Coll. Antropol. **35** (2011) 2: 275–280
Original scientific paper

Childhood and Adolescent Body Fat and Its Relationship with Health Outcome in 50 Year Old Males and Females: The Wrocław Growth Study

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A B S T R A C T

The aim of the study was to estimate the association between relative weight in childhood and adolescence and its relationship with adult health outcome. Longitudinal data of the body mass index (BMI) from the Wrocław Growth Study (WGS) covering ages 8 to 18 and then a follow-up at 50 were used. At the age of 50, 124 males and 139 females in the longitudinal study underwent medical examination. Systolic and diastolic blood pressure (SBP, DBP), total cholesterol (TCH), high density lipoprotein cholesterol level (HDL), low density lipoprotein cholesterol level (LDL), triglyceride level (TGL) and fasting glucose level (GLUC) were assessed by using standard techniques. The values of BMI were standardised with the LMS method. Multiple linear regression was used to assess the relationship between health parameters and BMI at ages 8–18, adjusted for BMI at the age of 50, separately for different age categories and parameters, except for blood pressure where the usage of anti-hypertension medication was additionally used as a control variable. In males total cholesterol concentration showed a significant negative correlation with standardised BMI at ages 9–12 and 16 and 17. In females, only blood pressure showed a significant negative relationship with standardised BMI in all age categories reaching the highest values at age 15. The BMI in childhood and adolescence have only a weak effect on health outcome at age 50.

Key words: *adult blood pressure, glucose, lipids, lipoproteins, childhood obesity*

Introduction

Numerous epidemiologic studies have shown that an increased level of lipids, lipoproteins and blood pressure are etiological risk factors for the incidence of cardiovascular and coronary heart diseases and mortality[1].

It is generally believed that risk factors occurring in adult life insufficiently contribute to the explanation of adult health outcomes. Therefore, factors existing and acting at different stages of life need to be considered. Bjõrntrop[2] has pointed out that the risk of health complications caused by obesity is the higher the longer it persists. Many studies have demonstrated an association between obesity in early life and an increased risk of morbidity and mortality from coronary heart diseases in adult life, and there is some evidence that these associations exist independent of adult body weight[3–5]. Other researchers have not provided evidence for a relationship between excessive adult health risks and childhood or teenage overweight[6].

Although childhood levels of fatness are predictive of fatness at later ages, a wide range of correlation coefficients has been reported[7–8]. Estimates of the proportion of overweight children who remain overweight as adults also vary[9]. Thus, it still remains unclear whether health complications in adulthood result from adult obesity *per se* or whether they depend on the age of onset or the time of incubation of obesity from earlier stages of life.

Using longitudinal data from the Wrocław Growth Study embracing ages 8–18 and 50, the purpose was to establish whether there is any association between the level of fatness in childhood and adolescence and adult health parameters, controlling for adult weight.

Received for publication February 8, 2008

Material and Methods

The subjects participated in a longitudinal study, the Wrocław Growth Study (WGS) conducted between 1961 and 1972[10–11]. All of the subjects were born in 1953 and measured annually at primary and secondary schools. The BMI for all individuals was standardised using reference data for the Wrocław population as part of the 3rd Anthropological Survey in Poland carried out by Waliszko et al.[12]. This cross-sectional study covered 1451 boys and 1388 girls born in the years 1959–1973, aged 7–18. Standardisation was done on the basis of the LMS method described by Cole[13]. This method for fitting anthropometric data allows for departure from normality while at the same time the percentiles can be calculated from the mean and SD[14–15]. Furthermore, the method allows for estimating for each tabulated age and sex L, M and S smoothed curves, which represent a Box-Cox power transformation to normality, the mean, and the coefficient of variation, respectively. Then, Z scores for the exact age of the subjects were calculated using the formula:

$$Z = \frac{(X / M)^{L} - 1}{LS};$$

where X was the measurement of subject and L, M, S appropriate values estimated for the exact age and sex based on the 3rd Anthropological Survey[13].

