# An analysis of characteristics of children and adolescents physical growth in the context of social and economical situation of families inhabiting the city of Bytom

**Ewa Niewiadomska[1], Elżbieta Czech[1], Adam Niewiadomski[2], Joanna Kasznia-Kocot[3], Michał Skrzypek[1]**

[1] Department of Biostatistics, Medical University of Silesia
[2] Institute of Information Technology, Technical University of Lodz
[3] Department of Epidemiology, Medical University of Silesia

**Abstract.** Underweight, overweight and obesity among children and adolescents is an important epidemiological problem, mostly because of consequences of health perturbations. This paper is intended to present the analysis of characteristics of children and adolescent physical growth in the context of social and economical situation of families inhabiting the city of Bytom. The Box-Cox transformation according to WHO standards for body weight, body height and BMI (Body Mass Index) is applied in the analysis. The transformation is a base for statistical analysis of measurable data using e.g. t-test, or Mann-Whitney test. Frequencies of underweight, overweight and obesity among children and adolescents are determined by centile ranks and growth charts by the Institute of Mother and Child in Warsaw, Poland, and analysed using differences significance test and the post-hoc test by Benferroni for percentages. The influence of social and economical factors are evaluated with $\chi^2$-test and log-linear analysis. The main conclusion of the analysis confirms that the percentage of children and adolescents with overweight or obesity is growing. Moreover, the influence of social and economical factors (e.g. education of parents, or the average income per person) is significant. These are premises for further investigations and research in this field.

## Introduction

Social and economical situation, life style and habits, mostly nutrition habits, evolve rapidly in the country of Poland in last years. This implies that scientific, especially statistical, research is still worth running to determine the influence of the environment on children and adolescents physical growth in the age of 7–18 [1]. The research of this age group is essential, mostly because of the fact that different housing and environmental conditions during childhood and adolescence, have strong impact on most of phenotype characteristics. Moreover, incoming problem of overweight and obesity, especially among children and adolescents is a serious premise to investigate and control this phenomenon. Overweight or obesity of children

and adolescents may cause consequences, mostly non-infectious chronic diseases and increased death rate among people over 50 [2–3].

Reports on anthropometric data and their statistical analysis in highly developed countries show that most people of low socioeconomic class(es) are exposed to overweight and obesity [4]. The research conducted in Poland is most frequently based on population of people inhabiting agglomerations with unemployment rate smaller than the average for the whole country. It is worth noticing that data and analysis of situations in agglomerations where the unemployment rates are large [5], one may expect both malnutrition and obesity problems. An example of such an agglomeration is the city of Bytom, where the unemployment rate exceeded 26% in 2004, while the average rate for the whole country was equal to 18.7% [6].

Thus, the main scope of this paper is to present and analyze the characteristics of children and adolescents physical growth in the context of social and economical situation of families inhabiting the city of Bytom and health conditions of children and adolescents at the age of 7–18.

## Methods

The collected data describe results of questionnaire (polled by the Municipality of the City of Bytom, Poland) devoted to the examination of health status of pupils of primary and secondary schools: children and adolescents in 12 age groups, from 7 to 18 years, in the 2003/2004 school year. The dataset contains 13 998 elements, including 6 987 boys and 6 963 girls. The number 13 950 well represents the population, because the total number of pupils in Bytom was 20 426 (2003/2004). In particular, anthropometric data on body height (in cm), body weight (in kg), and age (in years) were collected and taken into account in the presented examples and computations.

In order to detect and identify deviations of children and adolescents physical growth, the following parameters are taken into account: body height (exact to 1 cm) and body weight (exact to 1 kg). Age is evaluated exact to 1 day, but finally, mostly because of specificity of anthropometric data, children and adolescents are divided into the following one-year-age-groups: 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18 years.

The so-called *Body Mass Index*, (BMI, [kg/m$^2$]) is evaluated from body weight and body height as a descriptive characteristic of each pupil [7]:

$$\text{BMI} = \frac{\text{weight}}{\text{height} \cdot \text{height}} \qquad (1)$$

In medical examination and analysis, adults (above the age of 18) are qualified as "underweight" when BMI $\leq$ 20 kg/m$^2$, as "healthy weight" when $20 \leq$ BMI $\leq 25$, as "overweight" when $25 \leq$ BMI $\leq 30$, and as "obesity" when BMI $\geq 30$. However, for children and adolescents, the so-called *centile ranks* and *growth charts* were worked out by the Institute of Mother and Child in Warsaw, Poland [8]. The suspicion of underweight is found if the BMI is placed below the 5th percentile, overweight – if BMI varies between the 85th and 95th percentile, and obesity if BMI exceeds the 95th percentile [7, 9–10].

