–21.8), obese females (≥21.8) *(18)*. All parameters were expressed as mean values ± standard deviation (SD).

Statistical analysis

Descriptive statistics (mean ± SD) were used to characterize all parameters measured for both girls and boys. A Student t-test was used to compare parameters between each group of subjects. Normality was tested using Shapiro-Wilk test. When variables were not normally distributed, the Mann-Whitney Rank Sum Test was used. Statistical significance was set at $\alpha<0.05$. Correlation analysis among measured parameters was performed using Pearson's correlation coefficient at 95% confidence of interval. When variables were not normally distributed, Spearman Rank Order Correlation was performed. In order to achieve 80% power and $\alpha<0.05$ level of significance, Student t-test sample size analysis was used. That analysis established that a sample size of at least 90 participants was required and appropriate. Sigmaplot (v11.2, Systat Software, Chicago, USA) was used for statistical analysis.

RESULTS

Data were collected from 10% of the municipal primary schools in Osijek, Croatia. One hundred and eleven

children participated, 58 boys and 53 girls, aged 9±1 years. According to the BMI, sample showed that 14% of children are overweight and 15% are obese. 21% of boys were overweight and 17% were obese, while girls were 13% overweight and 15% obese (Table 1). The cut-offs guidelines applied were established by National center for Health Statistics as described in Methods section. Measured parameters for all participants are shown in Table 2.

Arterial blood pressure, fasting glucose levels, skin fold thickness, BMI and WC measurements

Overall boys had significantly higher SBP than girls (P=0.046). 5 boys and 4 girls were marked as hypertensive (SBP>95th percentile). Overweight/obese boys had significantly thicker upper arm skin fold and thigh skin fold compared to normal-weight boys (Table 3). Systolic blood pressure was significantly higher in overweight-obese than in normal-weight boys (Table 2). Overweight-obese boys also had significantly higher diastolic blood pressure (Table 3) and higher fasting blood glucose concentrations (Table 3) than normal-weight boys.

In boys, there were significant positive correlations of BMI with systolic blood pressure (r=0.470, P<0.001), diastolic blood pressure (r=0.482, P<0.001), upper arm skin fold (r=0.722, P<0.001) and thigh skin fold (r=0.479, P<0.001). Also WC showed statistically significant positive correlation with systolic blood pressure (r=0.466, P<0.001), diastolic blood pressure (r=0.344, P=0.014,), fasting glucose concentrations (r=0.343, P=0.015), upper arm skin fold (r=0.768, P<0.001) and thigh skin fold (r=0.426, P=0.001) in boys.

Overweight-obese girls had significantly thicker upper arm skin fold (P<0.001) and thigh skin fold (P=0.019) than normal-weight girls. Overweight-obese girls also had significantly greater WC than normal-weight girls (P<0.001). Systolic blood pressure (overweight/obese 107±7 mmHg vs. normal-weight 101±9 mmHg; Table 2), diastolic blood pressure (overweight-obese 66±6 mmHg vs. normal-weight 63±4 mmHg, Table 3), or fasting blood glucose concentrations (overweight-obese 5.26±0.43 mmol/L vs. normal-weight 5.02±0.5 mmol/L; Table 3) were not significantly different between overweight-obese and normal-weight girls. In girls, BMI showed positive correlation with upper arm skin fold (r=0.804, P<0.001) and thigh skin fold (r=0.615, P<0.001). WC also positively correlated with upper arm skin fold (r=0.694, P<0.001) and thigh skin fold (r=0.491, P<0.001), while no other correlations in girls were observed.

