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# Overweight, Obesity and Elevated Blood Pressure in Children and Adolecents

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**Abstract**
*Obejective:* Since many years in adults associations between dyslipidaemia, increased insulin resistance, arterial hypertension and the risk for cardiovascular diseases have been recognized. It was the aim of the present trial to investigate these associations and interactions between height, weight, body-mass index and blood pressure values in overweight/obese and normal weight children and adolescents.
*Patients and Methods:* 172 children and adolescents (n = 86 with overweight and obesity, n = 86 controls) were studied. In all the subjects anthropometrical data and blood pressure values were assessed.
*Results:* Overweight and obese children had significantly higher blood pressure values (systolic 117.9 ± 9.7, diastolic 75.6 ± 8.8 mmHg) than control subjects (systolic 111.4 ± 11.0, diastolic 69.5 ± 8.8 mmHg, $p<0.001/0.001$). Additionally in overweight and obese subjects the number of patients with blood pressure values below the 50th percentile was lower, but the numbers of children and adolescents with values ≥50th age-, height- and gender-specific percentiles were significantly higher. In multivariate analysis of overweight/obese children and adolescents only patients' BMI (R-square = 0.26, $\beta = 0.52$, $p<0.001$), but not sex, age, height or weight revealed any association with systolic blood pressure values. Diastolic blood pressure revealed an association with childrens' and adolescents' weight (R-square = 0.22, $\beta = 0.48$, $p<0.001$), but there were no associations with body-mass index, sex, age or height. In normal weight control subjects age ($\beta = 0.32$, $p = 0.01$) and height ($\beta = 0.28$, $p = 0.03$) showed associations with the systolic blood pressure values (R-square = 0.15), but only childrens' and adolescents' height ($\beta = 0.39$, $p<0.001$) was associated with diastolic blood pressure (R-square = 0.28).
*Conclusions:* Overweight and obesity in childhood are highly associated with multiple comorbidities, elevated blood pressure values, dyslipidaemia, reduced insulin sensitivity and alterations of large and minor vessels. Overweight and obesity in children and adolescents should not longer be regarded as variations of normality, but as diseases with an extremely high risk for the development of atherosclerosis and cardiovascular complications in adulthood. Knowledge of these complex associations implicate even in young age the need for intervention.

*Key words:* Body-mass index, cardiovascular diseases, arterial hypertension, dyslipidaemia, insulin resistance, carotid intima-media thickness

## Introduction

The association between obesity, high fasting triglycerides, elevated fasting plasma insulin, impaired glucose tolerance, arterial hypertension and the risk for development of cardiovascular disease has been long recognized [1]. Moreover, in the US as well as in a majority of west European countries, the prevalence of obesity has increased markedly [2, 3, 4]. Concurrently, several surveys have shown significant increases in diagnosed cases of diabetes mellitus, arterial hypertension and cardiovascular diseases, particularly in overweight and obese individuals [5, 6] over the past decades.

Dramatic increases in overweight and obesity, with increased risks for atherosclerotic diseases and early death, have not only been documented for adults but also for children and adolescents [4]. Young-Hyman et al. [7], Caprio et al. [8] and Iannuzzi et al. [9] have identified a cluster of factors common to the development of insulin resistance syndrome in 5 to 10 year-olds and pre-adolescent obese children. Although it is well-known that in a high percentage of children and adolescents who are overweight or obese, multiple cardiovascular risk factors already exist such as dyslipidaemia, elevated fasting glucose and insulin levels, increased intima-media thickness, carotid stiffness and arterial hypertension [7, 8, 9], for the most part it remains unclear whether there is a difference in mean blood pressure levels between overweight/obese and normal weight persons.

The aim of the trial was to conduct a prospective investigation of blood pressure values and possible associations to height, weight and body-mass index in a cohort of children and adolescents, hospitalised for weight reduction. The results are compared to anthropometrical data of a normal weight control group.

## Patients and Methods

Eighty-six overweight or obese children and adolescents hospitalised for weight reduction were consecutively recruited from the Department of Diabetes and Metabolic Diseases of the Inselklinik Heringsdorf, Seeheilbad Heringsdorf, Germany over a period of twelve months (04/2004-04/2005). The subjects were matched with healthy controls according to age and height. The controls were recruited from children of adult patients who were hospitalised at the Department for Adult Internal Medicine and the Department for Adult Psychosomatic Diseases of the Inselklinik Heringsdorf.

