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DETERMINANTS OF HEIGHT, WEIGHT AND BMI OF 3 TO 7 YEAR OLD CHILDREN FROM BRATISLAVA

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Abstract: *The effect of various factors on height, weight and BMI of 3 to 7 year old children was studied in a cross-sectional sample of 1024 girls and 1065 boys from Bratislava, Slovakia. Multiple regression was used to study the effect of age, sex, birth weight, birth length, duration of breast feeding, stature of parents, body weight of parents, birth order, number of siblings, persons per room, education of parents, per capita income, ownership of a car, smoking habits of parents and level of air pollution (SO_2, H_2S, lead, dust and soot) at the place of residence. Altogether these variables account for 76.5%, 55.1% and 13.4% of the variance of height, weight and BMI, respectively. While the effect of sex on all three growth parameters is negligible in early childhood, age is the most important determinant of height and weight of children of the respective age groups. BMI shows a slightly decreasing trend with increasing age, reflecting a linearisation of body built from age 3 to 7 years. When age and sex are controlled height and weight of parents are the most important determinants. While height and weight are positively related with both size parameters of the parents, BMI increases with weight of the parents, but decreases with increasing stature of parents. Furthermore birth length has a statistically significant ($p < 0.05$) positive effect on height and weight is positively associated with birth weight. BMI increases with birth weight and decreases with birth length. The only other factor which shows an effect on height and weight when all other variables are controlled is the smoking habit of the parents. Height of children of smoking parents tends to be lower than that of children from non-smoking parents, while on the other hand weight tends to be higher. These effects are also reflected by the results for BMI, which is significantly ($p < 0.05$) higher for children of smoking parents. In this study air pollution does not have an effect on height and weight. BMI, however, is positively related to increased levels of lead pollution, i.e. children residing in areas with comparatively high concentrations of airborne lead have a higher BMI than children from areas in which the acceptable level is not exceeded. On the other hand BMI is negatively related to the level of soot pollution. Although the effect is comparatively small with regard to the explained variance, both pollutants show to some extent a dose dependent effect.*

Key words: *Height; BMI; Socio-demographic factors; Air pollution.*

Introduction

Growth, which is a basic characteristic from conception through at least the first two decades of postnatal life, is the results of complex interactions between the genetically determined growth potential coded by the DNA and many - social, cultural, emotional, material, biochemical - environmental factors. The growth of a single child reflects the outcome of a very specific interaction between a quite unique individual genetic make-up and a just as unique environmental setting, and we are not able to disentangle the contribution or the effect of a single factor at the level of the individual. At the population level, however, we might approach the problem of quantifying the magnitude of the effect of different factors with the use of multivariate statistical methods. Since the effect especially of different environmental factors may vary from population to population it was the aim of the present study to identify some of the variables which are associated with variations of growth in height, weight and BMI of pre-school age children in Bratislava.

Material and Methods

Sample: The results are based on cross-sectional growth data of a sample of n = 2,098 3 to 7 year old boys and girls. The data have been sampled from 1988 to 1991 in 52 Kindergartens spread over the whole city area of Bratislava.

Data: The independent variables used in statistical analyses are: birth weight, birth length, height and weight of parents, duration of breast feeding, birth order, number of siblings, number of persons per room, ownership of a car and/or an allotment, education of parents, per capita income, smoking habits of parents and concentration of SO_2, lead, dust, soot and H_2O.

The metric traits (dependent variables) considered here are height, weight and body mass index (BMI). The response rate for somatometric traits was close to 100% (original sample size was n = 3,059), while the response rate for questionnaires was approximately 70%. There were no differences in the distribution of metric traits between children of responding and non responding parents.

Statistical Methods: The multivariate statistical methods used in the present analysis require that the dependent variable follows a Gaussian distribution. Since this requirement only applies for height several power transformations were used to get normally distributed BMI and weight data (Danker-Hopfe, Cermáková and Drobná 1996). For weight the best approximation could be obtained with α = -1 and for BMI α = -0.5 yielded the best result.

Results and Discussion

Growth is a process which is obviously reflected by changes in size parameters with age and often there are sex specific variations in those parameters as well. This is shown by the results of analysis of variance with age and gender being the only independent variables. Height increases significantly with age while there are no sex differences for children of the respective age groups. Weight also increases with age and is slightly higher in boys as compared to girls, at least for 3 and 4 year old children and BMI finally decreases very slightly with age and shows almost no sex differences in spite of the statistically significant effect which results from the large sample. The magnitude of the effect of these two variables is reflected in the amount of variance explained by these two independent variables. For height it is almost 62.6%, for weight it is 41.8% and only 1.3% of the variation of BMI in the data can be explained by age and gender.

