What is the risk for overweight children of being overweight at age 18 years?
The Wroclaw Growth Study

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ABSTRACT
It is widely acknowledged that overweight and/or obesity is associated with elevated morbidity and mortality. A variety of studies have shown that correlations between BMI during childhood and adulthood are generally low but increase during adolescence. However, the use of correlation coefficients has some disadvantages. The aim of this study was to estimate the risk of overweight and obesity at the age of 18 years from the occurrence of overweight and obesity at ages 8 to 17 years in boys and girls from the Wroclaw Growth Study, using three different risk estimates: relative risk (RR), odds ratio (OR), and risk differences (RD). Subjects with BMI higher than the value of 85th centile for the BMI, as estimated from the III Anthropological Survey, were defined as overweight and obese. All three risk estimates gave similar results. Until the age of 14 for boys and 13 for girls, risk remained unchanged on relatively low level, and was a little higher for boys than for girls. This suggests that being overweight in pre-adolescence is not a predisposing factor for becoming overweight in adulthood. After adolescence, risk increased steeply both in boys and girls. The results show that adolescence is a critical period for development of obesity in adulthood.

KEY WORDS
overweight, obesity, BMI, childhood, adolescents, adulthood, risk of overweight

Introduction
Excessive adiposity in the form of overweight and/or obesity is associated with elevated morbidity and mortality from a variety of conditions, including adult-onset diabetes, hypertension, hyperlipidemia, atherosclerosis, and coronary heart disease [JOUVRE et al. 1979, KROTKIEWSKI et al. 1983, PEKKANEN et al. 1990]. In spite of the growing concern for the health consequences of overweight and/or obesity, the prevalence of overweight and obesity has
increased considerably in the child, adolescent and adult segments of populations in North America and Europe [MOKDAD et al. 1999, RONA 1997, MALINA 2004]. Unfortunately, recent studies in Poland present a similar picture, especially after the socio-economic transformation initiated at the end of the 1980s. Overweight and obesity in 19-year-old males increased from 2.33% in 1965 to 14.31% in 2001 [BIELICKI et al. 2003, KOZIEL et al. 2004].

More disquieting is data that point to an increase of the proportion of overweight and obese children and youth in most developed countries, as well in Poland [KOZIEL et al. 2003]. Almost all relevant studies of school children show that the percentages of overweight subjects have doubled or even tripled during the last decade and that the tendency takes the proportions of an epidemic [TREMBLAY and WILLMS 2000]. The massive scale of this phenomenon and the rapidity of the trend make it practically certain that environmental rather than genetic factors are responsible.

Longitudinal studies of children and adolescents indicate that measures of body fat track reasonably well. For example, correlations between the BMI at various ages during childhood and adolescence and the BMI in adulthood are moderate during childhood, but increase with age during adolescence [ROLLAND-CACHERA 1995, GUO et al. 1994]. Other tracking studies commonly use a single age or an age range during childhood and/or adolescence relative to specific ages or age ranges in adulthood, in contrast to the preceding longitudinal observations which are based on samples followed from childhood through adolescence into adulthood. Data from 12 studies, using the BMI, relative body weight, weight-for-height, and skinfolds, were recently summarized in a comprehensive review by POWER et al. [1997]. They show that inter-age correlations in measures incorporating body mass (BMI, relative weight, weight-for-height) between childhood (<13 years) and adulthood (25-36 years) are generally low (~0.30), while those between adolescence (13-14 years) and adulthood (25-26 years) range from moderate to high: 0.46 to 0.91 in males and 0.60 to 0.78 in females [POWER et al. 1997].

The search for the factors responsible for the onset of obesity in childhood is of great importance for at least three reasons: (1) The risk of becoming obese in adulthood is a few times, and in some population even 6.5 times greater in obese than in normal-weighted children [SERDULA et al. 1993]. (2) The risk of health complications related to obesity in adult life is the higher the longer the obesity persists [BJORNTROP 1984, 1985]. (3) Children are more susceptible not only to preventive actions but also to changes and eliminations of already-existing health risk-factors [EPSTEIN et al. 1995].

The aim of this study is to estimate the risk of overweight and obesity at the age of 18 years in relation to the occurrence of overweight and obesity at ages 8 to 17 in boys and girls from the Wroclaw Growth Study.

Materials and methods

Sample

The Wroclaw Growth Study (WGS) followed boys and girls at approximately annual intervals between 1961 and 1972. All participants were inhabi-
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Residents of the city of Wroclaw in southwestern Poland [BIELICKI and WALISZKO 1975, WALISZKO and Jedlińska 1976]. The project began with 425 boys and 435 girls. During the first 8 years of the study, 390 subjects dropped out. By the end of the study period, the number of participants had become reduced to 196 boys and 212 girls. The subjects who persisted in the study did not differ in height and weight from those who had dropped out at the age of 8 years. Thus, dropout at this stage seems to have been random.