In 2003, the participants were invited again to carry out investigation. This time, 133 males and 148 females underwent medical examination in the Cardiological Centre »ProCorde« in Wrocław; however, because of some missing measurements, the number of subjects varies somewhat between different analyses. After at least five minutes of rest, systolic (SBP) and diastolic (DBP) blood pressure was measured on the left arm in a sitting position using the method recommended by WHO[16] with a sphygmomanometer. This was the standard monitoring procedure in the Clinic. While this differs from some research protocols for blood pressure measurement, the precision of the method was appropriate for internal comparison, while perhaps overestimating blood pressure relative to other methods. The fourth phase of the Korotkoff sounds was recorded. Blood samples were obtained from the ulnar vein between 7.00 and 9.30 a.m. in order to assess plasma lipid concentrations (HDL), total cholesterol (TCH), triglyceride levels (TGL), and fasting glucose levels (GLUC) using standard techniques. Before analysis, health parameters were log transformed due to skewed distribution. Height and weight were measured using a standard protocol[17]. The body mass index (BMI) was used as a measure of fatness [kg/m^2]. Additionally, all the subjects were interviewed by the cardiologist, who ascertained hypertension and usage of anti-hypertension medication.

Student's t-test was used to assess differences between means of health parameters between males and females measured at age 50. Pearson's correlation was used to measure the relationship between values of BMI in particular age categories and at age 50. Multiple linear regression was used in order to assess the relationship between health parameters and BMI at ages 8–18 in males and females, adjusted for BMI at age 50, separately for age categories and parameters, except blood pressure where the usage of anti-hypertension medication (yes/no) was additionally used as a control variable. All the regression models utilised standardised BMI on reference data for ages 8–18 and log transformed health parameters measured at age 50.

Results

Table 1 shows descriptive statistics for BMI in boys and girls aged 8–18 and at age of 50 years. The numbers of subjects in each age classes correspond to numbers of subjects with complete information included in regres-

TABLE 1
MEANS AND STANDARD DEVIATIONS OF RAW BMI VALUES (IN KG/M^2) BY AGE CATEGORY IN BOYS AND GIRLS BETWEEN 8 AND 18 YEARS OF AGE. THE NUMBER OF SUBJECTS INCLUDES ONLY SUBJECTS WITH COMPLETE INFORMATION.

Age	Males				Females			
	N	Mean	Median	SD	N	Mean	Median	SD
8	122	15.86	15.79	1.52	146	15.61	15.27	1.61
9	115	16.27	16.13	1.49	134	15.90	15.60	1.69
10	119	16.43	16.19	1.79	142	16.33	15.88	2.10
11	117	17.09	16.76	1.98	138	17.09	16.58	2.36
12	117	17.52	17.11	2.08	137	18.03	17.48	2.46
13	113	18.14	17.77	2.33	141	18.52	17.98	2.98
14	119	18.73	18.45	2.32	134	19.56	19.13	2.57
15	120	19.47	19.18	2.32	136	20.33	19.87	2.59
16	108	20.14	19.83	2.28	122	21.18	20.81	2.65
17	100	20.76	20.43	2.33	96	21.53	21.28	2.68
18	103	21.04	20.65	2.26	59	21.63	21.50	2.02
50	132	27.42	26.94	4.40	148	27.87	26.45	6.86

TABLE 2
MEANS, MEDIANS AND SDS FOR HEALTH PARAMETERS IN MALES AND FEMALES FROM THE WGS AT THE AGE OF 50

Parameters	Males				Females			
	N	Mean	Median	SD	N	Mean	Median	SD
TCH [mg/dL]	124	222.80	220.50	41.30	139	226.06	225.0	40.02
TGL [mg/dL]*	124	150.57	134.00	86.09	139	121.96	112.0	55.89
HDL [mg/dL]**	124	57.11	54.00	13.74	139	64.35	64.0	14.23
GLUC [mg/dL]	124	96.45	91.00	24.77	139	92.49	88.0	29.03
SBP [mmHg]	120	142.58	140.00	25.20	132	141.17	140.0	23.98
DBP [mmHg]	120	93.54	90.00	13.91	132	90.38	90.0	12.91

* sex differences significant at $p<0.01$; ** sex differences significant at $p<0.001$
WGS – Wrocław Growth Study; TCH – Total Cholesterol Level; HDL – High Density Lipoprotein Cholesterol Level; LDL – Low Density Lipoprotein Cholesterol Level; TGL – Triglyceride Level; GLUC – Fasting Glucose Level; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure

