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Obesity in adolescents from urban and rural areas – a comparison of physical fitness and markers of inflammation

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Abstract. – OBJECTIVES: Obesity entails serious health consequences associated with the development of inflammation in the body and it has an impact on physical fitness. Obesity is not only related to the development of inflammation in the body, but it is a condition involving the production of proinflammatory cytokines. Aim of this paper was the comparison of parameters of physical fitness and inflammatory condition in overweight and obese adolescents from urban and rural areas.

PATIENTS AND METHODS: The study involved 113 children aged from 12 to 18 who were overweight or obese (mean body weight 89.32 ± 17.69, height 168.6 ± 9.82, BMI 31.27 ± 4.38 BMI). Physical fitness was measured using the Eurofit test, while concentrations and profiles of the glycosylation of the acute phase proteins was investigated by means of electrophoretic methods.

RESULTS: The study demonstrated inferior results of fitness tests and the presence of features of inflammation in adolescents in both age groups, compared with their peers who had no problems with overweight or obesity. Boys from the younger group have a higher BMI and poorer Eurofit test results than their urban counterparts. Boys from rural areas show markers of acute inflammation, correlating with worse results of endurance, explosive power and speed tests.

CONCLUSIONS: Young people from rural areas are more at risk of metabolic consequences of obesity than their peers from urban areas, due to poorer fitness and already visible markers of inflammation.

Key Words:
Children, Inflammation, Obese, Physical fitness.

Introduction

The definition of overweight and obesity has varied over time due to increasingly advanced research methods. The word obesity refers to a condition caused by the excess of fat tissue. Similarly, the term overweight is defined as the excess weight relative to the height[1]. In June 2007, the Expert Committee on Pediatric Obesity changed the terminology[2], so that children with a Body Mass Index (BMI) at or between the 85th and 94th percentiles are now considered "overweight," and children with a BMI percentile at or above the 95th are now considered "obese".

The prevalence of obesity worldwide has become an epidemic. Results of subsequent studies clearly demonstrate a significant increase in the prevalence of individuals with a body mass index exceeding 30 kg/m^2. According to the World Health Organization (WHO)[3] in 2005, the problem of overweight and obesity in 2005 affected 1.6 billion people, while obesity affected 400 million of adults worldwide. The same data indicate that the problem of overweight affects at least 20 million children under five years of age. WHO estimates that in 2015 2.3 billion people will be overweight and at least 700 million people will be obese.

In the Member States of the European Union, for which Eurostat data are available[4], the percentage of obese and overweight women in 2008 fluctuated between 36.9% and 56.7%, while the percentage of overweight and obese men was between 51%-69.3%.

In Europe, the data from the MONICA research (Multinational Monitoring of trends and determinants in cardiovascular diseases study) conducted by the World Health Organization indicated that the number of children with obesity has increased and it is 10 times higher than in the 70s of the twentieth century.

The epidemiological data regarding Poland is far from optimistic. The results of NATPOL I research[5,6] presented in 1997 indicated that 38% of men and 30% of women aged 18-94 were overweight, while 16% of men and 19% of women suffered from obesity. Given the results of the

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NATPOL II study announced in 2002 the problem of overweight concerned 39% of men and 29% of women, while obesity was a problem for 19% of men and women.

At the end of September and at the beginning of October 2011 the results of the NATPOL study were announced[7]. The number of obese people increased by 5% compared to the previous study and, for example, the data for men show that a quarter of all men in Poland are obese. The data regarding physical activity were also presented and its level is the lowest among the youngest age groups between 18 and 39, while it is the highest in the oldest groups between 60 to 79.

The data on the problem of overweight and obesity in children are scarce. In the years 1994-1995 Oblaci ska et al[8] assessed the incidence of excessive body weight in children aged 6-17 years, using nets correlated with the ratio of body weight to height developed by Instytut Matki i Dziecka (the Institute of Mother and Child). Overweight was found in 8.7% of children and adolescents and obesity in 3.4%.

Obesity entails serious health consequences, leading to the development of cardiovascular diseases (coronary heart disease, hypertension, heart failure), hyperlipidemia, diabetes mellitus, gastrointestinal diseases and cancer[9,10]. At the same time it is increasingly emphasized[11] that obesity is not only related to the development of inflammation in the body, but it is a condition involving the production of proinflammatory cytokines, which are produced by the very fat tissue itself and contributing to its persistence and growth. Given the above facts, it was determined to investigate the parameters that could indicate the presence of inflammation in the bodies of teenagers subject to the study.