All subjects annually underwent an anthropometric examination in the Spring (April-May) of each year. All dimensions were measured by the same professional staff throughout the duration of the project. The present study utilizes only height and weight. Complete data for all age classes of 195 boys and 106 girls were used in the analysis.

**Definition**

The definitions of overweight and obesity were based on the reference data for the Polish population – the III Anthropological Survey carried on by WALISZKO et al. [1980]. This cross-sectional study covered 1451 boys and 1388 girls, born in the years 1959-1973, aged 7-18 years. We found the cut-off points recently recommended by the International Obesity Task Force [COLE et al. 2000] no value for our sample mainly because of the big time gap between those studies and that very few subjects were distinguishable as overweight or obese. Instead, the 85th percentile in the reference population was taken as the cut-off point for defining overweight and obesity. Only the cut-off point separating normal and overweight and obese (combined) subjects was used, since the value of 95th percentile distinguished too few obese subjects. The value was calculated by the LMS method [COLE and GREEN 1992].

**Estimates of risk**

Three indices of risk were used as calculated in this study [STREINER 1998]:

Relative risk (RR) – this index defines the probability of overweight children at the particular age to be overweight at age 18 compared to their normal peers. 

\[
RR = \frac{A/(A+B)}{C/(C+D)}
\]

Odds ratio (OR) – this index defines how many times it is more likely for overweight children at a particular age to be overweight at age 18 compared to their normal peers. 

\[
OR = \frac{A/C}{B/D}
\]

Risk differences (RD) – this index defines how much the risk for overweight children at the particular age to be overweight at the age 18 differs in comparison with normal-weighted peers. 

\[
RD = \frac{A/(A+B)}{C/(C+D)}
\]

where A, B, C, D – are the names of particular cells in a four-course table, and denote:

- A – the number of subjects who were overweight at a particular age as well as at age 18;
- B – the number of subjects who were overweight at a particular age as well as normal-weighted at age 18;
- C – the number of subjects who were normal-weighted at a particular age as well as overweight at age 18;
- D – the number of subjects who were normal-weighted at a particular age as well as at age 18.
Results

Table 1 presents descriptive statistics of BMI in boys and girls in age groups, including the values of 85th centile for BMI estimated on the basis of data from the III Anthropological Survey in Poland. These values of BMI represent the cut-off points that distinguish between normal and overweight subjects.

Changes of value of relative risk of development of overweight at age 18 years in relation to occurrence of overweight in ages 8-17 in boys and girls are presented in Figure 1. Until the age of 14 for boys and 13 for girls, the RR remains unchanged on a relatively low level, and it is a little higher for boys then for girls. After adolescence, the RR steeply increases both in boys and girls and becomes 6 to 8 times higher at the age of 17 compared to pre-adolescence. A very similar picture is shown by Figure 2, which presents changes in OR. The OR remains almost stable until the age of 14 in boys and 13 in girls, and then increases dramatically reaching values of 444 and 168 in boys and girls respectively, at age 17. Likewise, Fig. 1 shows that the values of OR are higher for boys than for girls in the pre-adolescent period. The RD values, shown in Figure 3, follow the same pattern: stability during the preadolescent period, followed by a steep increase thereafter, especially for boys. All these values thus give a similar picture of risk of remaining overweight in adulthood among subjects who were overweight as children.

Careful scrutiny of the changes of three indices of risk in pre-adolescent period reveals an interesting regularity. The values of the three indices are the lowest at age 8 both in boys and girls, and reaching the similar values at age 14 in boys and 13 in girls, except for the RD, when the value at age 14 is distinctly lower than at age 8 for boys. In boys the RR and OR peak at age 13, but for RD the peak is at ages 9 and 10. In girls the highest values of the indices in the pre-adolescent period are at age 9, thus occurring much earlier than in boys.