The exponential transformation Box-Cox is applied for body height, body weight, and BMI, with attention to age and gender, according to WHO [9] for children between 7 and 18 years. The transformation of $z$-value for measure $X$ (where $X \in \{$body height, body weight, BMI$\}$) and age $t$, are computed on the base of the following formula:

$$z_{ind} = \frac{\left(\frac{X}{M(t)}\right)^{L(t)} - 1}{S(t)L(t)} = \frac{X - M(t)}{SD(t)} \qquad \text{for} \qquad L \neq 0 \qquad (2)$$

and

$$z_{ind} = \frac{\log\left(\frac{X}{M(t)}\right)}{S(t)} \qquad \text{for} \qquad L = 0 \qquad (3)$$

using constant values $M(t)$ – median, $SD(t) = S(t) \cdot M(t)$, $L(t), SD(t)$ – standard deviation [10].

The following determinants of the social and economical environment are taken into account:
  – mother's and father's education (primary, vocational, secondary, higher),
  – mother's and father's employment (employed, unemployed),
  – number of persons in a family (2–3 persons, more than 3 persons),
  – a subjectively evaluated economical situation of the family (bad, good),
  – monthly income per person in the family (less than 25€ per person, 25-75€, 75-150€, more than 150€ per person).

The data was analyzed with the R language and R software package [11] as well as with Statistica v.8.0 [12]. Statistical significance is determined as $p < 0.05$. Measurable data are described by the mean $\bar{x}$ and standard deviation $\bar{X} \pm S$, and median and interquartile range, $IQR$, because of skewness of distributions. Percentages are used for nominal samples. The following tests are applied to check whether the distribution of data is normal: the Shapiro-Wilk normality test (for number of records smaller than 5000) and

the Cramer von Mises test. Statistical significance of differences is verified using Student's t-test and the Mann-Whitney test. Percentages are analysed using differences significance test (taking into account the post-hoc test by Benferroni for percentages) and $\chi^2$. Dependencies of two or more nominal samples are described using log-linear analysis.

## Results and discussion

The analysed characteristics of children and adolescent physical growth are specific and vary in age groups [Fig. 1]. The analysis of average body weight and body height shows that the largest increase of body height is observed among boys at the age of 13–14, and among girls at the age of 11–13 [Tab. 1]. This is related to the pubertal spurt of boys and girls, respectively. One may also observe the largest increase of body weight among boys at the age of 13–16, and among girls the age of 11–13, also related to the pubertal spurt.
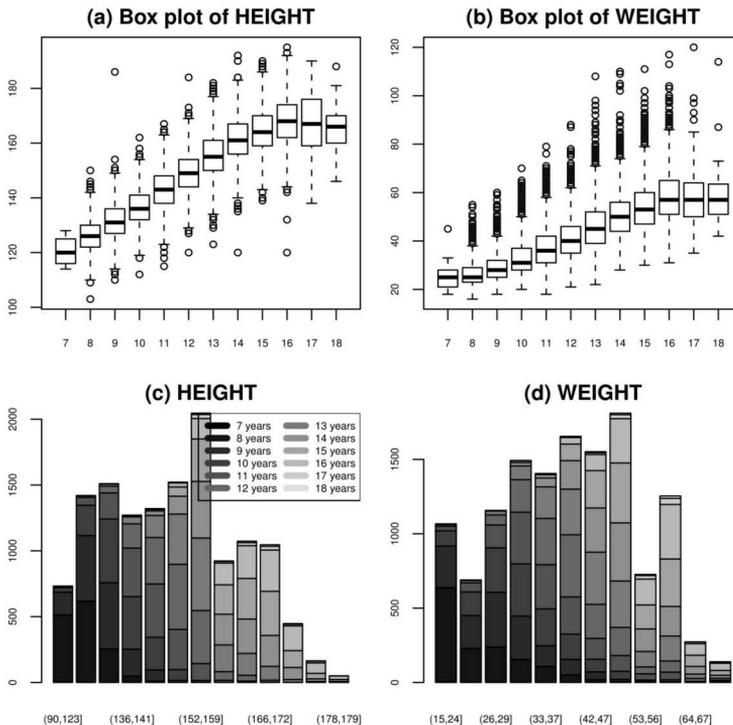