In a next step of analysis multiple linear regression models focusing on main effects were used to study the effect of the independent variables mentioned above. Variables measured on a metric scale were entered as continuous variables, those measured on a nominal or ordinal scale have been dichotomised. Thus altogether 40 independent variables have been entered into regression analyses.

When all independent variables - including age and sex - are used in regression analysis, the amount of explained variance varies from 76.5% for height over 55.1% for weight to 13.4% for BMI. This reflects that 13.9,13.3 and 12.1% of the variance of height, weight and BMI, respectively, is explained by independent variables other than age and gender.

To eliminate most of the effect of age and the effect of gender, in further analyses age and sex standardised values (SD- or z-scores) were used as dependent variables instead of original measurements and transformed values, respectively.

Table 1: Results of regression analysis based on SD-scores with 38 independent variables (p-values: ns: not significant, *: 0.05 > p > 0.01, **: 0.01 > p > 0.001; ***: p < 0.001).

Variable	Height	p	Weight	p	BMI	p
Constant	-17.147	***	-8.601	***	4.883	***
Elevated lead level	0.050	ns	0.386	ns	0.528	*
High lead level	-0.126	ns	0.483	ns	0.896	*
Slightly. elev. soot level	0.131	ns	-0.275	ns	-0.565	**
More elev. soot level	-0.020	ns	-0.305	ns	-0.459	*
High soot level	0.310	ns	-0.258	ns	-0.734	**
Birth weight (kg)	0.076	ns	0.257	***	0.338*10-3	***
Birth length (cm)	0.061	***	0.017	ns	-0.048	**
Father's height (cm)	0.035	***	0.013	**	-0.015	***
Father's weight (kg)	0.006	*	0.014	***	0.016	***
Mother's height (cm)	0.038	***	0.012	**	-0.021	***
Mother's weight (kg)	0.008	**	0.019	***	0.021	***
Ownership of an allotment	0.116	*	0.052	ns	-0.037	ns
Months of breast feeding: 2-4	0.130	**	0.014	ns	-0.118	*
Months of breast feeding: > 4	0.106	ns	0.066	ns	-0.011	ns
Smoking father: < 11 cig./d.	-0.112	*	-0.023	ns	0.077	ns
Smoking father: > 10 cig./d.	0.005	ns	0.111	ns	0.173	*
Smoking mother: < 11 cig./d.	0.059	ns	0.132	*	0.122	*
Smoking mother: > 10 cig./d.	-0.066	ns	0.084	ns	0.146	ns

Note: Since for none of the growth parameters the regression coeffcients of the dummy variables coding for elevated sulphur dioxide levels, elevated dust levels, elevated H_2S levels, birth order, number of siblings, number of persons per room, ownership of a car, education of parents and per capita income was statistically signifcant, they are not listed in this table.

The results of multiple regressions analysis for height (Table 1) show that none of the regression coefficients of the dummy variables coding for elevated levels of air pollution, birth order, number of siblings, number of persons per room, ownership of a car, education of parents and per capita income differed significantly from zero. Height is positively associated with birth length - not with birth weight -, father's and mother's height as well as father's and mother's weight. Furthermore children who were breast fed for at least one month tended to be slightly taller than formula-fed children. Ownership of an allotment was also positively related to height, while children of smoking fathers tended to be shorter than children of non-smoking fathers. Both p-values , however, were close to insignificance and the effect of smoking was not consistent, so that statistical significance here does not necessarily reflect that the observation is biologically meaningful.

Using the amount of variance explained by different sets of independent variables as a proxy of the magnitude of the biological significance of the effect it shows (see Table 2) that of the altogether 25.1% of variance of height SD-scores which is explained by the set of all independent variables 21.5% are explained by birth size parameters and height and weight of parents. Other factors, including SES, only account for 3.1% of the variance. Height and weight of the parents alone account for 19.3% of the variance and height of the parents alone can explain 17.5% of the variance of z-scores of height of the children. The data furthermore indicate that height and weight of parents don't have completely independent effects, and they also show that size at birth effects and the effect of size of parents are not completely independent.

Table 2: Amount of variance (%) of SD-scores explained by different sets of independent variables.

Set of Variables	Height	Weight	BMI
38 independent variables	25.1	18.2	12.5
Birth length and weight,height and weight of parents	21.5	15.9	9.2
38 independent variables minus birth lenght and weight; height and weight of the parents	3.1	2.4	3.7
Birth length and weight	6.7	7.1	3.0
Height and weight of parents	19.3	13.2	7.3
Height of parents	17.5	7.0	0.1
Weight of parents	7.8	11.2	5.6
BMI of parents			7.2

For weight only 5 of the altogether 38 independent variables are statistically significant different from zero. Height and weight of both parents and birth weight - not birth length - are positive predictors of the weight of the children. Furthermore one of the positive coefficients of the variables coding for parent's smoking habits was statistically significant. Children of mothers smoking less than 11 cigarettes/day tend to have a little more weight than children of non-smoking mothers, but again the observation concerning the effect of smoking is not completely consistent.