Table 1. *Overweight/obesity prevalence according to body mass index (BMI)*

	Boys	Girls	All
Total	58	53	111
Overweight	12	3	15
Obese	10	7	17
% OW	20.69	5.66	13.51
% obese	17.24	13.21	15.32

*OW/O – overweight/obesity
*BMI – body mass index

Table 2. *Antropometric measured parameters in all subjects*

		Height (m)	Weight (kg)	BMI	Waist circumference (cm)	Blood glucose concentrations mmol/L	Systolic pressure mmHg	Diastolic pressure mmHg	Skinfold (upper arm) (cm)	Skinfold (thigh) (cm)
All subjects (N=111)	All	1.44 (0.07)	36.97 (8.88)	17.75 (3.37)	65.50 (9.95)	5.14 (0.53)	106 (10)	64 (5)	14.92 (7.55)	31.83 (15.68)
	Overweight	1.48 (0.05)	43.35 (4.04)	19.73 (0.72)	70.77 (8.28)	5.30 (0.58)	114 (8)	67 (4)	18.54 (7.45)	28.00 (9.70)
	Obese	1.47 (0.09)	52.17 (7.48)	24.03 (1.8)	81.71 (6.37)	5.37 (0.42)	110 (10)	67 (5)	24.24 (5.75)	48.24 (18.26)
Boys (N=58)	All	1.46 (0.067)	38.20 (9.69)	17.84 (3.46)	66.93 (10.89)	5.18 (0.52)	107 (11)*	65 (5)	14.30 (8.0)	28.89 (14.9)
	Overweight	1.49 (0.05)	43.76 (4.39)	19.70 (0.77)	72.60 (8.61)	5.38 (0.63)†	115 (8)ℓ	67 (4)ˆ	18.20 (8.46)	25.00 (7.35)
	Obese	1.50 (0.08)	53.74 (6.7)	23.78 (1.96)	83.20 (7.48)	5.36 (0.43)	113 (11)	69 (4)	23.10 (6.61)	41.90 (12.01)
Girls (N=53)	All	1.42 (0.066)	35.70 (7.86)	17.65 (3.34)	64,10 (8,83)	5.10 (0.54)	103 (10)	64 (4)	15.67 (7.11)	34.82 (16.19)
	Overweight	1.45 (0.04)	41.70 (1.65)	19.84 (0.56)	64,67 (2,31)	5.033 (0.29)	110 (0)	68 (3)	19.67 (2.89)	38.00 (11,27)
	Obese	1.43 (0.08)	49.91 (8.47)	24.39 (1.62)	79,57 (3,91)	5.38 (0.46)	106 (8)	65 (7)	25.86 (4.18)	57.286 (22.58)

data are expressed as mean (SD),
*overall boys had significantly higher SBP than girls (P=0.046)
†overweight boys had higher fBGC than normalweight boys (P=0.0324)
ℓoverweight boys had higher SBP than normalweight boys (P<0.001)
ˆoverweight boys had higher DBP than normalweight boys (P=0.0015)

Table 3. *Differences in measured parameters between normal-weight and overweight/obese boys and girls*

Parameters	NWb(n=36)	OW/Ob (n=22)	NWg(n=43)	OW/Og(n=10)
Skinfold (thigh) (cm)	25	30*	35	47.5**
Skinfold (upper arm) (cm)	10.45 (5.23)	20.65 (7.83)†	15	23.5††
Diastolic pressure (mmHg)	65	70ℓ	65	65
Systolic pressure (mmHg)	103.83 (10.01)	114.21 (9.17)ˆ	100	110
Blood glucose concentration (mmol/L)	5.056 (0.486)	5.37 (0.522)ʃ	5.1	5.2

data are expressed as mean (SD)
NWb – normal weight boys, OW/Ob – overweight/obese boys; NWg – normal weight girls, OW/Og – overweight/obese girls
* difference in skinfold (thigh) between OW/Ob and NWb P<0.05
** difference in skinfold (thigh) between OW/Og and NWg P<0.05
† difference in skinfold (upper arm) between OW/Ob and NWb P<0.05
†† difference in skinfold (upper arm) between OW/Og and NWg P<0.05
ℓ difference in diastolic pressure between OW/Ob and NWb P<0.05
ˆ difference in systolic pressure between OW/Ob and NWb P<0.05
ʃ difference in blood glucose concentration between OW/Ob and NWb P<0.05