**Fig. 1. The structure of body weight and body height in the age groups: 1: boxplots of mean body height and body weight (on the top), and histograms of body height and body weight in age groups (on the bottom)**

**Tab. 1. Characteristics of body weight and body height of boys and girls in age groups**

| Age | N | Height | | | Weight | | |
|---|---|---|---|---|---|---|---|
| | | $\bar{x} \pm S$ | M | IQR | $\bar{x} \pm S$ | M | IQR |
| Boys | 6987 | 149.8 ±17.1 | 149.0 | 28.0 | 43.2 ±15.1 | 40.0 | 22.0 |
| 7 | 1 | 128.0 | 128.0 | 0.0 | 28.0 | 28.0 | 0.0 |
| 8 | 750 | 126.4 ± 6.0 | 126.0 | 8.0 | 26.9 ± 5.8 | 25.5 | 6.0 |
| 9 | 719 | 132.0 ± 6.6 | 132.0 | 8.0 | 30.2 ± 6.4 | 29.0 | 7.0 |
| 10 | 768 | 137.1 ± 6.7 | 137.0 | 9.0 | 33.5 ± 7.9 | 32.0 | 9.0 |
| 11 | 824 | 143.3 ± 7.5 | 143.0 | 10.0 | 38.1 ± 9.4 | 36.0 | 11.0 |
| 12 | 823 | 148.8 ± 7.3 | 149.0 | 9.0 | 41.3 ± 9.5 | 40.0 | 11.0 |
| 13 | 820 | 155.1 ± 9.1 | 155.0 | 12.0 | 46.6 ±11.5 | 45.0 | 15.0 |
| 14 | 760 | 162.9 ± 9.2 | 163.0 | 14.0 | 52.5 ±12.0 | 51.0 | 14.0 |
| 15 | 741 | 167.8 ± 8.5 | 168.0 | 12.0 | 56.6 ±11.9 | 55.0 | 14.0 |
| 16 | 667 | 173.6 ± 7.5 | 174.0 | 9.0 | 62.7 ±11.8 | 61.0 | 14.0 |
| 17 | 85 | 173.2 ± 8.9 | 175.0 | 12.0 | 62.4 ±13.4 | 61.0 | 12.0 |
| 18 | 29 | 170.3 ± 7.9 | 170.0 | 11.0 | 60.5 ±13.3 | 59.0 | 10.5 |
| Girls | 6963 | 147.6 ±14.8 | 150.0 | 25.0 | 41.6 ±13.2 | 41.0 | 20.0 |
| 7 | 8 | 119.9 ± 5.2 | 118.5 | 9.0 | 26.5 ± 8.8 | 24.5 | 9.0 |
| 8 | 694 | 125.3 ± 6.0 | 125.0 | 8.0 | 26.1 ± 5.6 | 25.0 | 7.0 |
| 9 | 789 | 131.0 ± 6.6 | 131.0 | 8.0 | 29.4 ± 6.5 | 28.0 | 7.0 |
| 10 | 740 | 136.1 ± 6.7 | 136.0 | 9.0 | 32.4 ± 7.1 | 31.0 | 9.0 |
| 11 | 689 | 142.8 ± 7.4 | 143.0 | 10.0 | 36.9 ± 8.9 | 35.0 | 12.0 |
| 12 | 823 | 149.4 ± 7.5 | 149.0 | 11.0 | 41.3 ± 9.4 | 40.0 | 12.0 |
| 13 | 882 | 155.4 ± 7.3 | 156.0 | 11.0 | 46.6 ± 9.9 | 46.0 | 12.0 |
| 14 | 739 | 159.9 ± 6.6 | 160.0 | 9.0 | 50.2 ± 9.2 | 49.0 | 11.0 |
| 15 | 793 | 161.6 ± 6.1 | 162.0 | 8.5 | 52.8 ± 9.2 | 51.0 | 12.0 |
| 16 | 710 | 163.4 ± 6.4 | 163.0 | 7.0 | 55.8 ± 9.7 | 54.0 | 10.0 |
| 17 | 71 | 160.2 ± 6.9 | 160.0 | 9.0 | 53.8 ± 8.7 | 54.0 | 10.0 |
| 18 | 25 | 160.8 ± 6.6 | 161.0 | 9.0 | 55.5 ±10.1 | 52.0 | 8.5 |
| All Children | 13950 | 148.7 ±16.0 | 149.0 | 25.0 | 42.4 ±14.2 | 41.0 | 21.0 |

Evaluation of influence of social and economical factors at basic measures of physical growth show that boys and girls whose mothers or fathers are employed and declare secondary or higher education, have significantly larger body weight and body height. If average income per person in the family is lower than 150€, body weight and body height of children and adolescent are smaller [Tab. 2, 3], cf. [13].