TABLE 3
CORRELATION BETWEEN BMI AT AGE 50 AND STANDARDISED VALUES OF BMI AT AGE 8 TO 18 IN MALES AND FEMALES

Age	Males			Females		
	N	r	p<	N	r	p<
8	121	0.42	0.001	133	0.33	0.001
9	112	0.41	0.001	124	0.34	0.001
10	117	0.45	0.001	128	0.43	0.001
11	115	0.46	0.001	124	0.67	0.001
12	115	0.47	0.001	123	0.49	0.001
13	111	0.54	0.001	128	0.54	0.001
14	117	0.56	0.001	123	0.50	0.001
15	118	0.58	0.001	122	0.49	0.001
16	106	0.66	0.001	110	0.49	0.001
17	99	0.70	0.001	90	0.50	0.001
18	101	0.67	0.001	52	0.37	0.002

sion models, i.e. BMI at particular age classes and at age 50 and values of particular health parameter measured at age 50. At the age of 18 years 7.6% of boys and 6.4% of girls were overweight and obese (above the 85th percentile for the reference population – the 3rd Anthropological Survey of Poland). Among them, 90.9% of boys and 86.7% girls remained overweight and obese at the age of 50 years (BMIł25.0; $\chi^2=5.24$; $p<0.05$).

Descriptive statistics for health parameters, BMI and waist circumferences measured at age 50 are presented in Table 2. There were significant sex differences in average values of three features. Males had higher blood concentration of triglycerides and lower blood concentration of the HDL-cholesterol fraction. They also had higher values of waist circumferences; however, these differences could be overestimated due to the higher body height of males. It is interesting that despite the non-significant sex differences in average BMI, there were significant sex differences in the variation of this feature ($F=1.96$, $p<0.001$, Table 2). This suggests the existence of sex differences in the distribution of BMI at the age 50. Still, the proportions of overweight and obese (BMIł25.0) subjects amount to 66.4% and 63.5% for males and females, respectively, and do not confirm this suggestion.

Table 3 presents the values of Pearson's correlations between standardised values of BMI at a particular age and at the age of 50 in males and females. In males, the values of the correlation coefficient progressively increased with age, gaining the highest value at the age of 17, amounting to 0.70. In females, at the beginning the value of the correlation coefficient increased up to 12–13 years of age, and then remained at the same level to age 17, and then dropped at age 18, probably due to the low number of subjects measured at this age.

Standardised betas derived from multiple linear regressions applied to age class and sex separately are presented in Table 4. The relationships between log transformed health parameters and standardised BMIs for each age category were adjusted for BMI, and additionally for usage of anti-hypertension medication in the case

TABLE 4
RELATIONSHIP BETWEEN STANDARDISED VALUES OF BMI AT AGE 8 TO 18 AND VALUES OF LIPIDS, LIPOPROTEINS AND BLOOD PRESSURE AT AGE 50, ADJUSTED FOR BMI AT 50, IN MALES AND FEMALES FROM THE WGS. RESULTS OF MULTIPLE LINEAR REGRESSION

a) Males

Age class →	8	9	10	11	12	13	14	15	16	17	18
TCH	–0.12	–0.28**	–0.28**	–0.29**	–0.31**	–0.30**	–0.30**	–0.28*	–0.32*	–0.43**	–0.31*
TGL	0.02	–0.14	–0.002	–0.03	–0.04	–0.06	–0.11	–0.12	–0.09	–0.29*	–0.11
HDL	–0.17	–0.16	–0.17	–0.21*	–0.19	–0.19	–0.25*	–0.27*	–0.28*	–0.18	–0.18
GLUC	0.36***	0.002	0.34***	0.30**	0.27**	0.29**	0.14	0.13	0.15	0.14	0.12
SBP	–0.16	–0.22*	–0.19	–0.20	–0.18	–0.19	–0.16	–0.17	–0.33*	–0.37**	–0.25*
DBP	–0.27*	–0.19	–0.19	–0.19	–0.17	–0.17	–0.18	–0.14	–0.25*	–0.34*	–0.23

b) Females

Age class →	8	9	10	11	12	13	14	15	16	17	18
TCH	0.01	0.03	–0.002	–0.06	–0.03	0.07	0.15	0.14	0.14	0.12	0.25
TGL	0.03	0.01	0.05	0.05	0.14	0.15	0.16	0.12	0.08	–0.10	0.01
HDL	–0.05	–0.02	–0.05	–0.03	–0.07	0.03	–0.04	0.02	–0.04	0.08	–0.08
GLUC	–0.01	–0.10	–0.02	–0.02	–0.01	–0.03	–0.10	–0.01	–0.05	–0.11	0.27
SBP	–0.21*	–0.15	–0.14	–0.20*	–0.25**	–0.21*	–0.27**	–0.31**	–0.26**	–0.41***	–0.11
DBP	–0.23**	–0.17*	–0.15	–0.15	–0.21*	–0.12	–0.18	–0.28**	–0.21*	–0.35**	–0.01