DISCUSSION

The salient findings of the study are: a) both BMI and WC significantly correlate with blood pressure values in boys, while overweight/obese boys have significantly higher values of blood pressure compared to normal weight boys; b) obesity markers are good predictor of cardiovascular risks for boys; b) no relationship between obesity markers (i.e BM, WC, upper arm and thigh skin folds) and BP was observed in girls; and c) in contrast to boys, in girls there is no difference in blood pressure values in regard to presence of overweight/obesity. The first aim of the present study was to assess the prevalence of overweight and obesity in prepubertal school children due to the general lack of these data. Our study indicates sex-related cardiovascular and metabolilc differences in even apparently healthy children. Majority of the studies examine wide age range, including prepubertal children and adolescents (21,22). Jannsen and colleagues compared overweight and obesity prevalence in school-aged youth from 34 different countries in their study from 2001–2002(2). Their study has showed that 10.6% of school-aged youth in Croatia is overweight and 1.8% is obese. Compared to Jannsen et al. results, our results showed that 13.51% of preadolescents are overweight and 15.32% are obese, which indicates significant increase of overweight and obesity trends in Croatia. Furthermore, Jelakovic et al *(24)* reported that 3.54% of adolescents in the city of Koprivnica, North-West part of Croatia were obese. This large difference in results could be outcome of geographical diversity of Croatia, since Jelakovic et al examined just one part of Croatia, and Jannsen's result are giving global picture of all parts of Croatia evenly. Our examined population is great enough to be representative of Eastern Croatia, since Osijek is the largest city in this region. Furthermore, our study has focused to the population of preadolescents, 9 years old precisely, which can also be one of reasons of the difference in results. However, the more feasible explanation for observed increase in obesity and overweight prevalence are raising trends of sedentary games and activities, decrease of physical activity and enlarged food intake in preadolescent children, which associated lead to increased weight in preadolescents *(25)*.

Childhood obesity is associated with increased rates of hypertension, hyperlipidemia, diabetes mellitus type 2 and early development of atherosclerotic lesions in adult age *(6)*. In our study, measured anthropometric parameters, blood pressure and fasting blood glucose levels are significantly higher in overweight-obese boys compared to normal-weight boys and BMI and WC of boys significantly positively correlated with systolic and diastolic blood pressure and fBGC in boys, supporting predictive risk for future development of CV diseases in boys. Surprisingly, this relationship was not seen in girls; overweight-obese girls had only significantly thicker upper arm skin fold and thigh skin fold when compared to normal-weight girls, with no correlation among BMI and WC to measured cardiovascular and metabolic values. This is a significant cognition which shows some kind of protection of developing cardiovascular risk factors in girls compared to the boy at same age, and this protection is not related to female sex hormones, since our study group was in prepubertal phase of sexual maturation. Positive correlation of obesity markers, BMI and WC, to blood pressure, blood glucose concentrations and skin folds confirmed hypothesis that overweight and obesity can precipitate and lead to higher values of measured parameters which are considered to be the indicators of increased risk for developing chronic diseases *(27)*.

Recent studies examined relationship of obesity, physical activity and cardio-metabolic risk factors in children, reporting a worsening of risk parameters for cardiovascular disease in overweight and obese children *(27, 28, 29)*. According to Friedman et al. meta-analysis, SBP was higher by 4.54 mmHg in overweight children, and 7.49 mmHg in obese children compared to normal-weight

children *(28)*. Our results are consistent with these findings, which showed the difference of 11 mmHg between overweight-obese and normal-weight boys and 6 mmHg overweight-obese and normal-weight girls. Interestingly, none of recent studies reported about differences in increased parameters when comparing overweight-obese boys and girls. Our study showed that overweight-obese boys have significantly higher values of SBP, DBP, fBGC, upper arm and thigh skin fold than normal-weight boys, while overweight-obese girls had significantly higher only upper arm and thigh skin fold compared to normal-weight girls. These results indicate that overweight-obese boys might have higher tendency to develop chronic diseases in adulthood than overweight-obese girls. Lots of studies examined relation of overweight/obesity to the cardiovascular risk factors and metabolic syndrome in adults or adolescents *(29)*. Jelakovic et al *(24)* noticed correlation of blood pressure and BMI in adolescents. Our study is the first to examine correlation of overweight/obesity to blood pressure and fasting blood glucose concentrations in prepubertal children. Though activity of sex hormones in prepubertal children is minimized, some studies showed that prepubertal girls have higher estradiol serum concentrations as compared with prepubertal boys *(30)*. Furthermore, total estrogenic bioactivity demonstrated that prepubertal girls have significantly higher total estrogenic status in comparison with prepubertal boys *(31,32)*. As mentioned before, androgens have lipolytic effect, estrogens in the reproductive age of women are associated with increase of subcutaneous fat, while in postmenopausal phase are associated with increase of abdominal fat. This evidence can be related to the difference in correlations detected in boys compared to the correlations detected in girls in our study and should be further investigated.