Current studies also show that children and rural youth are more likely to develop obesity than their urban counterparts[12]. The factors that contribute to the differentiation between residents of urban and rural areas include the socio-economic status and the presence of physical constraints. Therefore, in this regard it was decided to check the level of physical fitness using the European physical fitness test – Eurofit[13] in both of these groups. This test is a reliable and valid instrument to measure physical fitness in children, it measures valuessuch as balance, cardio-respiratory (aerobic) endurance, muscular endurance (abdominal and upper body), flexibility, power, speed, speed agility and strength.

Aim of this paper was the comparison of parameters of physical fitness and inflammatory condition in overweight and obese adolescents from urban and rural areas.

Patients and Methods

The studies involved 113 children, aged from 12 to 18 years who were overweight or obese. The mean body weight was 89.32 ± 17.69, the average height was 168.6 ± 9.82, the mean BMI was 31.27 ± 4.38. The investigated group was divided according to sex and age ranges (12-14 and 15-18 years) (Table I).

Table I. Division of the study group by sex and age.

Boys N = 54			Boys aged 12-14 years N = 22		Boys aged 15-18 years N = 32	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Height	165.61	7.44	166.90	8.53	177.03	8.09
Weight	84.00	13.47	89.53	12.54	103.16	18.60
BMI	30.59	4.21	31.73	3.62	32.81	4.77
Girls N = 59			**Girls aged 12-14 years N = 20**		**Girls aged 15-18 years N = 39**	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Height	171.74	11.04	163.40	8.22	166.74	6.86
Weight	94.89	19.89	77.94	13.52	87.10	12.50
BMI	31.97	4.51	29.08	3.79	31.37	4.25

Division of the Study Group by Sex and Age

For each adolescent BMI was calculated according to the formula: (weight/height^2 kg/m^2). Participants were considered overweight or obese based on age specific BMI curves when their BMI was more than or equal to the international cutoff point corresponding to the curve that passes through the BMI curve of either 25 or 30, respectively, at the appropriate age[14].

Weight was assessed to the nearest 0.1 kg using a certified electronic scale [Tanita electronic scale BWB-800 MA (Wunder SA.BI. Srl)], with the subject wearing sports clothing and no shoes. Height to the nearest 0.01 m was measured using a stadiometer (Holtain Ltd., Crymych, Pembs, UK). Physical examination was carried out to exclude all symptoms of on-going infection or inflammation of any origin.

The study was carried out in Ciechocinek in the years 2010-2012.

Physical fitness was measured using the Eurofit test which consists of: flamingo balance (FLB – balance), plate tapping (PLT – coordination and speed), sit-and reach (SAR – flexibility), standing broad jump (SBJ – explosive strength), handgrip (HGR- static strength), sit-ups (SUP – trunk strength and endurance), bent-arm hang (BAH – upper body strength and endurance) and shuttle run 10×5 m (SHR – speed and agility), 20 m endurance shuttle run (ESR- cardio-respiratory endurance)[13].

The obtained results of the Eurofit physical fitness test were compared with centile nets developed by Słupnicki et al[15] for Polish youth, and with the results presented by Sobieska et al[16] for a similar study group.

Blood samples were collected once from all participants. Serum was separated in a routine way and frozen until investigation. The concentration of acute phase proteins: alpha1-acid glycoprotein (AGP); and alpha1-antichymotrypsin (ACT) was measured by immunoelectrophoresis according to Laurell[17]. Antibodies and standard solutions came from DakoCytomation (Glostrup, Denmark). Additionally, the glycosylation profiles of AGP and ACT were analyzed by crossed-affinity immunoelectrophoresis with Concanavalin A[17]. Reference values for acute-phase proteins in children were established earlier in the same laboratory, using the same methods. Normal serum values for AGP and ACT have been reported to be 800 ± 100 mg/L and 400 ± 50 mg/L, respectively[18].

Statistical Analysis

The description of the investigated variables was performed using the mean with a standard deviation (demographic data, protein parameters) or medians and quartiles (for the EUROFIT test) respectively. The comparison of the investigated subgroups was performed by means of the U Mann-Whitney test, the correlations were calculated using the Spearman test. The Statistica 10.0. software was used for this purpose.

For all the statistical analyses performed, the significance value of $p < 0.05$ was set.

Results

A comparison of BMI for age groups 12-14 and 15-18 years depending on sex and place of residence (urban/rural) was performed and it was demonstrated that in both age groups higher BMI was observed in rural boys (in the group of 12-14 year olds BMI ± 33.96 vs 30.90, while in the group of 15-18 year olds BMI was 33.76 vs 32.44). Among the investigated girls aged 12-14 years both from urban and rural areas there was a problem of overweight (BMI 28.85/29.97), while obesity was found only in a group of older girls (BMI 30.45/33.71) with higher BMI among the rural girls.