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

TABLE 5
RELATIONSHIP BETWEEN VALUES OF HEALTH PARAMETERS AND BMI AT THE AGE OF 50 IN MALES AND FEMALES

Health parameters	Males	Females
TCH	–0.14	–0.14
TGL	0.24**	0.37***
HDL	–0.30**	–0.45***
GLUC	0.44***	0.40***
SBP	0.33***	0.46***
DBP	0.38***	0.49***

of blood pressure at age 50. In males total cholesterol concentration showed a significant negative relationship with standardised BMI at ages 9–18. The strongest relationship appeared at age 17. For the remaining parameters, the relationships were generally not significant only for glucose at ages 8–13, for SBP at ages 9 and 16–18, and for DBP at ages 8 and 16–17. In females, only blood pressure showed a significant negative relationship with standardised BMI in nearly all age categories, reaching the highest values at age 17. All the remaining parameters showed not significant relationship with standardised BMI at ages 8–18.

Table 5 presents the relationship between the values of health parameters and BMI at age 50 in males and females. In males, serum fasting glucose concentration and blood pressure showed the highest relationship with BMI at age 50, whereas total cholesterol concentration showed a non-significant relationship. In females, BMI at age 50 showed the highest significant relationship with systolic and diastolic blood pressure, especially from age 14 to 17, but non-significant with total cholesterol concentration.

Relationships between the values of health parameters and standardised BMI at ages 8–18, adjusted for BMI, usage of anti-hypertension medication, number of children and stage of menopausal changes in females are presented in Table 6. After adding to potentially confounding variables those relationship were a little atten-

TABLE 6
RELATIONSHIP BETWEEN STANDARDISED VALUES OF BMI AT AGE 8 TO 18 AND VALUES OF LIPIDS, LIPOPROTEINS AND BLOOD PRESSURE AT AGE 50, ADJUSTED FOR BMI AT 50, MENSTRUATION (REGULAR, IRREGULAR OR NON–EXISTENT) AND NUMBER OF CHILDREN IN FEMALES FROM THE WGS. RESULTS OF MULTIPLE LINEAR REGRESSION.

	BMI 8	BMI 9	BMI 10	BMI 11	BMI 12	BMI 13	BMI 14	BMI 15	BMI 16	BMI 17	BMI 18
SBP	–0.14	–0.16	–0.09	–0.18	–0.21*	–0.20*	–0.22*	–0.25**	–0.22*	–0.16	0.08
DBP	–0.14	–0.13	–0.07	–0.09	–0.15	–0.11	–0.11	–0.21*	–0.15	–0.09	

uated, however still remained significant at some age categories, especially at ages 12–16 for systolic blood pressure.

Discussion and Conclusion

Based on a longitudinal study comprising data on individuals from 8 to 18 years of age and at age 50, associations between BMI and health parameters in males and females allowing for actual BMI were assessed. The clearest results were the findings of a negative association between total cholesterol concentration and BMI at ages 9–18 in males; and systolic blood pressure in females at ages 11–17.

Such long-term studies of health consequences of overweight are rare. Wright et al.[6] using 932 subjects coming from a single 1947 birth cohort, showed that BMI at age 9 was inversely and significantly correlated with lipid and glucose metabolism in both sexes, and with blood pressure in women, after adjusting for adult BMI. In women the correlation between lipid and glucose at age 50 and BMI at age 13 still remained significant and negative. Those results for the age of 9 were very similar to our findings and correlations were in the same range of values. Exploring a similar data set, Vanhala et al.[18] reported a significant relationship between obesity at age 7 and the risk of developing the metabolic syndrome at age 37 and more. These two findings are thus contradictory. Another large study, using a similar range of risk factors, found also zero or negative relationship between high childhood BMI and metabolic outcomes at adulthood after adjustment for BMI[19].

