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# Sexual Dimorphism in Body Composition, Weight Status and Growth in Prepubertal School Children from Rural Areas of Eastern Austria

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**A B S T R A C T**

*Sexual dimorphism in stature, weight status and body composition were analyzed in a sample of 398 prepubertal children (213 girls, 185 boys) ageing between 7 and 10. Furthermore the prevalence of overweight was tested. Body composition parameters were determined using TBF 105 Body composition analyzer according to BIA-method. Highly significant sex differences in body composition were observed ($p < 0.001$). In contrast, stature, weight and BMI showed no significant differences between the two sexes. Nevertheless, a significant higher portion ($p < 0.05$) of girls (29%) corresponded to the definition overweight according to ASNS (Austrian Survey of Nutritional Status), while only 20% of the boys felt into the category overweight. The results of the present study showed not only significant sex differences in body composition, especially in fat mass, long before puberty onset, but also a significantly higher prevalence of overweight among prepubertal girls in comparison to prepubertal boys.*

## Introduction

The health status of individuals or populations is closely linked to nutritional status. While malnutrition and underweight are typical nutritional problems of Third World countries, overweight and obesity belong to the most important health risk factors of contemporary industrialized societies[1]. Obesity in association with a centralized fat distribution is associated with an increased risk for the development of the so-called metabolic syndrome and is also described as an important risk factor for colon and breast cancer[2]. However, obesity, especially centralized obesity, is not only a health problem of adults, especially middle-aged people,

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who represent the main risk group to develop a metabolic syndrome and colon or breast cancer, obesity and overweight are also marked problems during childhood and adolescence[1]. Especially during the last three decades the prevalence of overweight and obesity in childhood and adolescents is rising[1,3–5]. This secular trend may be the result of behavioral changes taking place during the past three decades such as steadily decreased energy expenditure, low physical activity levels, spending a lot time of watching TV[6–9], and changed nutritional habits[10]. Unfortunately obesity present in childhood or adolescence increases the likelihood of adult obesity and therefore morbidity and mortality during adult phase of life[11,12]. Especially a centralized fat distribution which is known to be associated with the health risks mentioned above during adulthood, seems to persist throughout childhood and adolescence up to adult age[13]. A centralized fat distribution and a high amount of fat tissue are typical for overweight and obese children and adults. However body composition and fat distribution vary with age and sex. During childhood fat distribution patterns and body composition seems to be similar in girls and boys, gender differences occur during adolescence[14,15]. This is true of fat distribution patterns as well as body composition characteristics. Boys accumulate relative more fat on the upper body, while girls appear to gain fat tissue on upper and lower body at a similar pace. In general, gender differences in body composition especially in the body fat content are usually said to arise during adolescence, when the energetic demands of reproduction make additional fat deposits in females as energy stores necessary. Gender differences in body composition during prepubertal phase of life are considered to be slight[16] and boys and girls exhibit similar average weights and heights[17]. The application of dual energy X-rays absorptiometry (DEXA) resulted in more precise data and several papers have noted a lower body fat mass in boys than girls aged 9 to 10 years[18,19]. Furthermore it was shown, that even in children aged 3 to 8 years girls had significantly more absolute and relative fat mass than boys, while boys exhibited higher amounts of lean soft tissue mass (muscle) and bone mass than girls[20]. The results of these papers plead for marked gender differences in body composition long before reproductive function makes these differences necessary.

The aim of the present study was to analyze sex differences in body composition and sex differences in the prevalence of overweight in prepubertal children. Furthermore the impact of socioeconomic parameters on growth, weight status and body composition during prepubertal phase of life was tested.

## Materials and Methods

*Area of research*

This research took place in the central part of lower Austria in the south of the river Danube valley. Lower Austria belongs to the eastern Bundesländer of Austria and is a predominantly agricultural region. The administrative center is St. Pölten with 50 026 inhabitants and an altitude of 267m over sea level. Data collection was carried out in 4 primary schools in four different villages (Bischoffstetten, Kilb, Hürm, Kirnberg) in the west of St. Pölten in the political district Melk between April and June1998. The political district Melk is 80km in west the Austrian capital Vienna and a typical agricultural area of the low altitude part of Austria.

