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Anthropometric and Cardiopulmonary Parameters in Bulgarian and Romany Children: Cross-sectional Study

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Aim To examine anthropometric parameters and cardiopulmonary function in Bulgarian and Romany children.

Methods Two hundred and ten healthy children (153 Bulgarian and 57 Romany) of similar age (10.5 ± 0.5 years, mean ± standard deviation) underwent an anthropometric and pulmonary function assessment and performed an exercise test on a treadmill, using the modified Balke protocol.

Results Bulgarian children were significantly taller (145 ± 7 vs 142 ± 7 cm) and heavier (39 ± 9 vs 35 ± 8 kg) than Romany children. They also had more body fat (20.5 ± 8.1% vs 17.8 ± 7.6% in Romanies). In a subset of the whole sample, it was established that Bulgarian children had significantly higher birth weight in comparison with Romanies (3,358 ± 513 vs 3,095 ± 435 g; $P = 0.006$). Mean absolute values of vital capacity (VC), forced expiratory volume in 1 s (FEV_1) and transfer factor ($T_{L,CO}$) were lower for Romany than for Bulgarian children, 7.8%, 7.3%, and 10.2%, respectively. The data from the incremental treadmill test showed that peak oxygen uptake (VO_2 peak) did not differ significantly between the two ethnic groups (1,341 ± 293 vs 1,260 ± 280 mL/min). The level of physical exertion was almost the same in the studied groups (respiratory exchange ratio (RER) = 1.08 ± 0.08 vs 1.08 ± 0.06), but the perception of exertion was higher in Bulgarian children (Borg score = 4.9 ± 1.5 vs 3.2 ± 1.5; $P < 0.001$).

Conclusions There are significant differences between Bulgarian and Romany children with regard to anthropometric parameters, including stature, lung function indices, and perception of exertion.

Romanies constitute a substantial part of the population of a number of European countries, especially in the Balkan and Carpathian regions. Over 5 million Roma people live in Central and Eastern Europe (1). This minority usually has bad health status which has not been sufficiently elucidated (2). There is a need for further research into the health of Roma people, with particular emphasis on developmental issues. Such research must be handled with sensitivity, recognizing the social and political context of the societies concerned (3).

Although much research now exists on some groups, such as Asians and African-Americans, the health of many other groups have received little attention. In this sense, the Roma people are only one among several neglected communities, although their situation is particularly difficult (4).

Research showed that ethnic differences are an important determinant of cardiopulmonary function (5-8). Applying adequate reference values is essential for the correct interpretation of the data from functional tests. Deriving an appropriate reference equation requires inclusion of anthropometric parameters and age (9,10). This problem is of considerable significance in the pediatric age group because of the great dynamics in anthropometric characteristics and the corresponding functional parameters (9).

To the best of our knowledge, the functional profile of Romany children has not been a subject of detailed research, which is surprising when considering their vast spatial dissemination. As a result, there is insufficient information regarding the ethnic differences in anthropometric and cardiopulmonary parameters in Romany children.

Subjects and Methods

Subjects and Design

Two hundred and ten healthy children – 153 Bulgarian (75 boys and 78 girls) and 57 Romany (28 boys and 29 girls) of comparable age (mean ± standard deviation 10.5 ± 0.5 years; range 10-11) took part in the study.

All of the children were pupils of the 4th and 5th grade from a primary school in Plovdiv, South Bulgaria. A total of 250 leaflets of invitation to the trial were distributed among all the pupils from 4th and 5th grade, and we received 217 (85.2%) of them back. Two hundred and ten children completed the study successfully and were taken into account in the statistical processing of the data. The Bulgarian/Romany ratio in the studied group was 3/1 and reflects the real distribution of the two ethnic groups in the respective school (total of 814 pupils – 251 Romany and 563 Bulgarian). The children were in good health, without chronic diseases, taking no medications that might affect exercise capacity. They were generally physically active, but not engaged in regular sports activities. Prior to the test procedures, written informed consent was obtained from a parent or guardian and the associated risks and benefits were explained. The procedures used in this study were approved by the Institutional Ethics Committee of the Plovdiv Medical University.

Anthropometric Measurements

All participants were subjected to complete anthropometric measurements, including skinfolds. The skinfold thicknesses measured by caliper (Harpenden, British Indicators Inc, London, UK) over the triceps and subscapular regions were added together to give the sum of skinfolds and percent body fat (FAT%) was calculated using Slaughter equations (11). The values of body surface area (BSA) were obtained by the method of Gehan and Georges (12) $BSA = 0.02350 \times Ht^{0.42246} \times Wt^{0.51456}$ (m^2), where Ht is height in cm and Wt is weight in kg. Dimensions of the thorax were assessed through the measurements of chest circumference at full inspiration (CCI) corresponding to total lung capacity (TLC), as well as the measurements of chest circumference at full expiration (CCE), corresponding to residual volume (RV). For stratifying children according to their body mass index (BMI), we used the cut off points published by Cole et al based on BMI centiles for subjects aged 2-18 years (13).