The inclusion criteria for both overweight/obese children and adolescents and control subjects were: age 6-16 years, no personal history of diabetes mellitus or impaired fasting glucose, hypercholesterolaemia, or arterial hypertension, an absence of any pharmacological therapy, and no history of cardiovascular disease. Obesity was defined as a body-mass index (BMI) >95$^{th}$ percentile of the reference values as stated by the National Guidelines [10].

Measurements of height and body weight were assessed with the patients wearing light clothing and without shoes. Blood pressure in the sitting position was measured after the patients and controls had rested for 10 min by using a standard sphygmomanometer according to the World Health Organization (WHO) recommendations [11]. To define normal and elevated ranges of blood pressure values, percentile charts taken from the pooled data of studies on blood pressure conducted in six north-west European countries (a total of 28,043 children) were used [12].

### Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 12.0). All continuous data are presented as mean ± standard deviation (SD) or, if the data showed no normal distribution, as median and range. Dichotomous data were presented as number (n) or in percent (%). Univariate, unadjusted analyses between overweight/obese and control subjects were performed with the independent samples t-test, chi-square test, Fisher's exact test for frequencies at or below 5 and the Wilcoxon's rank sum test. Pearson's correlation coefficient was calculated and multivariate analysis was used to evaluate the presence of associated variables in the relationship between overweight/obesity status and blood pressure values. Significance was defined at the 0.05 level.

## Results

Table 1 shows anthropometrical parameters in overweight/obese and normal weight children. Overweight and obese children had significantly higher blood pressure values compared to the control subjects. There were no differences between female and male overweight/obese children and adolescents (females: 117.2 ± 8.8/74.4 ± 7.9 mmHg, males: 118.5 ± 10.6/76.9 ± 9.7 mmHg, p = 0.53/0.19) and normal weight controls (females: 110.0 ± 10.2/68.3 ± 8.8 mmHg, males: 112.6 ± 11.7/70.4 ± 8.7 mmHg, p = 0.29/0.27).

Following the age-, height- and gender specific blood pressure percentiles developed by de Man et al. [12] only 30/86 (35%) of the overweight/obese children and adolescents had systolic blood pressure values <50th percentile, 56/86 (65%) had values within the 50-95th percentile, but no patient had a systolic blood pressure value ≥95th percentile. 12/86 (50%) of the children and adolescents had diastolic blood pressure values <50th percentile, 37/86 (43%) had values within the 50-95th percentile und 37/86 (43%) had values ≥95th percentile. In the normal weight subjects the number of patients with blood pressure values below the 50th percentile was higher, but the numbers of children and adolescents with values ≥50th percentile were significantly lower (Figs. 1a and 1b).

None of the overweight/obese or normal weight children and adolescents were diagnosed with arterial hypertension (systolic and diastolic blood pressure values ≥ 95th percentile [11]).

### Correlation and Multivariate Analysis

In the overweight/obese children and adolescents, systolic and diastolic blood pressure values showed significant positive correlations with patients' BMI (systolic blood pressure: r = 0.52, p<0.001, diastolic blood pressure: r = 0.46, p<0.001) (Figs. 2a and 2b) and age (systolic blood pressure: r = 0.37, p<0.001, diastolic blood pressure: r = 0.27, p = 0.013) (Figs. 3a and 3b).

In the normal weight controls, systolic and diastolic blood pressure values were positively correlated with

*Table 1.* Anthropometrical parameters of overweight/obese children and adolescents and normal weight controls.

| **Children/adolescents** | **Overweight/obese** | **Normal weight controls** | **p-value** |
|---|---|---|---|
| Number (n) | 86 | 86 | / |
| Females (n/%) | 45 (52%) | 39 (45%) | 0.45 |
| Age (years) | 13.9 ± 2.3 | 14.1 ± 2.2 | 0.64 |
| Weight (kg) | 84.1 ± 18.9 | 59.4 ± 14.5 | <0.001 |
| Height (cm) | 165.3 ± 10.5 | 166.3 ± 11.8 | 0.56 |
| BMI (kg/m$^2$) | 30.5 ± 4.8 | 21.3 ± 3.9 | <0.001 |
| Systolic blood pressure (mmHg) | 117.9 ± 9.7 | 111.4 ± 11.0 | <0.001 |
| Diastolic blood pressure (mmHg) | 75.6 ± 8.8 | 69.5 ± 8.8 | <0.001 |