*Participants*

After the approval of the Lower Austrian supervisory school authority in St. Pölten, we contacted school directors and teachers of the primary schools and they sent letters to the parents of the children

to get their approval for the investigation too. 95% of the contacted parents gave their consent to the investigation. Therefore a sample of 398 children (213 girls, 185 boys), ages between 7 and 10, who attended public primary schools in one of the four villages mentioned above was cross sectionally measured. All children were white Europeans with German mother tongue. The sample represented 95% of the 7 to 10 year old children of the four villages under discussion.

*Somatometrics and nutritional status*

Stature was measured with a Martin anthropometer to the nearest millimeter according to the technique described by Knussmann[21]. Weight was recorded with a scale precise to 100g. The children wore only under wear. Weight status was determined using body mass index (BMI) $kg/m^2$. Although the BMI is increasingly used for the diagnosis of obesity, and underweight in childhood and adolescence, up to now there is a lack of European standards. In the present study we used according to the ASNS (Austrian Study of Nutritional Status)[22] the 85$^{th}$ percentile as cut-off between normal weight and obesity and the 10$^{th}$ percentile as cut-off between underweight and normal weight for 7, 8 9 and 10 year old children.

*Body composition*

Body composition was determined using a TBF 105 Body composition analyzer according to BIA-method. In this BIA system two foot-pad electrodes are incorporated into a precision electronic scale. Impedance of the lower extremities and body weight is measured simultaneously while the subject is standing on the scale. The electrodes are in contact with soles and heels of both feet. Biological impedance was measured with 4 terminals and uses a standard 50 kHz – 0.8 mA sine wave constant current. The voltage drop was compared with the heel electrodes. TBF 105 automatically measured weight and impedance. The computer software in the machine then used the measured resistance, the programmed subjects gender, group (child, adult or adult athlete), and stature height and the measured weight to calculate the body density based on previously derived equations obtained from regression analyses with underwater weighing. This was then applied automatically to the standard densiometric formula according to Brozek to calculate the fat percentage. The following variables were determined: Total fat percentage (fat %), absolute Fat mass (in kg) (FM), lean body mass (in kg) (LBM), total body water in kg (TBW). The coefficient of variation for within day impedance measurement was 0.9% and the between days coefficient of variations was 2.1% [23]. According to Nunez et al.[23] the leg- to-leg pressure contact electrode BIA system has overall performance characteristics for impedance measurement and body composition analysis similar to conventional arm-to-leg electrode BIA and offers the advantage of increased speed and ease of measurement. The BIA method using bipolar foot electrodes is described as useful and reliable technique for measuring body composition by several studies[23–26]. In the present study the method was especially useful because the body fat analyzer was easy to transport to the schools were the data collection took place and the children had only went up on the scale and the determination of body weight and body composition were performed simultaneously.

*Socioeconomic variables*

All children get an anonymous questionnaire which their parents had to fill in, few days before the investigation in the school took place. The questionnaire contained questions regarding educational level and profession of the parents, the age of the parents at child birth and

native language of the parents. The finished questionnaires were collected together with the somatometric and body composition data.

*Statistical analyses*

Statistical analyses were carried out using SPSS for Windows 7.0 (Microsoft corp.) After computing descriptive statistics (mean, standard deviation, median) z-scores of the somatometric and body composition variables were computed. Student t-tests were computed to test sexual dimorphism in somatometric and body composition variables. One-way ANOVA (Duncan post hoc tests) were used to assess mean differences in somatometric and body composition z-score by socioeconomic parameters. Cross-tabs (Chi-squares) were computed to test the interaction between sex, age, parental educational level, parental profession and weight status of the children.