Pulmonary Functional Parameters

Pulmonary function testing was carried out with a diagnostic system MasterScreen Diffusion™ (E. Jaeger, Würzburg, Germany) in a seated position, with a nose clip. We performed spirometry, measurement of diffusion capacity, forced expiration, maximal inspiratory and expiratory pressures.

The equipment was suited for pediatric measurements, ie the chair, mouthpiece, and the whole setting was accommodated to fit children's proportions. Regular calibration was done with a 3 liter calibration syringe.

Forced expiratory maneuvers complied with the general acceptability criteria (14,15). At least three technically acceptable attempts of maximal forced expiratory flow-volume curves were recorded. Spirometric reference values for European children (16), previously validated for Bulgarian population (17), were used.

For the diffusion capacity (transfer factor – $T_{L,CO}$) the mean of two single-breath measurements was used. One hundred seventy one children (127 Bulgarian and 44 Romany) met all the acceptability criteria for the performance of diffusion capacity test. $T_{L,CO}$ and transfer coefficient ($T_{L,CO}/V_A$) values were given unadjusted for hemoglobin (Hb). For the transfer factor, we used reference values developed by us (yet unpublished) on 570 healthy children aged 7-18 years.

The best from at least three measurements for maximal inspiratory (at RV) and expiratory (at TLC) mouth pressure (PI_{max} and PE_{max}) was used for the final calculation.

Cardiopulmonary Exercise Parameters

The treadmill test was performed in a laboratory compliant with the guidelines of the AHA (18). The children were habituated to both the general environment and the actual procedures. The cardiopulmonary exercise test was carried out on a motor driven, electronically controlled treadmill (TrackMaster™, JAS Fitness Systems, Pensacola, FL, USA) using our modification of the Balke protocol (19), which involved two warm up stages on the level at 2.7 and 4.0 km/h, respectively, and nine one-minute increments with constant velocity of 5.4 km/h, starting from 6% elevation and increasing with 2% every minute until exhaustion or elevation of 22%. Recovery period had standard three minutes duration (2.7 km/h and zero elevation).

Throughout the test, gas exchange variables were determined with an on-line computerized system CardiO$_2$™ (Medical Graphics, St Paul, MN, USA) using standard open circuit techniques. Data were averaged every 30 s and used to calculate oxygen uptake (VO_2; mL/min, standard temperature pressure dry, STPD), and carbon dioxide output (VCO_2; mL/min, STPD and respiratory exchange ratio, RER). The system was calibrated before each test with gases of known concentrations. Heart rate was monitored electrocardiographically (Hellige, Freiburg, Germany) and the oxygen saturation was traced with pulseoxymeter Pulseox DP-8 (Minolta, Osaka, Japan).

Anaerobic threshold (AT) was determined as the level of VO_2 at which at least one of the following was present: 1) increase in ventilatory equivalents for oxygen (V_E/VO_2) without simultaneous increase in ventilatory equivalents for carbon dioxide (V_E/VCO_2); and 2) disappearance of the linear relation between VCO_2 and VO_2 (V-slope method).

Other Measurements

At the end of each exercise increment and throughout the recovery period the children were asked to rate the perceived exertion using the Borg Category-Ratio Scale (20) depicting fatigue (dyspnea) from "not at all" to "maximal" by means of ten grades.

For clarifying children's health and social status, the parents were asked to fill out a questionnaire on child's birth weight and gestational age (estimated by the calendar method), disease history since birth, the presence of symptoms and complaints for the last 12 months, rate of physical activity, presence of pets at home, domestic hygienic conditions, type of domestic heating, smoking at home, family social status, and number of children in the family.

Statistical Methods

All values were expressed as mean ± standard deviation. The distribution of quantitative variables was tested by the Kolmogorov-Smirnov test. The following statistical analyses were performed: descriptive statistics, Mann-Whitney or Student *t* test where appropriate, χ^2 test, Fisher exact test, correlation analysis, and stepwise regression analysis. All analyses were performed using the Statistical Package for Social Sciences Package for Windows, version 10.05 (SPSS Inc., Chicago, IL, USA). A level of $P<0.05$ was considered to be statistically significant.

Results

The anthropometric measurements in Bulgarian and Romany children showed that Bulgarian children were significantly taller and heavier in comparison with Romany children (Table 1).

They also differed significantly with regard to the amount of fat. The overweight children constituted 22.2% of the Bulgarian group (7.8% with obesity) whereas there were 14.0% (1.8% with obesity) in the group of Romany children ($P=0.516$). Significant differences existed only in the measured chest circumference at full inspiration.