The physical fitness results were analyzed for the investigated age groups on the basis of the Eurofit test and it was examined whether there was a difference between boys and girls from urban and rural areas (Table II).

Eurofit test results by age and sex versus the place of residence (urban/rural). For each test, a general difference towards healthy peers was given. Darker area denotes the result for a subgroup that differed from other subgroups.

Statistically significant difference was found at $p < 0.05$.

It is worth noting that for boys from the rural area, both younger and older, the fitness results were extremely worse than for healthy peers and worse than observed in peers from the urban area. No big differences were observed between girls.

For all the investigated teenagers, the measured values of acute phase proteins were higher than normal. There were no differences between the groups divided according to the urban or rural area, but a tendency to a more altered glycosylation profile of AGP was noticed (more "acute" profile with increased ConA reactivity) in boys

Table II. Eurofit test results by age and sex versus the place of residence (urban/rural). For each test, a general difference towards healthy peers was given. Darker area denotes the result for a subgroup that differed from other subgroups.

Parameter	Girls 12-14 median (quartiles 25-75)		Boys 12-14 median (quartiles 25-75)	
	Urban	Rural	Urban	Rural
FLB Better	0 0-1	0 0-2	0.5 0.0-3.0	0.5 0.0-3.0
PLT Better	17.5 15.0-19.5	17.9 14.9-18.3	17.3 13.7-19.9	17.5 13.8-20.5
SAR Much better	16.5 15.0-21.0	14.0 12.0-17.0	9.5 6.5-16.5	2.0 -2.0-10.0 worse
SBJ Worse/much worse	119.0 104.0-139.0	134.0 115.0-134.0	139.0 101.0-155.0	121.5 83.0-137.0
HGR Better	28.0 22.5-30.0	26.0 25.0-26.0	32.5 25.5-37.0	26.0 24.0-34.0 worse
SUP 30 sec Much worse	15.0 12.5-16.0	20.0 17.0-22.0	17.5 15.5-20.0	17.0 14.0-21.0
BAH Much worse	0.0 0.0-1.5	0.0 0.0-0.0	1.0 0.0-8.9	0.0 0.0-0.0
SHR Worse	26.1 24.1-27.8	26.3 25.0-26.6	24.7 23.4-26.6	29.2 24.0-32.0 much worse
ESR worse	14.5 7.0-30.0 much worse	17.0 14.0-30.0	17.5 11.5-29.5	16.0 9.0-23.0
Parameter	**Girls 15-18 median (quartiles 25-75)**		**Boys 15-18 mediana (quartiles 25-75)**	
	Urban	**Rural**	**Urban**	**Rural**
FLB Better	0.0 0.0-1.0	0.0 0.0-0.1	0.0 0.0-1.0	0.0 0.0-2.0
PLT Better/norm	12.83 11.8-15.7	12.7 11.0-13.7	12.1 10.8-14.8	11.4 10.9-13.6
SAR Better	19.5 10.0-24.0	18.0 15.0-21.0	15.0 3.0-23.0	7.0 1.0-15.0 worse
SBJ Much worse	123.5 110.5-137.5	123.0 109.0-131.0	148.0 132.0-170.0	156.0 140.0-173.0
HGR Better/norm	30.0 26.5-34.0	31.0 27.0-34.8	44.0 32.0-49.0	47.0 31.5-54.5
SUP Worse	15.5 13.0-19.0	15.0 11.0-22.0	20.0 15.0-24.0	18.0 17.0-21.0
BAH Much worse	0.0 0.0-0.0	0.0 0.0-0.0	1.0 0.0-7.0	0.0 0.0-0.0
SHR Worse	26.5 24.8-28.9	25.8 24.3-27.3	24.0 22.5-26.0	23.3 22.9-24.0
ESR Worse	24.0 11.0-41.5	45.0 10.0-51.0 Better	35.0 13.0-60.0	31.0 25.0-45.0

from the rural area. As the relatively large standard deviation of all studied parameters was found, no statistically significant differences between the groups were shown.

A number of AGP variants are known to exist and their distribution in percentages is as follows: W0 (43%), W1 (45%), W2 (12%), and W3 (2%)[18].

For ACT, the serum concentration of this protein was within the normal range except for older boys, in whom elevated values were found. For ACT, the following variants and respective distributions have been reported: A1 (25%), A2 (24%), A3 (26%), and A4 (25%)[18].

The glycosylation profile of ACT was altered in almost all children towards lower reactivity with ConA, which was previously described as a chronic inflammatory process. This feature was mostly present in older boys, mainly from the rural area (Table III).