## Results

*Socioeconomic characteristics*

The socioeconomic parameters are listed in Table 1. As to be expected in this rural area the majority of father and mothers had finished primary school (until their 14$^{th}$ year of life) only and started with professional training (up to 3 years) immediately after finishing school. Only few parents stayed at school until 18 years and reached high school degree. No parents reached a University degree. Although the research area is a typical agricultural region less than 20% of the fathers worked exclusively as farmers. Nevertheless more than 80% were so called »Nebenerwerbsbauern«. The majority of women (more than 50%) stayed at home as farmer or housewives.

*Weight status*

As to be seen in Figure 1 and 2 the body mass index of the majority (more than 70%) of girls and boys corresponded to the definitions of normal weight according to Zarfel and Elmadfa[22]. Nevertheless significant gender differences in weight status were observed (Chi-square = 4.75, $p < 0.05$). While more than 1% of the boys were classified as underweight only 0.5% of the girls corresponded to the definitions of underweight. In contrast, nearly 30% of the girls were overweight or obese but »only« 20% of the boys corresponded to the definitions of overweight.

*Gender differences in growth and body composition*

The comparison of stature, body weight and body mass index as indicator for weight status yielded no significant differences between girls and boys. As to be seen in Figure 3 stature which represents skeletal growths shows no gender differences up to 8 years and only small gender

**TABLE 1**
SOCIOECONOMIC PARAMETERS

| Socioeconomic variable | girls | boys |
|---|---|---|
| **Education of father** | | |
| Pflichtschule | 84.0% | 85.9% |
| Secondary school | 13.5% | 9.0% |
| High school degree | 2.5% | 5.1% |
| University degree | 0.0% | 0.0% |
| **Education of mother** | | |
| Pflichtschule | 81.9% | 79.2% |
| Secondary school | 15.2% | 14.0% |
| High school degree | 2.9% | 6.7% |
| University degree | 0.0% | 0.0% |
| **Profession of father** | | |
| Farmer | 14.9% | 20.3% |
| Worker | 38.8% | 39.0% |
| Employee | 36.3% | 31.6% |
| Employer | 10.0% | 9.0% |
| **Profession of mother** | | |
| Farmer (Housewife) | 56.4% | 57.8% |
| Worker | 10.8% | 11.1% |
| Employee | 30.9% | 27.2% |
| Employer | 2.0% | 3.9% |

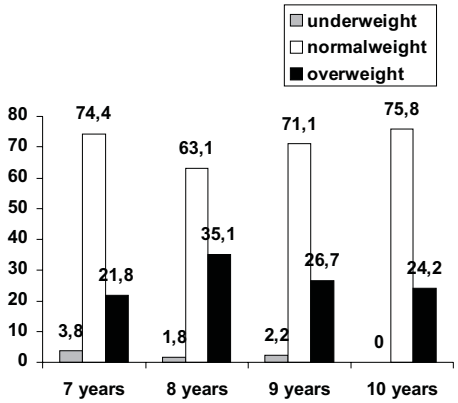


*Fig. 1. Weight status in girls by age.*

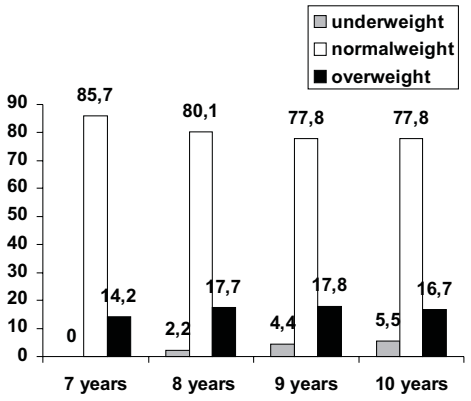


*Fig. 2. Weight status in boys by age.*

differences between 8 and 10 years. Body weight increased nearly identical in boys and girls between 7 and 10 years. In contrast, the body mass index in 8 to 10 year old girls was higher, however insignificantly higher, than in boys. Although the gender differences in stature, weight and BMI were insignificant, marked differences occurred in body composition. Girls surpassed boys in absolute and relative fat mass in all age categories, while boys exhibited significant higher values in lean body mass and total body water in each age class (see Table 2, Figures 3–8).