**Tab. 2. Standardized characteristics of body height of boys and girls in the age of 7–10, related to social and economical factors**

| Social and economical factors | Boys | $p$-value $\bar{x} \pm S$ | Girls | $p$-value $\bar{x} \pm S$ |
|---|---|---|---|---|
| **Mother's education** Primary/Vocational Secondary/Higher | $-1.01 \pm 2.3$ $-0.49 \pm 2.6$ | $p < 0.0001^*$ | $-0.84 \pm 2.4$ $-0.44 \pm 2.3$ | $p < 0.0001^*$ |
| **Father's education** Primary/Vocational Secondary/Higher | $-0.91 \pm 2.9$ $-0.52 \pm 2.6$ | $p < 0.0001^*$ | $-0.75 \pm 2.3$ $-0.48 \pm 2.4$ | $p < 0.0001^*$ |
| **Mother's employment** Employed Unemployed | $-0.67 \pm 2.7$ $-1.04 \pm 3.1$ | $p < 0.0001^*$ | $-0.59 \pm 2.4$ $-0.84 \pm 2.1$ | $p < 0.0001^*$ |
| **Father's employment** Employed Unemployed | $-0.09 \pm 2.8$ $-1.11 \pm 2.8$ | $p < 0.0001^*$ | $0.56 \pm 2.2$ $-1.01 \pm 2.4$ | $p < 0.0001^*$ |
| **Subjectively evaluated economical situation** good bad | $-0.59 \pm 2.5$ $-1.12 \pm 3.2$ | $p < 0.0001^*$ | $-0.52 \pm 2.2$ $-0.91 \pm 2.6$ | $p < 0.001^*$ |
| **Month income per person** Below 150€ Over 150€ | $-0.82 \pm 2.8$ $-0.41 \pm 2.8$ | $p < 0.0001^*$ | $-0.71 \pm 2.3$ $-0.28 \pm 2.2$ | $p < 0.001^*$ |

Standardization according to the WHO Child Growth Standards
* Statistical significance $p < 0.05$, Mann-Whitney test

**Tab. 3. Standardized characteristics of body-weight of boys and girls related to social and economical factors**

| Social and economical factors | Boys | $p$-value $\bar{x} \pm S$ | Girls | $p$-value $\bar{x} \pm S$ |
|---|---|---|---|---|
| **Mother's education** Primary/Vocational Secondary/Higher | $-0.20 \pm 1.2$ $0.22 \pm 1.2$ | $p < 0.0001^*$ | $-0.41 \pm 1.2$ $-0.02 \pm 1.2$ | $p < 0.0001^*$ |
| **Father's education** Primary/Vocational Secondary/Higher | $-0.11 \pm 1.3$ $0.19 \pm 1.2$ | $p < 0.0001^*$ | $-0.35 \pm 1.2$ $-0.01 \pm 1.1$ | $p < 0.0001^*$ |
| **Mother's employment** Employed Unemployed | $0.10 \pm 1.3$ $-0.25 \pm 1.2$ | $p < 0.0001^*$ | $-0.15 \pm 1.2$ $-0.43 \pm 1.2$ | $p < 0.0001^*$ |
| **Father's employment** Employed Unemployed | $0.09 \pm 1.3$ $-0.38 \pm 1.2$ | $p < 0.0001^*$ | $-0.17 \pm 1.2$ $-0.55 \pm 1.2$ | $p < 0.0001^*$ |
| **Subjectively evaluated economical situation** good bad | $0.13 \pm 1.2$ $-0.29 \pm 1.3$ | $p < 0.0001^*$ | $-0.12 \pm 1.2$ $-0.40 \pm 1.3$ | $p < 0.0001^*$ |
| **Month income per person** Below 150€ Over 150€ | $-0.05 \pm 1.3$ $0.37 \pm 1.2$ | $p < 0.0001^*$ | $-0.28 \pm 1.2$ $0.06 \pm 1.1$ | $p < 0.0001^*$ |