Parameters describing acute phase proteins concentrations and glycosylation profiles, in groups divided according to sex, age and living environment.

When the associations between the EUROFIT results and acute phase parameters were investigated, no statistically significant correlations were found for girls from the rural area. For other groups, the following statistically significant correlations were detected: (Spearman's r is given with appropriate acute phase parameters $p < 0.05$) (Tables IV, V).

Correlations between parametrs of physical fitness (EUROFIT elements) and parameters of acute phase proteins, in boys divided according to age and living environment.

Correlations between parametrs of physical fitness (EUROFIT elements) and parameters of acute phase proteins, in girls divided according to age and living environment.

Discussion

The few studies on the prevalence of obesity among children and adolescents conducted by Oblaci ska et al[8] in the 90s show that excessive body weight was more common in girls and in children living in urban areas. In contrast, studies by Davis et al[12], presented in 2011, show that rural children are more likely to be obese.In these studies, 22% of children in rural areas were classified as obese compared to 17% of urban children. Similar findings are presented by data from studies by Crooks and Davy et al from 2000 and 2004[19,20]. This information is consistent with our own studies on boys from rural areas in both age groups and girls from rural areas aged 15-18 years, who manifested higher BMI compared to their urban counterparts.

A higher level of physical activity is associated with superior physical, social and psychological health in young people, physical activity is inversely proportional to overweight and obesity in young people[21].

The research on generally interpreted physical activity carried out, for instance, on the number of students who walked or rode a bike to school, shows that the number decreased from 41% in 1999 to 13% in 2001[22].

A more detailed study by Ara et al[23] using the Eurofit physical fitness test indicates that all of its components with the exception of isometric force among overweight and obese children are

Table III. Parameters describing acute phase proteins concentrations and glycosylation profiles, in groups divided according to sex, age and living environment.

	12-14 years old				15-18 years old			
	Girls		Boys		Girls		Boys	
Parameter	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
AGP mg/L	937 ± 324	1095 ± 418	1001 ± 421	984 ± 365	1326 ± 313	867 ± 299	914 ± 287	843 ± 243
W0%	44.4 ± 3.4	44.1 ± 3.1	41.5 ± 3.5	37.0 ± 2.9	40.8 ± 3.4	36.6 ± 3.2	36.9 ± 3.5	40.8 ± 3.1
W1%	43.1 ± 2.8	46.5 ± 2.8	44.4 ± 3.1	40.6 ± 2.7	42.7 ± 3.2	42.4 ± 2.9	42.6 ± 2.8	44.1 ± 2.9
W2%	11.3 ± 1.9	8.6 ± 1.7	11.7 ± 1.9	17.2 ± 2.0	14.1 ± 1.8	18.8 ± 1.7	17 ± 1.3	12.2 ± 0.9
W3%	1.1 ± 0.3	0.7 ± 0.2	2.4 ± 0.3	5.2 ± 1.2	2.3 ± 0.6	2.2 ± 0.7	3.4 ± 0.6	2.9 ± 0.8
ACT mg/L	371 ± 97	395 ± 121	340 ± 101	346 ± 99	511 ± 114	357 ± 99	483 ± 101	460 ± 98
A1%	27 ± 2.6	28.9 ± 2.7	27.9 ± 2.4	30.8 ± 2.9	26.2 ± 3.3	22.4 ± 3.2	21.4 ± 2.9	28.5 ± 4.0
A2%	32.6 ± 2.7	33.2 ± 2.6	31.3 ± 2.6	33.6 ± 2.7	31.7 ± 3.2	33.7 ± 3.3	29.6 ± 2.8	32.3 ± 2.9
A3%	21.8 ± 1.7	20.1 ± 1.8	24.1 ± 2.0	22.3 ± 1.9	21.4 ± 1.3	29.3 ± 1.8	23.8 ± 1.2	21 ± 1.3
A4%	10.9 ± 0.9	12 ± 0.7	12.0 ± 1.2	9.9 ± 1.1	16.7 ± 1.1	7.6 ± 0.9	19.7 ± 1.2	13 ± 0.9
A5%	7.6 ± 0.5	5.8 ± 0.4	4.7 ± 0.7	3.4 ± 0.6	4.1 ± 0.3	7.1 ± 0.8	5.5 ± 0.3	5.2 ± 0.4

Table IV. Corelations between parametrs of physical fitness (EUROFIT elements) and parameters of acute phase proteins, in boys divided according to age and living environment.