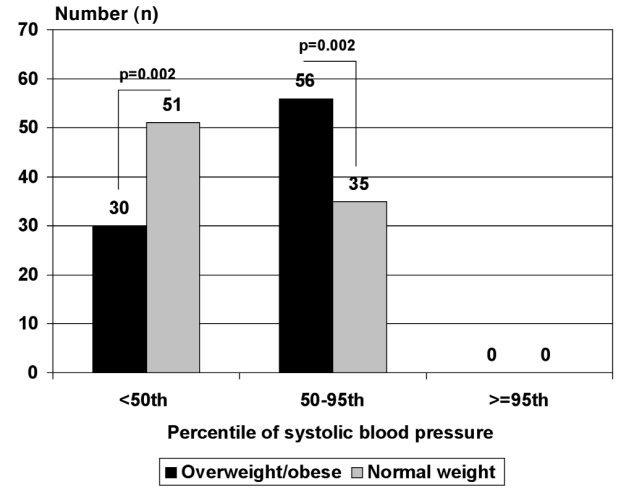


*Fig. 1a*. Number of overweight/obese and normal weight children and adolescents below the 50th, within the 50th and 95th and ≥95th systolic blood pressure percentile [12].

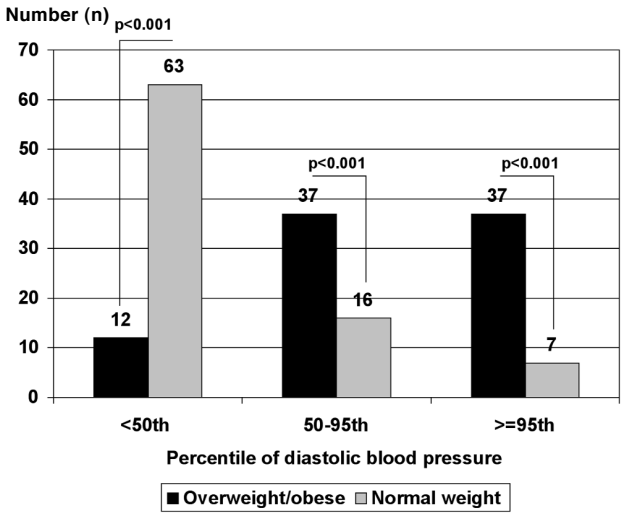


*Fig. 1b*. Number of overweight/obese and normal weight children and adolescents below the 50th, within the 50th and 95th and ≥95th diastolic blood pressure percentile [12].

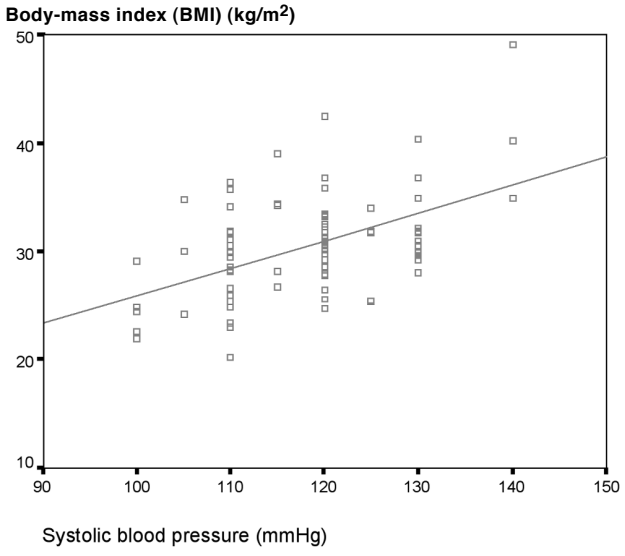


*Fig. 2a*. Correlation between body-mass index and systolic blood pressure in 86 overweight/obese children and adolescents.


*Fig. 2b*. Correlation between body-mass index and diastolic blood pressure in 86 overweight/obese children and adolescents.

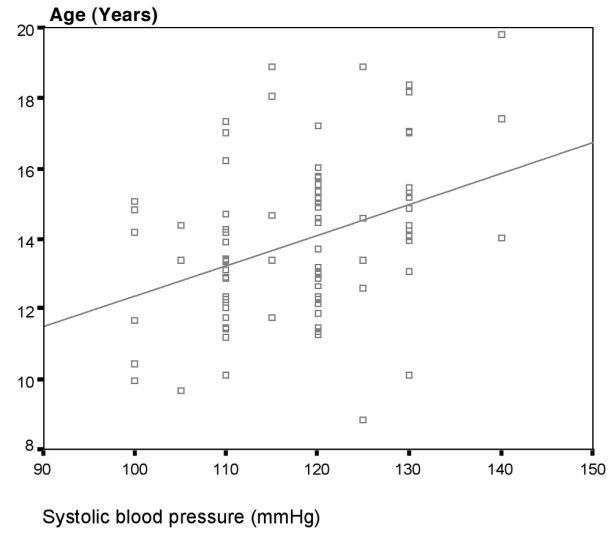


*Fig. 3a*. Correlation between age and systolic blood pressure in 86 overweight/obese children and adolescents.