Standardization according to the WHO Child Growth Standards
* Statistical significance $p < 0.05$, Mann-Whitney test

According to percentiles about BMI values [7–8], 7.2% children and adolescents are underweighted (6.9% boys and 7.6%, $p = 0.11$). 76% children and adolescents are of healthy weight. About 10% are overweighted and 6.3% are obese, see [Fig. 2]. Percentage of boys with overweight or obesity is 14.4% and is significantly smaller than the percentage of girls that equals 17.0% ($p < 0.0001$). Basing on the analysed data, 95% confidence interval of percentage with underweight of children and adolescents in the age of 7–18 with underweight in Bytom is 6.8–7.7%, and with overweight or obesity – 15.1–16.3%.
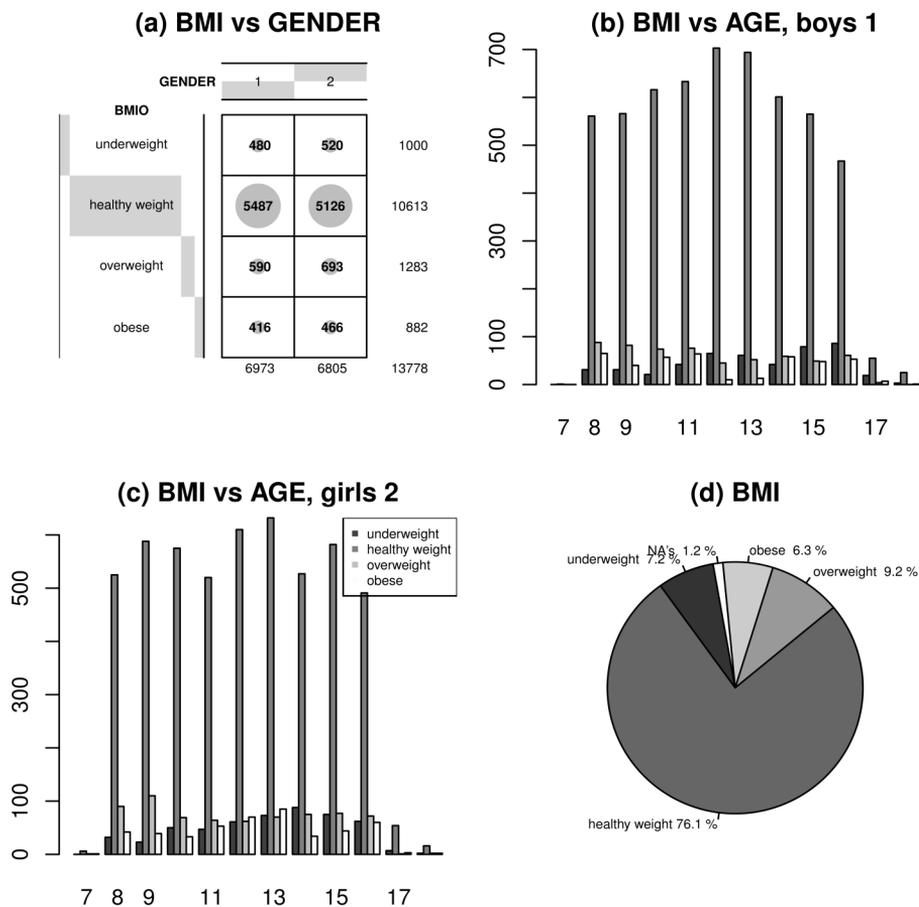


**Fig. 2.** (a) **Summary of BMI according to gender,** (b) **histogram of BMI according to age (boys),** (c) **histogram of BMI according to age (girls),** (d) **Percentage of underweight, healthy weight, overweight, and obesity by BMI**

These results are consistent with results from 2005 showing that 16–22% of children and adolscents in the age of 7–17 inhabiting European countries are overweighted or obese, and about 4–6% are obese [14].

Distribution of children and adolescents with overweight or obesity is significantly diversified in age groups ($p < 0.0001$). The significantly largest percentage is observed in the following age groups for both genders: 8, 9, 11, and 16 years old ($p < 0.05$). A similar situation is observed among boys ($p < 0.0001$) – the largest percentage appears for the 8–11 and 16 age groups ($p < 0.05$). The largest percentage of girls with overweight and obesity appears for the age of 8 ($p < 0.05$), see [Tab. 5].