**TABLE 2**
MEAN VALUES (STANDARD DEVIATIONS) OF STATURE, WEIGHT, ABSOLUTE FAT MASS, FAT PERCENTAGE, LEAN BODY MASS, TOTAL BODY WATER AND BMI FOR GIRLS AND BOYS SEPARATELY BY AGE

| Age (years) | N | Stature | Weight | FM (kg) | Fat% | LBM | TBW | BMI |
|---|---|---|---|---|---|---|---|---|
| | | | | **Girls** | | | | |
| 7 | 78 | 125.0 (5.6) | 25.3 (4.6) | 5.7** (2.5) | 21.7** (5.3) | 19.6** (2.4) | 14.3** (1.8) | 16.2 (2.4) |
| 8 | 57 | 132.2 (5.4) | 29.7 (5.7) | 7.4** (3.2) | 23.9** (5.8) | 22.4** (2.8) | 16.4** (2.1) | 16.9 (2.9) |
| 9 | 45 | 134.5 (6.1) | 31.7 (7.1) | 8.4** (4.2) | 25.1** (6.8) | 23.4** (3.3) | 17.1** (2.4) | 17.4 (2.9) |
| 10 | 33 | 142.2 (6.8) | 36.5 (9.1) | 9.3* (4.4) | 24.4** (5.1) | 26.9* (5.1) | 19.7* (3.8) | 17.9 (3.2) |
| | | | | **Boys** | | | | |
| 7 | 56 | 125.4 (5.4) | 26.1 (6.4) | 3.9** (2.9) | 14.2** (5.9) | 22.2** (4.2) | 16.2** (3.1) | 16.5 (3.0) |
| 8 | 45 | 132.2 (7.4) | 29.3 (5.8) | 4.9** (2.5) | 15.8** (5.0) | 24.5** (3.6) | 17.9** (2.6) | 16.6 (1.9) |
| 9 | 45 | 136.6 (6.2) | 31.3 (6.4) | 5.5** (3.9) | 16.4** (6.8) | 25.9** (3.1) | 19.0** (2.3) | 16.7 (2.8) |
| 10 | 36 | 143.3 (6.4) | 36.5 (7.4) | 6.8* (3.7) | 17.6** (5.9) | 29.7* (4.3) | 21.7* (3.1) | 17.6 (2.6) |

FM = fat mass (kg); LBM = lean body mass (kg); TBW = total body water;
BMI = body mass index (kg/m$^2$).

* boys' and girls' values differ by < 0.01;
** boys' and girls' values differ by < 0.001.