*Fig. 3b*. Correlation between age and diastolic blood pressure in 86 overweight/obese children and adolescents.

subjects' age (systolic blood pressure: r = 0.51, p <0.001, diastolic blood pressure: r = 0.27, p = 0.01), height (systolic blood pressure: r = 0.49, p<0.001, diastolic blood pressure: r = 0.40, p<0.001), weight (systolic blood pressure: r = 0.64, p<0.001, diastolic blood pressure: r = 0.56, p<0.001) and BMI (systolic blood pressure: r = 0.48, p<0.001, diastolic blood pressure: r = 0.30, p = 0.005).

In multivariate analysis of overweight/obese children and adolescents only patients' BMI (R-square = 0.26, $\beta$ = 0.52, p<0.001), but not sex, age, height or weight revealed any association with systolic blood pressure values. Diastolic blood pressure revealed an association with children and adolescents' weight (R-square = 0.22, $\beta$ = 0.48, p<0.001), but there were no associations with body-mass index, sex, age or height.

In the normal weight control subjects, age ($\beta$ = 0.32, p = 0.01) and height ($\beta$ = 0.28, p = 0.03) showed associations with the systolic blood pressure values (R-square = 0.15), but only children and adolescents' height ($\beta$ = 0.39, p<0.001) was associated with diastolic blood pressure (R-square = 0.28). All other parameters included in the model revealed no associations (sex, body-mass index, weight).

## Discussion

Overweight and obese children and adolescents have significantly higher blood pressure values compared with the healthy normal weight controls. Moreover, in overweight and obese children and adolescents the percentage of persons with blood pressure values above the 50th age-, height- and gender-specific percentiles [12] is higher than in the normal weight controls.

In a multicenter trial published in 1999 Soergel [13] found in 1141 healthy children and adolescents a moderate increase of blood pressure values in both boys and girls, associated with height. Similar data were previously reported by de Man et al. [12] who developed reference charts on blood pressure. The present trial revealed comprehensive data for normal weight healthy controls. Also in this cohort systolic and diastolic blood pressure values showed significant associations with subjects age and/or height. In contrast, in the overweight and obese children and adolescents not height or age, but weight or BMI revealed significant associations. These somewhat contradictory findings in overweight and obese children and adolescents compared with normal weight controls, suggest that body-mass index and weight may represent powerful risk factors for elevated blood pressure values, although no subjects were diagnosed with arterial hypertension [11]. Several studies on adults [1, 14, 15, 16] have shown that elevated blood pressure levels affect the structural and mechanical properties of both major and minor blood vessels. Hence elevated blood pressure values and arterial hypertension are determinants of atherosclerosis with increased risk for cardiovascular diseases. Moreover, in adults as well as in children and adolescents, several studies have demonstrated a clear and positive correlation between body weight and the presence and degree of other risk factors for atherosclerotic diseases such as insulin resistance, dyslipideamia with elevated triglyceride- and reduced HDL-levels and elevated C-reactive protein [17]. To investigate whether obesity in childhood may cause premature vascular alterations in both sexes, Iannuzzi et al. studied 100 children with a mean age of 10 years and a mean BMI of 27.8 kg/m$^2$ [9], both parameters slightly lower than in the present trial. Interestingly in this study, as well as higher fasting cholesterol, higher fasting triglycerides, higher fasting glucose and C-reactive protein levels, the authors also found an increased carotid intima-media thickness and stiffness compared with healthy control subjects. From this data, derived from an even younger and less obese cohort of children and adolescents, it can be assumed that such alterations may be indicators of early, preclinical atherosclerosis. Together all these studies provide clear evidence that obesity in childhood is highly associated with multiple comorbidities, elevated blood pressure values, dyslipidaemia, reduced insulin sensitivity and alterations of major and most likely minor blood vessels. Overweight and obesity in children and adolescents should no longer be regarded as variations of normality, but as a disease with an extremely high risk for future development of atherosclerosis and cardiovascular complications in adulthood. Awareness of these complex associations point to the urgent need for early intervention. Based on the present epidemiological data, as long as no data derived from well-designed intervention studies yet exist, weight reduction and risk-factor control as well as the early treatment of elevated blood pressure levels even if not yet diagnosed as hypertensive, should be emphasized. Particularly in view of the dramatic increase of weight and obesity amongst children and adolescents in the past few decades [18], comprehensive strategies for the long-term prevention of risk factors and atherosclerosis and its sequelae should begin early in childhood.

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