The problem of malnutrition and underweight is significantly different for boys ($p < 0.0001$) and for girls ($p < 0.0001$). Significantly large percentage of boys with underweight is observed among 12–13 and 15–17 age groups. Among girls, significantly large percentage is observed for 14—17, see [Tab. 5]

Comparing the standardized values of BMI for both genders in corresponding age groups, statistically significant differences are observed for 8–14 and 17 age groups, see [Tab. 4].

**Tab. 4. Standardized characteristics of BMI due to gender in age groups**

| Age | Boys $\bar{x} \pm S$ | Girls $\bar{x} \pm S$ | p-value |
|-----|-----|-----|-----|
| 7 | 0.92 | $0.83 \pm 1.7$ | – |
| 8 | $0.26 \pm 1.3$ | $0.10 \pm 1.2$ | $p < 0.05^*$ |
| 9 | $0.27 \pm 1.3$ | $0.09 \pm 1.1$ | $p < 0.01^*$ |
| 10 | $0.23 \pm 1.2$ | $-0.02 \pm 1.2$ | $p < 0.001^*$ |
| 11 | $0.22 \pm 1.3$ | $-0.13 \pm 1.2$ | $p < 0.0001^*$ |
| 12 | $0.01 \pm 1.3$ | $-0.25 \pm 1.2$ | $p < 0.001^*$ |
| 13 | $-0.05 \pm 1.3$ | $-0.24 \pm 1.2$ | $p < 0.05^*$ |
| 14 | $-0.18 \pm 1.2$ | $-0.31 \pm 1.1$ | $p < 0.05^*$ |
| 15 | $-0.30 \pm 1.2$ | $-0.26 \pm 1.0$ | $p = 0.52$ |
| 16 | $-0.23 \pm 1.1$ | $-0.16 \pm 1.0$ | $p = 0.17$ |
| 17 | $-0.50 \pm 1.3$ | $-0.19 \pm 0.9$ | $p < 0.05^*$ |
| 18 | $-0.62 \pm 1.2$ | $-0.11 \pm 1.0$ | $p = 0.11$ |

Standardization according to the WHO Child Growth Standards
* Statistical significance $p < 0.05$, t test, Mann-Whitney test

According to the results of research run by National Food and Nutrition Institute in 2000, underweight is observed in 11.8% of boys, and at 14.2% of girls. Overweight or obesity is observed in 12.6% of boys and 12.2% of girls [15]. In comparison to these results, we may observe statistically significant decrease of percentage of underweight children and adolescents