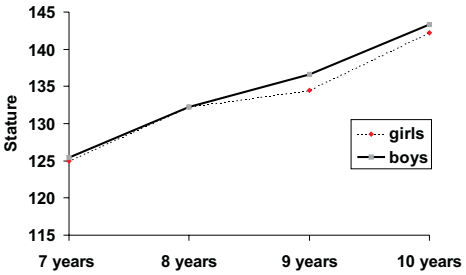


*Fig. 3. Stature: cross-sectional.*

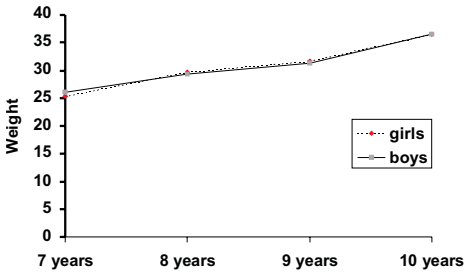


*Fig. 4. Weight: cross-sectional.*

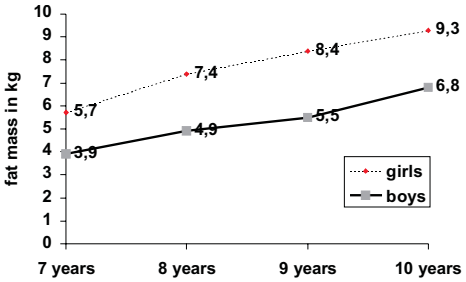


*Fig. 5. Fat mass (in kg): cross-sectional.*

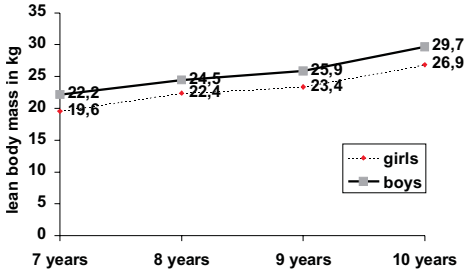


*Fig. 6. Lean body mass (in kg): cross-sectional.*

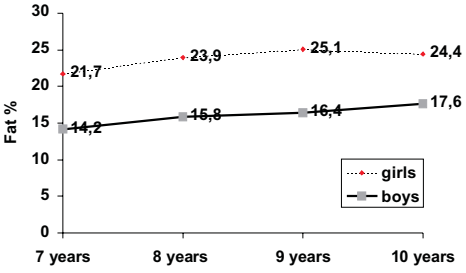


*Fig. 7. Fat (%): cross-sectional.*

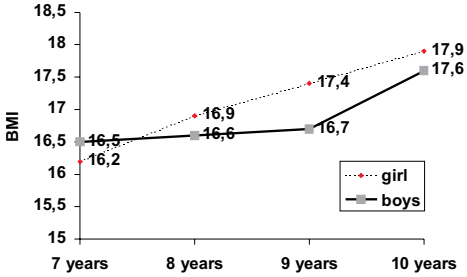


*Fig. 8. BMI: cross-sectional.*

*Socioeconomic factors and growth*

Only few significant interactions between socioeconomic variables and skeletal growth were found. With increasing educational level of the mother stature of the offspring increased significantly ($p < 0.05$). No significant associations were found between fathers educational level, fathers or mothers profession and children stature (see Table 3).

*Socioeconomic factors and body composition*

A statistically significant association between socioeconomic parameters and body composition variables or weight status occurred between lean body mass and mothers education and body mass index and fathers profession only. With increasing educational level of the mother lean body mass increased significantly ($p < 0.03$).