Recent studies examined and evaluated nutrition behavior in school children, showing inadequate nutritional habits *(33,34)*. The reason of alarming overweight/obese trends might be parental subjectivity and unawareness of their children's weight, not recognizing their children's eating habits and therefore reduced insistence on adhering to the healthy nutrition guidelines, even though children seem to be very familiar with them. In addition, the relation of energy consumption and physical activity is also extremely important to keep body weight normal in every, and particularly early childhood age of life. Since these children are in prepubertal phase of development, there are many methods of preventing the development of obesity in adult age, like diet interventions and regular everyday physical activity interventions *(35,36)*.

Limitation of the study: Our sample included children from small area of living with similar daily habits, which is representative for selected region, but could affect prevalence of overweight and obesity in prepubertal children generally. Fasting blood glucose concentration data were available for 87% of our study sample because of children's fear and discomfort. Furthermore, in our study sex hormone were not measured, however children did not have signs of puberty in this prepubertal phase according to the Tanner's stages of sexual maturation *(19)*.

In conclusion, our study provided new information on overweight and obesity prevalence in preadolescent of 9 years old. The difference in measured parameters was noticed in overweight/obese boys compared to normal-weight boys only, but not in girls, indicating that overweight-obese boys might have higher tendency to develop chronic diseases, particularly hypertension in adulthood than overweight-obese girls. Our study is the first to demonstrate the correlation of obesity to both blood pressure and fasting blood glucose concentrations in prepubertal boys, but not girls, indicating that these parameters can be considered as cardiovascular risk factors in male adults as well as in prepubertal children before the activation of the sex hormones. Therefore, obesity can precipitate impairment of cardiovascular factors in prepubertal children, leading to increased risk for cardiovascular diseases development in adulthood.

REFERENCES

1. KELISHADI R, MIRMOGHTADAEE P, NAJAFI H, KEIKHA M 2015 Systematic review on the association of abdominal obesity in children and adolescents with cardio-metabolic risk factors. J Res Med Sci 20(3): 294–307
2. JANSSEN I, KATZMARZYK PT, BOYCE WF, VEREECKEN C, MULVIHILL C, ROBERTS C, CURRIE C, PICKETT W 2005 Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. Obes Rev 6(2): 123–132. https://doi.org/10.1111/j.1467-789X.2005.00176.x
3. NEOVIUS M, LINNE Y, ROSSNER S 2005 BMI, waist circumference and waist-hip-ratio as diagnostic tests for fatness in adolescents. Int J Obes (Lond) 29: 163–169. https://doi.org/10.1038/sj.ijo.0802867
4. EBBELING CA, PAWLAK DB, LUDWIG DS 2002 Childhood obesity: public-health crisis, commonsense cure. Lancet 360: 473–482. https://doi.org/10.1016/S0140-6736(02)09678-2
5. WIJNHOVEN TM, VAN RAAIJ JM, YNGVE A, SJÖBERG A, KUNEŠOVÁ M, DULEVA V, PETRAUSKIENE A, RITO AI, BREDA J 2015 WHO European Childhood Obesity Surveillance Initiative 2008: weight, height and body mass index in 6–9-year-od children. Pediatr. Obesity 18(17): 3108–3124
6. WEISS R, BREMER AA, LUSTIG RH 2013 What is metabolic syndrome, and why are children getting it? Ann. N. Y. Acad. Sci 1281: 123–140. https://doi.org/10.1111/nyas.12030
7. ZIMMET P, ALBERTI G, KAUFMAN F, TAJIMA N, SILINK M, ARSLANIAN S, WONG G, BENNETT P, SHAW J, CAPRIO S, INTERNATIONAL DIABETES FEDERATION TASK FORCE ON EPIDEMIOLOGY AND PREVENTION OF DIABETES 2007 The metabolic syndrome in children and adolescents. Lancet 369: 2059–2061
8. DECKELBAUM RJ, WILLIAMS CL 2001 Childhood obesity: the health issue. Obes Res 9: 239S–2343S. https://doi.org/10.1038/oby.2001.125
9. WHO Information Series on School Health- Promoting Physical Activity in Schools: An Important Element of a Health-Promoting