**Tab. 5. Frequency of underweight, overweight or obesity in age groups**

| Age | Underweight N (%) | Healthy Weight N (%) | Overweight N (%) | Obese N (%) | Overweight/Obese N (%) |
|---|---|---|---|---|---|
| Boys | 480 (6.9%) | 5487 (78.7%) | 590 (8.5%) | 416 (6.0%) | 1006 (14.4%) |
| 7 | 0 (0%) | 1 (100%) | 0 (0%) | 0 (0%) | 0 (0%) |
| 8 | 31 (4.2%) | 561 (75.3%) | 88 (11.8%) | 65 (8.7%) | 153 (20.5%)* |
| 9 | 31 (4.3%) | 566 (78.7%) | 82 (11.4%) | 40 (5.6%) | 122 (17.0%)* |
| 10 | 21 (2.7%) | 616 (80.2%) | 74 (9.6%) | 57 (7.4%) | 131 (17.1%)* |
| 11 | 42 (5.2%) | 633 (77.7%) | 76 (9.3%) | 64 (7.9%) | 140 (17.2%)* |
| 12 | 65 (7.9%)* | 703 (85.4%) | 45 (5.5%) | 10 (1.2%) | 55 (6.7%) |
| 13 | 61 (7.4%)* | 694 (84.6%) | 52 (6.3%) | 13 (1.6%) | 65 (7.9%) |
| 14 | 42 (5.5%) | 601 (79.1%) | 59 (7.8%) | 58 (7.6%) | 117 (15.4%) |
| 15 | 79 (10.7%)* | 565 (76.2%) | 49 (6.6%) | 48 (6.5%) | 97 (13.1%) |
| 16 | 86 (12.9%)* | 467 (70.0%) | 61 (9.1%) | 53 (7.9%) | 114 (17.1%)* |
| 17 | 19 (22.4%)* | 55 (64.7%) | 4 (4.7%) | 7 (8.2%) | 11 (12.9%) |
| 18 | 3 (10.3%) | 25 (86.2%) | 0 (0.0%) | 1 (3.4%) | 1 (3.4%) |
| Girls | 520 (7.6%) | 5126 (75.3%) | 693 (10.2%) | 466 (6.8%) | 1159 (17.0%) |
| 7 | 0 (0.0%) | 6 (75.0%) | 1 (12.5%) | 1 (12.5%) | 2 (25%) |
| 8 | 32 (4.6%) | 525 (76.2%) | 90 (13.1%) | 42 (6.1%) | 132 (19.2%)* |
| 9 | 23 (3.0%) | 588 (77.4%) | 110 (14.5%) | 39 (5.1%) | 149 (19.6%) |
| 10 | 50 (6.9%) | 575 (79.1%) | 69 (9.5%) | 33 (4.5%) | 102 (14.0%) |
| 11 | 47 (6.9%) | 520 (76.0%) | 64 (9.4%) | 53 (7.7%) | 117 (17.1%) |
| 12 | 61 (7.6%) | 610 (76.0%) | 62 (7.7%) | 70 (8.7%) | 132 (16.4%) |
| 13 | 73 (8.5%) | 632 (73.5%) | 70 (8.1%) | 85 (10.0%) | 155 (18.0%) |
| 14 | 88 (12.2%)* | 527 (72.8%) | 75 (10.4%) | 34 (4.7%) | 109 (15.1%) |
| 15 | 75 (9.6%)* | 582 (74.8%) | 77 (9.9%) | 44 (5.7%) | 121 (15.6%) |
| 16 | 62 (9.1%)* | 491 (71.7%) | 72 (10.5%) | 60 (8.8%) | 132 (19.3%) |
| 17 | 7 (10.8%)* | 54 (83.1%) | 1 (1.6%) | 3 (4.6%) | 4 (6.2%) |
| 18 | 2 (9.1%) | 16 (72.7%) | 2 (9.1%) | 2 (9.1%) | 4 (18.2%) |
| All children | 1000 (7.2%) | 10613 (77.0%) | 1283 (9.3%) | 882 (6.4%) | 2165 (16.1%) |

* Statistical significance $p < 0.05$, test of equality of proportions

($p < 0.0001$) inhabiting the city of Bytom, except of boys in the age of 13–15 ($p = 0.17$).

However, the results describing percentages of children and adolescents with overweight and obesity are alarming: they significantly exceed the values from 2000 in all age groups (!) ($p < 0.0001$). The increase of percentages of obese children and adolescents is so rapid, that its reasons should not be searched only among biological factors. Also external (i.e. non-biological) factors, e.g. education or employment of parents must be taken into account [Tab. 6]. Primary or vocational education of fathers, employment of fathers, subjectively good economical situation of the family, and over 3 persons in a family increase statistically significant percentage of children and

adolescent with underweight, overweight or obesity, which is consistent with results described in the literature [13, 16–17]. Underweight, overweight and obesity is related to primary or vocational education of mothers, to unemployment of mothers and to low income per person in a family – 75–150€.

Among reasons of overweight and obesity, the lack of physical activities can be found [1]. Only about 30% of children and adolescents are physically active (except for physical education lessons at school), see [Tab. 6].