**TABLE 3**
SOCIOECONOMIC PARAMETERS AND ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES

| | N | Stature | Weight | BMI | Fat % | FM | LBM |
|---|---|---|---|---|---|---|---|
| | | | | **Father's education** | | | |
| < High school | 320 | 0.02 (1.01) | 0.02 (1.01) | 0.03 (1.01) | 0.01 (1.00) | 0.01 (1.01) | 0.02 (1.02) |
| High school | 43 | –0.02 (0.88) | –0.15 (0.74) | –0.19 (0.80) | –0.04 (0.92) | –0.12 (0.79) | –0.14 (0.79) |
| Post secondary | 14 | –0.15 (1.10) | –0.83 (1.46) | –0.11 (1.40) | –0.33 (1.39) | –0.07 (1.63) | 0.07 (1.18) |
| F-value | | 0.16 n.s. | 0.59 n.s. | 0.96 n.s. | 0.77 n.s. | 0.37 n.s. | 0.46 n.s. |
| | | | | **Mother's education** | | | |
| < High school | 308 | –0.02 (0.99)* | –0.03 (1.00) | –0.03 (0.99) | –0.01 (1.00) | –0.01 (1.01) | –0.03 (0.99)* |
| High school | 56 | –0.10 (1.00)* | –0.01 (0.91) | 0.13 (1.10) | 0.05 (1.11) | 0.02 (1.01) | –0.06 (0.92) |
| Post secondary | 18 | 0.52 (1.14)* | 0.43 (1.36) | 0.14 (1.09) | –0.09 (0.89) | 0.15 (1.17) | 0.58 (1.33)* |
| F-value | | 2.95 $p < 0.05$ | 1.77 n.s | 0.82 n.s. | 0.16 n.s. | 0.25 n.s. | 3.31 $p < 0.03$ |
| | | | | **Father's profession** | | | |
| Farmer | 66 | –0.09 (0.93) | 0.08 (1.05) | 0.20 (1.20)* | 0.07 (1.08) | 0.09 (1.11) | 0.05 (1.04) |
| Worker | 147 | –0.03 (1.05) | –0.03 (1.06) | –0.06 (0.96) | –0.06 (0.98) | –0.04 (1.01) | –0.02 (1.03) |
| Employee | 129 | 0.02 (1.01) | –0.08 (0.89) | –0.12 (0.79)* | –0.07 (0.88) | –0.09 (0.81) | –0.05 (0.95) |
| Employer | 36 | 0.12 (0.92) | 0.19 (1.10) | 0.19 (1.21) | 0.22 (1.21) | 0.25 (1.28) | 0.12 (1.01) |
| F-value | | 0.39 n.s | 0.88 n.s. | 2.82 $p < 0.05$ | 1.39 n.s. | 1.41 n.s | 0.32 n.s |
| | | | | **Mother's profession** | | | |
| Farmer/ Housewife | 219 | –0.09 (1.01) | –0.04 (1.08) | 0.01 (1.06) | –0.04 (1.01) | –0.02 (1.07) | –0.05 (1.03) |
| Worker | 42 | –0.04 (1.09) | –0.06 (0.95) | –0.09 (0.79) | 0.01 (0.86) | –0.06 (0.81) | –0.04 (1.06) |
| Employee | 112 | 0.13 (0.97) | 0.04 (0.91) | –0.04 (0.91) | 0.01 (0.97) | –0.01 (0.89) | 0.07 (0.99) |
| Employer | 11 | 0.21 (0.59) | 0.47 (0.94) | 0.63 (1.48) | 0.54 (1.52) | 0.61 (1.54) | 0.31 (0.51) |
| F-value | | 1.34 n.s. | 1.01 n.s | 1.57 n.s | 1.15 n.s. | 1.41 n.s. | 0.65 n.s. |

Regarding the profession of the father children of farmers showed the highest weight status, while the offspring of employees exhibited the lowest weight status ($p < 0.05$) (see Table 3). No significant associations were found between socioeconomic parameters and absolute and relative fat mass and body weight.

## Discussion

Body composition reflects nutritional status and weight status to some extent and is influenced by age, sex, ethnicity, physical activity and disease[27,28]. From childhood through adolescence to adulthood body composition changes and the degree of this change is sex dependent[29]. Sexual dimorphism in body composition is evident from adolescence onward throughout adult life and is explained proximate by quantitative gender differences in sex hormone production[30] and ultimate by mechanisms of sexual selection (male-male competition) and natural selection (energetic requirements for successful reproduction). During adolescence boys show a greater increase in lean body mass than girls, who conversely have a greater increase in absolute and relative fat mass[16,29,31]. The accumulation of additional fat deposits in females during adolescence reflects the enormous energetic demands of reproduction in females[32]. Fat deposits should be accumulated during puberty or short before and therefore gender differences in body composition should be observable not later than at this stage of development. For a long time prepubertally sexual dimorphisms in body composition was considered to be slight only[16], although at birth there are appreciable sex differences in the thickness of subcutaneous fat tissue and in

overall body mass[33]. According to McGowan et al.[33] female babies showed a higher subcutaneous fat mass at five different sites, while boys are on the average 200g heavier than girls at birth. During infancy, childhood and juvenile phase the energetic requirements of boys and girls are more or less equal, they differ not in height and weight. Sex differences in body composition were discussed as relevant not before puberty onset. Nevertheless an increasing number of papers describes gender differences in body composition during early childhood and juvenile phase[18–20,34–36]. The authors of all these papers described a significant higher amount of body fat in girls than in boys and an increased fat free tissue mass in boys even at ages between 3 an 10 years. The results of the present paper are in accordance with those observations mentioned above. Even long before puberty onset, girls exhibited a higher amount of absolute and relative fat mass, a lower amount of lean body mass although boys and girls did not differ significantly in stature, weight and body mass index. In this way the hypothesis that sex differences in body composition are observable long before the onset of puberty is corroborated by the results of the present study.