Eurofit	Boys 12-14 years		Boys 15-18 years	
	Urban	Rural	Urban	Rural
FLB		W0% = 0.89; A5% = 0.89	A4% = –0.65	W3% = 0.79
PLT		W0% = 0.97; W2% = –0.9		AGP = –0.74
SUP	A2% = –0.57; A3% = –0.57	W3% = 0.9	AGP = 0.77	
SAR				
SBJ	W2% = –0.54; ACT = 0.67		W1% = –0.55	A1% = 0.76; A3% = –0.83
HGR	AGP = –0.58; W0% = –0.54; A3% = –0.5			
BAH				W2% = –0.77; W3% = 0.88; A4% = –0.75
SHR				ACT = –0.71
ESR				

below normal. It should be noted that the issue of the level of physical activity and the occurrence of obesity among rural children is becoming an increasingly discussed subject. There are several suggestions that worsened physical activity variables may be more important for rural children and should directly implicate treatment interventions targeting pediatric obesity among rural and urban children[12].

Similar tendencies were shown in the presented physical fitness evaluation studies among urban and rural children. It has been observed, taking into account the entire group of younger children, that explosive strength, endurance and speed were impaired, while in boys from rural areas, apart from severe problems with speed, also inferior flexibility and static force were reported (measured as HGR – hand strength). Similar re-

Table V. Corelations between parametrs of physical fitness (EUROFIT elements) and parameters of acute phase proteins, in girls divided according to age and living environment.

Eurofit	Girls 12-14 years		Girls 15-18 years	
	Urban	Rural	Urban	Rural
FLB				
PLT				
SUP	AGP = –0.66; A5% = 0.5			
SAR			W0% = 0.68; W2% = –0.73; W3% = –0.44	
SBJ	AGP = –05; A1% = –0.61; A5% = 0.51			
HGR	AGP = 0.51; A5% = –0.53			
BAH	W3% = 0.69			
SHR				
ESR				

sults were obtained in older children. It appears that it is low efficiency that is the most worrying sign of performance problems associated with obesity, as it may be the first sign of the metabolic syndrome disorder. However, it was demonstrated that both balance and coordination/speed in all age groups were not worse than in healthy peers.

The analysis of the relationship between the results of the performance test and the severity of the inflammatory process revealed several correlations.

These correlations indicate that the AGP concentrations and variants showing the acute inflammatory process were related to worsened parameters of EUROFIT that require speed, endurance and explosive force. Thus, it may be concluded that the acute inflammatory status present in the bodies of the evaluated individuals (and probably caused or at least related to obesity, as any signs of clinically noticeable infection or inflammation were excluded) was related to worse parameters of physical fitness. Static force was not impaired and was negatively correlated to inflammatory indicators.

The only significant correlations were observed in girls from the urban area. The SAR parameter, that is closely related to visceral obesity, correlated negatively with those variants of AGP that indicated acute inflammatory conditions. This could suggest that mainly this type of obesity may contribute to inflammatory-like status in obese teenagers.

Although flexibility in girls was normal, it negatively correlated with the exponents of acute inflammation. As flexibility investigated by means of the SAR sample depends primarily on abdominal obesity, it may indicate that this type of obesity is related to the production of substances increasing the inflammatory condition. This is further evidenced by a significantly worse result of the performance test, particularly in girls from rural areas.

It may be concluded in general that the character of obesity in adolescents, mainly in boys from rural areas impairs their physical fitness even more than in peers from urban areas. It is not lack of physical work, but probably no sport activity instead that contributes to a more sedatory lifestyle and to obesity. We cannot extrapolate our results to the whole population and still the number of overweight or obese individuals from urban areas was larger than from rural ones, but the character of obesity in those adolescents (mainly boys) from outside the cities was highly more destructive. We may only assume that girls seem to be less affected as due to some sociocultural aspects they care more about their healthy behavior. Nevertheless, much more attention should be paid to physical activity as the way out of the vicious circle of overweight – obesity – lowered mobility and civilization diseases as a result.

Conclusions

1. Boys from the younger group have a higher BMI and poorer Eurofit test results than their urban counterparts.
2. Boys from rural areas show exponents of acute inflammation, correlating with worse results of endurance, explosive power and speed tests.
3. In case of girls overweight rather than obesity was the problem, while protein parameters demonstrated no profound disorders.

Ethics Statement

The performed study involved human subjects for measurements and observations. The research was performed after obtaining approval from the Bioethics Committee, Institutional Review Board at Poznan University of Medical Sciences issued on 3 April 2008. The authors declare that all identifiable human data used for tests and examinations in the study underwent research procedures in accordance with the ethics standards of the re- sponsible Committee on Human Experimentation and with the Helsinki Declaration of 1975, as revised in 1983.

Conflict of interest

The Authors declare no conflict of interests.

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