**Tab. 6. Frequency of underweight, overweight or obesity related to social and economical factors**

| Social and economical factors | Underweight | Healthy weight | Overweight | Obesity |
|---|---|---|---|---|
| **Mother's education** Primary/Vocational Secondary/Higher $p < 0.0001*$ | 652 (66.7%) 325 (33.3%) | 5 765 (55.2%) 4 679 (44.8%) | 646 (50.9%) 622 (49.1%) | 466 (54.1%) 396 (45.9%) |
| **Father's education** Primary/Vocational Secondary/Higher $p < 0.0001*$ | 727 (75.3%) 238 (24.7%) | 6 794 (66.0%) 3 507 (34.0%) | 789 (63.3%) 457 (36.7%) | 568 (66.4%) 287 (33.6%) |
| **Mother's employment** Employed Unemployed $p < 0.0001*$ | 368 (38.8%) 580 (61.2%) | 4 907 (48.1%) 5 304 (51.9%) | 608 (48.6%) 644 (51.4%) | 409 (48.2%) 440 (51.8%) |
| **Father's employment** Employed Unemployed $p < 0.0001*$ | 632 (70.1%) 270 (29.9%) | 7 602 (77.0%) 2 265 (23.0%) | 954 (79.8%) 241 (20.2%) | 631 (77.6%) 182 (22.4%) |
| **Subjectively evaluated economical situation** good bad $p < 0.01*$ | 379 (66.7%) 189 (33.3%) | 4 564 (73.5%) 1 648 (26.5%) | 575 (75.8%) 184 (24.2%) | 346 (71.6%) 137 (28.4%) |
| **Month income per person** Less than 25€ 25–75€ 75–150€ Over 150€ $p < 0.0001*$ | 161 (16.9%) 473 (49.8%) 263 (27.7%) 53 (5.6%) | 1 177 (11.8%) 4 393 (43.9%) 3 396 (33.9%) 1 047 (10.5%) | 118 (9.8%) 490 (40.5%) 435 (36.0%) 166 (13.7%) | 99 (11.9%) 337 (40.6%) 309 (37.2%) 86 (10.3%) |
| **Persons in a family** 2–3 More than 3 $p < 0.0001*$ | 169 (17.2%) 816 (82.8%) | 2 501 (23.8%) 8 015 (76.2%) | 369 (28.9%) 909 (71.1%) | 236 (27.0%) 638 (73.0%) |
| **Additional sport activities** YES NO $p < 0.0001*$ | 247 (25.1%) 739 (74.9%) | 3 197 (30.6%) 7 267 (69.4%) | 360 (28.5%) 904 (71.5%) | 225 (25.8%) 648 (74.2%) |

\* Statistical significance $p < 0.05$, $\chi^2$ test

An attempt of determining of log-linear model is the next phase: the model must describe an influence of combination of samples representing chosen social and economical factors at values of BMI. Hence, the following factors:
  – mother's and father's education,
  – mother's and father's employment,
  – subjectively evaluated economical situation of the family
are considered.

The best – because the least complex – model that explains the observed counts as statistically significant ($\chi^2 = 37.19$, $p = 0.96$) contains at most four-factor interactions due to value of BMI. Thus, the following interactions must be taken into account in the model:
  – influence of mother's education, father's education and subjectively evaluated economical situation at values of BMI ($p < 0.05$),
  – influence of mother's education, mother's employment and subjectively evaluated economical situation at values of BMI ($p < 0.05$),
  – influence of mother's employment, father's employment and subjectively evaluated economical situation at values of BMI ($p < 0.05$),
  – interaction of all listed social and economical factors ($p = 0.64$).

The log-linear analysis, especially of margin totals of contingency tables in the defined model, allows us to conclude that larger number of children and adolescent with underweight, overweight or obesity is observed among:
  – growing up in families with subjectively good economical situation, in which mothers or fathers declare primary or vocational education,
  – mothers of which declare primary or vocational education, are employed and in subjectively good economical situation,
  – fathers or mothers of which are employed and in subjectively good economical situation of the family.

## Conclusions

The presented statistical analysis of influence of social and economical factors on physical growth of children and adolescents inhabiting the city of Bytom allows us to conclude that:
  – *Frequency of underweight, overweight or obesity is dependent on age groups*: the largest number of boys with overweight or obesity is observed in the 8–11 and 16 age groups, and of girls – in the age of 8. The largest number of girls with underweight is observed in the 14–17, and of boys – 12–13 and 15–17.

– The percentage of children and adolescents with *overweight or obesity has increased since 2000.* The number of children with *underweight has decreased, except for boys in the age of 13–15.*
– Primary or vocational father's or mother's education, employed father, unemployed mother, subjectively good economical situation, average income 75–150€ per person or over 3 persons in the family *reduce the risk of overweight or obesity.*
– Primary or vocational mother's education and low income per person in a family *causes the possibility* of underweight of children and adolescents.
– Larger *body height and body weight* are observed in the case of children and adolescents of mothers or fathers with secondary or higher education, with subjectively good economical situation and month income larger than 150€.
– We observe dependences between BMI values and:
  – mother's education, father's education and subjectively evaluated economical situation of the family;
  – mother's education, mother's employment and subjectively evaluated economical situation of the family;
  – mother's employment, father's employment and subjectively evaluated economical situation of the family.

Because of upcoming phenomena of overweight and obesity among children and adolescents, preventive treatment and prophylaxis, as far as epidemiological investigations must be considered, to control proper physical growth of children and adolescents.

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