Regarding sex differences in weight status categories, we found a significantly higher percentage of overweight or obesity in girls than boys in our sample: Although boys and girls did not differ significantly in stature, weight and body mass index, 29.1% of the girls could be classified as overweight following the weight status definitions of the ASNS[22], while this was true of 20% of the boys only. Our results were in accordance with the findings of Cameron and Getz[37], who reported an increased prevalence of obesity in African adolescent females and with the findings of Neutzling et al.[38] who described a twice as high prevalence of obesity within females than within males in a Brazilian sample. On the other hand our results were in marked contrast to the findings of Rolland-Cachera et al.[39], and Mast et al.[35], who described higher body weights and body mass indices in boys. Even the Austrian survey of nutritional status[22] yielded a higher prevalence of overweight in body than in girls during childhood and adolescence. Furthermore we have to state another unexpected observation: We found no significant differences in stature between the two sexes. Boys showed only a slightly higher stature than girls even in the age class 9 and 10 years, and this result is rather unexpectable: Until about 9 to 10 years boys and girls are very close in height, with boys being very slightly taller and heavier. Growth velocity is nearly identical in girls and boys until the onset of the adolescent growth spurt[40,41]. The earlier onset of puberty in girls leads to an acceleration of height at 9 or 10 years and so to higher statures in girls at this age. Our results with a slightly increased stature even in 10 year old boys is therefore in contrast to the descriptions of Preece[40] and Bogin[41]. The slightly higher stature and the significantly lower amount of body fat observed in boys is also in contrast to the findings of Himes and Roche[42], who reported that obese children are of above average stature and that stature is positively correlated with the amount of subcutaneous fat tissue during prepuberty. These unexpected results, which are not in accordance with previous studies, especially with the results of the Austrian survey of nutritional status[22] demonstrates the limitations of possible interpretations of the results of this study. We have to be aware that we only analyzed a relatively small sample from a small rural area of Austria and the results are therefore not representative for Austria in general.

**Acknowledgements**

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## SPOLNI DIMORFIZAM U GRAĐI TIJELA, TJELESNOJ MASI I VISINI U ŠKOLSKE DJECE PRETPUBERTETSKE DOBI IZ RURALNIH PODRUČJA ISTOČNE AUSTRIJE

### S A Ž E T A K

Spolni dimorfizam u visini tijela, tjelesnoj masi te građi tijela analiziran je na uzorku od 398 pretpubertetske djece (213 djevojčica, 185 dječaka) stare od 7 do 10 godina. Prevalencija pretilosti među djecom ovog uzrasta također je testirana. Parametri građe tijela određeni su korištenjem TBF analizatora tjelesne građe prema BIA metodi. Opažene su visoko značajne razlike u tjelesnoj građi ($p < 0.001$) između dječaka i djevojčica. Nasuprot tome, visina tijela, tjelesna masa i BMI nisu pokazali značajne razlike među spolovima. Značajno ($p < 0.05$) veći postotak djevojčica (29%) u odnosu na dječake (20%) pripada kategoriji pretilih, prema definiciji pretilosti ASNS-e (Austrian Survey of Nutritional Status). Rezultati ove studije pokazali su ne samo značajnu spolnu razliku u građi tijela (posebice u količini masnog tkiva) znatno prije početka puberteta, već i značajno višu prevalenciju pretilosti u pretpubertetskih djevojčica u odnosu na dječake.