Table 1. Mean, median and standard deviation of BMI, and value of 85th centile for III Anthropological Survey estimated by the LMS method, in age classes in boys and girls

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N  Mean</td>
<td>Median</td>
</tr>
<tr>
<td>8</td>
<td>236 15.73</td>
<td>15.61 1.35</td>
</tr>
<tr>
<td>9</td>
<td>225 16.14</td>
<td>15.95 1.37</td>
</tr>
<tr>
<td>10</td>
<td>231 16.26</td>
<td>16.08 1.61</td>
</tr>
<tr>
<td>11</td>
<td>233 16.96</td>
<td>16.65 1.77</td>
</tr>
<tr>
<td>12</td>
<td>225 17.36</td>
<td>17.05 1.82</td>
</tr>
<tr>
<td>13</td>
<td>222 17.91</td>
<td>17.56 2.07</td>
</tr>
<tr>
<td>14</td>
<td>233 18.57</td>
<td>18.35 2.11</td>
</tr>
<tr>
<td>15</td>
<td>228 19.43</td>
<td>19.22 2.17</td>
</tr>
<tr>
<td>16</td>
<td>216 20.15</td>
<td>19.83 2.16</td>
</tr>
<tr>
<td>17</td>
<td>199 20.81</td>
<td>20.62 2.18</td>
</tr>
<tr>
<td>18</td>
<td>195 21.17</td>
<td>20.89 2.22</td>
</tr>
</tbody>
</table>
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**Fig. 1.** Changes of Relative Risk (RR) of development of overweight at age 18 years in relation of occurrence of overweight during ages 8–17 years in boys and girls.

**Fig. 2.** Changes of Odds Ratio (OR) of development of overweight at age 18 years in relation to occurrence of overweight during ages 8–17 in boys and girls.
Discussion

Relationships between the degree of adiposity during childhood, adolescence, and adulthood are of interest primarily because of the disease risks associated with adult obesity. Numerous studies have shown that obese children, like obese adults, tend to have adverse levels of lipids, blood pressure, insulin and other factors for coronary heart diseases [BERENSON et al. 1993], and there is some evidence that these associations are independent of the adult weight [MUST et al. 1992].

The present study has attempted to estimate the risk of becoming overweight at age 18 years for children overweight at ages 8 through 9 years. The three risk estimates used show that the risk in question remains stable until adolescence, and then increases for overweight subjects of both sexes. It is interesting that being overweight in pre-adolescence seems to have no bearing on becoming overweight in young adulthood. The present findings agree with those of other researchers, in emphasizing the importance of adolescence as a critical period in the development of obesity in young adulthood [GUO et al. 2000, 2002]. There are substantial sex differences in the risk between the age classes. The risk of becoming overweight for overweight boys was higher than for girls up to age 14. Thereafter, the risk increased one year earlier for girls than for boys, and become higher during ages 14-17.

There are numerous studies examining the persistence (tracking) of fatness from childhood and adolescence to

Fig. 3. Changes of Risk Differences (RD) of development of overweight at age 18 years in relation to occurrence overweight during ages 8–17 in boys and girls.
adulthood. However, the magnitude of risk for fatter children varies from study to study and depends upon the cut-off chosen to define overweight and/or obesity, as well as the initial age at which the participants are examined [SERDULA et al. 1993, POWER et al. 1997].

Most researchers use correlations between the levels of fatness in childhood and adulthood that vary from 0.25 to 0.65 in males and from 0.21 to 0.58 in females [POWER et al. 1997]. It seems, however, that this approach has two disadvantages: Firstly, BMI is not a perfect measure of overall fatness, especially for adolescents, where the use of Rohrer’s index is recommended [COLE 1986]. This is demonstrated by use of correlations between BMI and the sum of skinfold thicknesses at various ages. These are lowest in childhood, then increase before puberty, then decrease, and increase again after adolescence. They are slightly higher in boys than girls. Secondly, a high value of BMI does not necessarily signify excessive fatness, especially in young adult boys [BOUCHARD et al. 1997]. Muscle mass increases considerably during male adolescence and continues to increase into the mid-20s [MALINA and BOUCHARD 1991], so that a young adult with an elevated BMI does not have to be fat: he may just as well have a high fat-free mass. On that account it seems reasonable to use an arbitrarily-defined fraction from the righthand tail of the BMI distribution. For example, there is a much higher probability that the subjects with BMI above the value of 85th centile have excess fatness rather than excess fat-free mass.

It is difficult to directly compare our results with other findings, mainly due to differences in study designs. SERDULA et al. [1993] reviewed the literature and quoted convergent results. For obese preschool children, the risk of adult obesity was 2.0 to 2.6 times greater than that for non-obese children. Among obese school-age children, the risk ratios were 3.9 and 6.5. The latter results are very similar to ours for boys at age 8 and a little higher than that for girls.

Our observations indicate that adolescence is a critical period for the development of obesity at ages 16-20 yrs and its persistence into adulthood. WHITAKER et al. [1997] found that even after adjustment for parental obesity, the odds ratio for adult obesity being associated with childhood obesity ranged from 1.3 for 1-2 year olds to 17.5 for 15-17 year olds. Obesity in older children and adolescents is thus a significant precursor of adult obesity. DIETZ [1994] postulated that in this period significant psychosocial and behavioural changes occur that actuate behaviour predisposing to obesity.