School. Geneva, Switzerland. http://ww.who.int/school_youth_health/resources/information_series/FINAL%20Final

10. JOLLIFFE CJ, JANSSEN I 2006 Vascular risks and management of obesity in children and adolescents. Vascul Health Risk Manag 2: 171–187. https://doi.org/10.2147/vhrm.2006.2.2.171
11. SALLAM T, WATSON KE 2013 Predictors of cardiovascular risk in women.Womens Health (LondEngl) 9(5): 491–498. https://doi.org/10.2217/whe.13.44
12. ABRAMSON BL, MELVIN RG 2014 Cardiovascular risk in women: focus on hypertension. Can J Cardiol 30(5): 553–559. https://doi.org/10.1016/j.cjca.2014.02.014
13. OSKUI PM, FRENCH WJ, HERRING MJ, MAYEDA GS, BURSTEIN S, KLONER RA 2013 Testosterone and the cardiovascular system: a comprehensive review of the clinical literature. J Am Heart Assoc 2(6): e000272. https://doi.org/10.1161/JAHA.113.000272
14. GRODSTEIN F, MANSON JE, COLDITZ GA, WILLETT WC, SPEIZER FE, STAMPFER MJ 2000 A prospective, observational study of postmenopausal hormone therapy and primary prevention of cardiovascular disease. Annals of Internal Medicine 2000 133(12): 933–941. https://doi.org/10.7326/0003-4819-133-12-200012190-00008
15. LIZCANO F, GUZMÁN G 2014 Estrogen Deficiency and the Origin of Obesity during Menopause. Biomed Res Int 2014:757461. https://doi.org/10.1155/2014/757461
16. O'REILLY MW, HOUSE PJ, TOMLINSON JW 2014 Understanding androgen action in adipose tissue. J Steroid Biochem Mol Biol 143C: 277–284. https://doi.org/10.1016/j.jsbmb.2014.04.008
17. TRAISH AM 2014 Adverse health effects of testosterone deficiency (TD) in men. Steroids 88C: 106–116. https://doi.org/10.1016/j.steroids.2014.05.010
18. APTER D, SIPILÄ I 1993 Development of children and adolescents: physiological, pathophysiological, and therapeutic aspects. Curr Opin Obstet Gynecol 5(6): 764–773. https://doi.org/10.1097/00001703-199312000-00010
19. TANNER JM 1986 Normal growth and techniques of growth assessment. Clin Endocrinol Metab 15(3): 411–451. https://doi.org/10.1016/S0300-595X(86)80005-6
20. KUCZMARSKI RJ, OGDEN CL, GRUMMER-STRAWN LM, FLEGAL KM, GUO SS, WEI R, MEI Z, CURTIN LR, ROCHE AF, JOHNSON CL 2000 CDC growth charts: United States Adv Data (314): 1–27
21. KELDER S, HOELSCHER DM, BARROSO CS, WALKER JL, CRIBB P, HU S 2005 The CATCH Kids Club: a pilot after-school study for improving elementary students' nutrition and physical activity. Public Health Nutrition 8(2): 133–140. https://doi.org/10.1079/PHN2004678
22. OGDEN CL, KUCZMARSKI RJ, FLEGAL KM, MEI Z, WEI R, GRUMMER-STRAWN LM, CURTIN LR, ROCHE AF, JOHNSON CL 2002 Centers for Disease Control and prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version. Pediatrics 109(1): 45–60. https://doi.org/10.1542/peds.109.1.45
23. BRACALE R, MILANI L, FERRARA E, BALZARETTI C, VALERIO C, RUSSO V NISOLI E, CARRUBA MO 2013 Childhood obesity, overweight and underweight: a study in primary schools in Milan. Eat Weight Disord 18: 183–191