A comparison of the amount of variance of z-scores for weight explained by different sets of independent variables shows that of the 18.2% of the variance of the SD-scores of weight 15.9% can be explained by height and weight of parents and birth size. All other factors account for only 2.4% of the variance - with the underlying model not even being statistically significant. While birth weight and height account for 7.1% of the variance height and weight of the parents alone might explain 13.2%. Again the results show that these two sets of variables share some common explained variance. While for height of the children height of the parents has the greatest effect, for weight it is the weight of parents, which alone explains 11.2% of the variance of the weight of the children.

For BMI a slightly different picture emerges. Again height and weight of parents have a statistically significant effect. While birth length was a predictor of height in childhood and birth weight was a predictor of weight, both are predictors of BMI. All weight variables are positively related to BMI, while all length variables show negative associations with BMI in childhood.

The results of regression analysis furthermore show that breast-fed children tend to have a lower BMI in childhood than bottle-fed children or those who have been breast-fed only for a short period of time. Differences in weight in early childhood according to the mode of nutrition are well documented. In countries where formulae of high quality are available and the risk of contamination is low, breast fed infants on average are lighter during the first months and years of life, respectively, than their bottle-fed counterparts. The effect of breast-feeding on weight in childhood could not be shown in the present study, but it seems that BMI is even more affected by early infant feeding practices than weight.

Furthermore two of the regression coefficients coding for smoking habits of the parents are statistically significant. For BMI the results are consistent and they point towards a dose-response-relationship. Children of smokers have a higher BMI than children of non-smokers. The effect of smoking can be considered as an effect of indoor air pollution. A growth inhibiting effect of smoking during pregnancy is well documented so are several health effects of ETS exposure in early postnatal life. Studies related to effects of ETS on postnatal growth, however, are comparatively scarce. There are papers , e.g. by Rona, Chinn and Florey (1985) and Berkey, Ware, Speizer and Ferris (1984), showing that the height of ETS exposed 5 to 11 year old children is smaller than that of non-exposed children, even if birth weight, height of parents, number of siblings and an index of room quality is statistically controlled.

Finally two air pollutants show a statistically significant effect on BMI. That elevated soot levels are associated with a lower BMI corresponds to what we might expect. From experimental studies it is known that exposure to PAH (polycyclic aromatic hydrocarbons) which are set free by incomplete burning of organic substances and which are known to be adsorbed to soot particles leads to a decrease of body weight in animals.

The results concerning the effect of lead might be more surprising. Although in the present study no effect of lead pollution on height and weight was observed, BMI is higher in children exposed to elevated lead levels. This observation corresponds to some data from the literature. Recently Danker-Hopfe and Hulanicka (1995,1996) found a statistically significant earlier occurrence of menarche in a sample of girls from lead smelter neighbourhoods in Upper Silesia. This association persisted when education of the father, economic situation of the family and family size were controlled. On the other hand several studies have shown, that weight and body composition, respectively, are correlates of the timing of occurrence of menarche. Furthermore a study by Kim, Hu, Rotnitzky, Bellinger and Needleman (1995), which is based on the data from the Boston Longitudinal Study on effects of low level lead exposure showed that dentine lead level was not only a statistically significant predictor of BMI in children even when age, sex, baseline body size and mother's socio-economic status were controlled, but was also a predictor of changes of BMI in a longitudinal perspective. Kim et al. (1995) summarise their observation as follows: „The results suggest that chronic lead exposure in childhood may results in obesity that persists into adulthood".

Thus the observed positive relation between BMI and lead exposure is not a completely isolated observation. The effect is even much more marked for skinfold thicknesses and an anthropometrically derived index of %fat, this, however will be discussed in more detail elsewhere.

Although this aspect certainly deserves further recognition we have to be aware that for BMI as well as for height and weight the effect of individual growth dispositions as reflected by birth size and height and weight of parents is more important than the effect of other independent variables, like air pollution and smoking habits of parents. Of the 12.5% of the variance of BMI z-scores explained by all independent variables only 3.7% are explained by factors other than height and weight of parents and size parameters at birth. While the latter set of variables accounts for 9.2% of the variance height and weight of parents alone may account for 7.3% of the variance of BMI z-scores, the same amount can be explained by the BMI of parents.

Conclusion

Individual growth dispositions and prenatal development for which birth weight and length as well as height and weight of the parents, respectively, are indicators, are the most important determinants of height, weight and BMI of 3 to 7 year old children in Bratislava, with height of the parents being the most important factor for height and weight being the most important factor for weight and BMI being the most important factor for BMI

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