The original conception of the “adiposity rebound” was proposed by ROLLAND-CACHERA et al. [1984] which suggests that children with an early increase of BMI after a low at about 6 years of age, are at higher risk of obesity when they become adults. Four other publications have confirmed that early adiposity rebound is associated with an increased BMI in adulthood, although several concerns in this regard were raised [DIETZ 2000]: Firstly, since correlations of age at rebound and of BMI at rebound with adult BMI are nearly identical it seems that adiposity rebound could constitute an epiphenomenon. Secondly, it might be difficult to determine the age of rebound in individuals, since adiposity rebound is based on
population measures. Measurement error would probably confound the assessment of early-age BMI rebound in young children. Thirdly, the factors predisposing early BMI rebound are not well understood. No significant association was found between protein, fat, or carbohydrate intake and the timing of BMI rebound [DOROSTY et al. 2000].

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References

Bouchard C., Malina R.M., Perusse L., 1997, Genetic of fitness and physical performance, Human Kinetics: Champaign, IL
Cole T., Green P.J., 1992 Smoothing reference centile curve: The LMS method and penalized likelihood, Statistics in Medicine, 11, 1305-1319
Koziel S., Uljaszek J.S., Bielicki T., 2003, Economic transition, socio-economic status and the onset of obesity among Polish children, Final report of joint research project for British Council and SCSR Poland
Krotkiewski M., Björntorp P., Sjostrom L. Smith U., 1983, Impact of obesity on metabolism in men and women. Importance of re-
gional tissue distribution, J. Clin. Invest., 72, 1150-1162
MALINA R.M., BOUCHARD C., 1991, Growth, maturation and physical activity, Human Kinetics, Champaign IL

Streszczenie

Istnieje obszerna i przekonująca literatura wskazująca, że nadmierne otruszenie ciała stanowi czynnik podwyższający ryzyko zachorowalności a także śmiertelności. Pomimo wzrastającej świadomości zagrożenia zdrowia jakie niesie z sobą nadmierne otruszenie wciąż obserwuje się wzrastający odsetek dzieci, nastolatków a także dorosłych nie tylko w krajach wysoko uprzemysłowionych ale także w Polsce. Badania ciągle wskazują, że związki korelowane pomiędzy BMI w różnych klasach wieku w dzieciństwie i okresie pokwitania a BMI w wieku dorosłym są umiarkowane w dzieciństwie ale wzrastają w okresie pokwitania. Wydaje się, że użyta do badania tych związków korelacja nie w pełni opisuje dane zjawisko. Po pierwsze, BMI nie jest najlepszą miarą otruszenia w okresie dzieciństwa i pokwitania. Po drugie, średnia wartość BMI jest obarczona pewnym błędem, ponieważ nie rozróżnia otruszenia od szczupłej masy ciała – wysoka wartość BMI może być spowodowana silnym umiejętnym czyli mezomorficznym typem budowy ciała. Wolne od tych ograniczeń jest zastosowanie frakcji BMI powyżej określonej wartości dla każdej klasy wieku.

Celem niniejszej pracy było oszacowanie ryzyka rozwoju nadwagi i otyłości w wieku 18 w zależności od wystąpienia nadwagi i otyłości w wieku 8-17 lat u chłopców i dziewcząt z Wrocławskich Badań Longitudinalnych. W tym celu na podstawie wartości 85 centyla dla BMI wyznaczonego w oparciu i materiał z III Zdjęcia Antropologicznego wydzielono osobników z nadwagą i otyłością. Ryzyko rozwoju nadwagi i otyłości szacowano trzema wskaźnikami ryzyka: ryzykiem względnym (RR), ilorazem szans (OR) oraz różnicą ryzyka (RD). Uzyskane wyniki dla wszystkich wskaźników były zbliżone. Do wieku 14 lat u chłopców i 13 u dziewcząt wskaźniki ryzyka utrzymywały się na stałym względnie niskim poziomie u obu płci, jednakże wyższym u dziewcząt niż u chłopców. Pod koniec okresu pokwitania wskaźniki gwałtownie wzrastały u chłopców i dziewcząt. Wyniki te wskazują, że wiek pokwitania stanowi krytyczny okres dla rozwoju nadmiernego ołuszczenia w okresie dorosłym. W związku z tym wszelkie programy profilaktyczne zapobiegające rozwojowi otyłości powinny być głównie adresowane do młodzieży w okresie pokwitania.