24. PEĆIN I, SAMOVOJSKA R, HEINRICH B, ZELJKOVIĆ-VRKIĆ T, LAGANOVIĆ M, JELAKOVIĆ B 2013 Hypertension, overweight and obesity in adolescents: the CRO-KOP study. Coll Antropol 37(3): 761–764
25. RAUNER A, MESS F, WOLL A 2013 The relationship between physical activity, physical fitness and overweight in adolescents: a systematic review of studies published in or after 2000. BMC Pediatrics 13:19. https://doi.org/10.1186/1471-2431-13-19
26. HE FJ, MARRERO NM, MACGREGOR GA 2008 Salt intake is related to soft drink consumption in children and adolescents: A link to obesity? Hypertension 51: 629–634. https://doi.org/10.1161/HYPERTENSIONAHA.107.100990
27. SOROF J, DANIELS S 2002 Obesity Hypertension in Children: A problem of Epidemic Proportions. Hypertension 40: 441–447. https://doi.org/10.1161/01.HYP.0000032940.33466.12
28. FRIEDEMANN C, HENEGHAN C, MAHTANI K, THOMPSON M, PERERA R, WARD AM 2012 Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis. BMJ 345:e4759. https://doi.org/10.1136/bmj.e4759
29. SOROF J, DANIELS S 2002 Obesity hypertension in children: a problem of epidemic proportions. Hypertension 40(4): 441–447. https://doi.org/10.1161/01.HYP.0000032940.33466.12
30. KLEIN KO, BARON J, COLLI MJ, MCDONNELL DP, CUTLER GB 1994 Estrogen levels in childhood determined by an ultrasensitive recombinant cell bioassay. J Clin Invest 94(6): 2475–2780. https://doi.org/10.1172/JCI117616
31. PARIS F, SERVANT N, TÉROUANNE B, BALAGUER P, NICOLAS JC, SULTAN C 2002 A new recombinant cell bioassay for ultrasensitive determination of serum estrogenic bioactivity in children. J Clin Endocrinol Metab 87(2): 791–797. https://doi.org/10.1210/jcem.87.2.8269
32. TCHERNOF A, DESPRÉS JP 2013 Pathophysiology of human visceral obesity: an update. Physiol Rev 93(1): 359–404. https://doi.org/10.1152/physrev.00033.2011
33. WOJTYŁA-BUCIORA P, STAWIŃSKA-WITOSZYŃSKA B, KLIMBERG A, WOJTYŁA A, GOŹDZIEWSKA M, WOJTYŁA K, PIĄTEK J, WOJTYŁA C, SYGIT M, IGNYŚ I, MARCINKOWSKI JT 2013 Nutrition-related health behaviours and prevalence of overweight and obesity among Polish children and adolescents. Ann Agric Environ Med 20(2): 332–340
34. KESZTYÜS D1, TRAUB M, LAUER R, KESZTYÜS T, STEINACKER JM 2017 Skipping breakfast is detrimental for primary school children: cross-sectional analysis of determinants for targeted prevention. BMC Public Health 17(1):258
35. CARLSON JJ, EISENMANN JC, PFEIFFER KA, JAGER KB, SEHNERT ST, YEE KE, KLAVINSKI RA, FELTZ DL 2008 (S) Partners for Heart Health: a school-based program for enhancing physical activity and nutrition to promote cardiovascular health in 5th grade students. BMC Public Health 8:420. https://doi.org/10.1186/1471-2458-8-420
36. REINEHR T, DE SOUSA G, TOSCHKE AM, ANDLER W 2006 Long-term follow-up of cardiovascular disease risk factors in children after an obesity intervention. Am J Clin Nutr 84(3): 490–496