It seems that such a negative relationship between high childhood BMI and metabolic outcomes at adulthood, after adjusting for adult BMI, does exist. A number of biological and non-biological mechanisms might be used to explain the effect of high childhood BMI on health impairments at adulthood. One may assume that the negative relationship between childhood and adolescent BMI and blood pressure at age 50 could result in females from their reproductive history. It has been shown in a cross-sectional study that the number of childbirths has a significant effect on BMI in adult females after controlling for their social status[20]. We repeated the analysis by including the number of children and information on menopausal status. The association proved a little weaker but still remained negative and significant. Furthermore, it might be possible that although tracking between BMI at childhood and adulthood is observed, the BMI in both periods may reflect different body compositions (muscle mass, bone mass) so that BMI at different ages may not be fully comparable[19]. BMI seems to be insensitive to fat distribution, which is characterised by ontogenetic changes defined as the subcutaneous fat redistribution process and sex dimorphism (Malina 2005)[21]. This hypothesis was confirmed only in males, suggesting that in females the effects are real[6].

In the light of our results, it is noteworthy to discuss findings on the U- or J-shaped relationship between BMI and biological fitness and mortality. It is a well-documented fact that this relationship is not linear and leanness elevates the risk of premature mortality, although to a lesser degree than does obesity[22]. Also lean men revealed impaired function of the circulatory and respiratory systems, similarly to obese men[23]. This suggests that the negative relationship between childhood BMI and metabolic outcomes at adulthood might result from the elevated risk of health disorders among lean and obese adults as compared with adults with normal weight, and thus a U- or J-shaped relationship between childhood and adolescent BMI and metabolic outcomes at adulthood.

In conclusion, it should be kept in mind that the subjects followed up in this study were born in 1953, i.e. several years after the end of World War II, when the population of Wrocław was exposed to generally poor nutritional, health and dwelling conditions[23]. During their lifetime significant changes have occurred in all these respects in Poland, especially during the period of transition from socialism to a free market economy initiated in the early 1990s. In Western Europe, adult obesity has been rising since the 1960s[25–26], but in Poland only moderately until the year 1995[27–28]. Thus, our subjects grew up under specific socio-economic conditions and our findings should not be uncritically generalised as true for the present-day population.

Acknowledgements

This study was supported by State Committee for Research (Poland) grant NR 3P04C 02323 and the Health Department of the City of Wrocław, Poland under the Preventive Programme of Cardiovascular Diseases. The authors would like to acknowledge with gratitude the long-lasting cooperation of the participants of the Wrocław Growth Study.

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MASNO TKIVO U DJETINJSTVU I ADOLESCENCIJI I NJEGOVA POVEZANOST SA ZDRAVSTVENIM STATUSOM PEDESETOGODIŠNJIH STARIH ŽENA I MUŠKARACA: WROCŁAWSKA STUDIJA RASTA

SAŽETAK

Cilj rada bio je uspostaviti povezanost između relativne težine u djetinjstvu i adolescenciji i tu povezanost sa zdravstenim statusom odrasle dobi. Longitudinalni podaci indeksa tjelesne mase iz Wrocławske studije pokrivaju dob od 8 do 18 te slijed od 50 godina. U dobi od 50 godina, 124 muškarca i 139 žena longitudinalnom studijom prošli su medicinski pregled. Sistolički i dijastolički krvni tlak, ukupni kolesterol, HDL kolesterol, LDL kolesterol, razina triglicerida i nivo glukoze mjereni su standardnim tehnikama. Vrijednosti indeksa tjelesne težine standardizirani su putem LMS metode. Višestrukom linearnom regresijom došlo se do veze između zdravstvenih parametara i indeksa tjelesne mase u dobi između 8 i 18 godina, prilagođeno za indeks tjelesne mase za dob od 50 godina, odvojeno za različite dobne skupine i parametre, osim za krvni tlak gdje je korišten lijek protiv visokog tlaka kao dodatna kontrolna varijabla. Kod muškaraca ukupna koncentracija kolesterola pokazuje značajnu negativnu vezu sa standardiziranim indeksom tjelesne mase u dobi 9–12 i 16 i 17 godina. U žena, jedino krvni tlak pokazuje značajan negativan odnos sa standardiziranim indeksom tjelesne mase u svim dobnim skupinama, a najveću vrijednost postiže u dobi od 15 godina. Indeks tjelesne mase u djetinjstvu adolescenciji ima mali utjecaj na ishod zdravstvenog stanja u dobi od 50 godina.