The main pulmonary function parameters are presented in Table 2. The mean absolute

Table 1. Anthropometric parameters (mean±standard deviation) in Bulgarian and Romany children, Bulgaria 2004

Parameters	Bulgarian children	Romany children	Z value*	*P*
Age (years)	10.5±0.5	10.5±0.5	-0.13	0.898
Height (cm)	145.1±6.7	141.8±6.6	-3.02	0.003
Weight (kg)	38.7±9.2	35.2±7.8	-2.80	0.005
Body mass index (kg/m^2)	18.2±3.3	17.4±2.8	-1.55	0.122
Body surface area (m^2)	1.26±0.17	1.18±0.14	-3.04	0.002
Fat (%)	20.5±8.1	17.8±7.6	-2.32	0.020
Chest circumference at full inspiration (cm)	73.4±6.1	71.9±6.2	-2.09	0.036
Chest circumference at full expiration (cm)	68.1±6.8	67.1±6.1	-0.929	0.353

*Mann-Whitney *U* test.

Table 2. Pulmonary function parameters (mean±standard deviation) in Bulgarian (n=127) and Romany (n=44) children, Bulgaria 2004

Parameter*	Bulgarian children	Romany children	Z† value	P
VC (mL) (% predicted)	2,598±378 (99.2±10.3)	2,396±372 (97.3±11.0)		
FEV_1 (mL) (% predicted)	2,290±334 (106.3±12.1)	2,123±338 (105.0±11.3)	-3.30 (-0.65)	0.001 (0.514)
FEV_1/VC (%)	88.3±5.8	88.8±5.8	-0.62	0.534
PI_{max} (cm H_2O)	86±20	81±18	-1.82	0.069
PE_{max} (cm H_2O)	114±24	110±21	-0.93	0.354
$T_{L,CO}$† (mmol×min^{-1}×kPa^{-1}) (% predicted)	5.75±1.0 (96.7±12.7)	5.16±0.96 (92.4±11.0)	-3.78 (-2.65)	<0.001 (0.008)
$T_{L,CO}$/VA (mmol×min^{-1}×kPa^{-1}×L^{-1})	1.69±0.20	1.68±0.22	-0.07	0.946

*Abbreviations: VC – vital capacity; FEV_1 – forced expiratory volume in 1 s; PI_{max} – maximal inspiratory pressure; $T_{L,CO}$ – carbon monoxide diffusion capacity (transfer factor); $T_{L,CO}/V_A$ – transfer coefficient.
†Mann-Whitney *U* test.

Table 3. Cardiopulmonary parameters (mean±standard deviatiion) in Bulgarian (n=127) and Romany children (n=44), Bulgaria 2004

Parameter*	Bulgarian children	Romany children	Z value†	P
V_T (mL)	940±213	889±201	-1.71	0.087
Breathing frequency (min^{-1})	45.5±9.2	46.0±8.3	-0.56	0.575
V_E (L/min)	42.0±10.2	40.3±9.8	-1.19	0.235
VO_2 peak (mL/min)	1341±293	1260±280	-1.92	0.054
VO_2/kg (mL×kg^{-1}×min^{-1})	34.9±3.7	36.1±5.2	-1.00	0.319
VO_2/BSA (mL×min^{-1}×m^{-2})	1059±124	1059±150	-0.38	0.705
VO_2/HR (mL×min^{-1}×$beat^{-1}$)	7.5±1.7	7.6±1.7	-0.20	0.843
Heart rate (beat/min)	179±9	167±12	-6.06	<0.001
Respiratory exchange ratio	1.08±0.08	1.08±0.04	-0.42	0.674
V_E/VCO_2 AT	29.0±2.1	29.7±1.8	-1.39	0.211
Borg score	4.9±1.5	3.2±1.3	-6.43	<0.001

*Abbreviations: V_T – tidal volume; V_E – minute ventilation; VO_2 peak – peak oxygen uptake; BSA – body surface area; VO_2/HR – oxygen pulse; V_E/VO_2 – ventilatory equivalent for oxygen; V_E/VCO_2 – ventilatory equivalent for carbon dioxide; AT – anaerobic threshold.
†Mann-Whitney *U* test.

values for vital capacity (VC), forced expiratory volume in 1 s (FEV_1), and $T_{L,CO}$ were respectively 7.8%, 7.3%, and 10.2% lower in Romany children compared with Bulgarian. No differences were detected with regard to PI_{max} and PE_{max}. There were no differences between Bulgarian and Romany children concerning the volume-standardized parameters – forced expiratory volume in 1 s/vital capacity (FEV_1/VC %) and $T_{L,CO}/V_A$. With the exception of $T_{L,CO}$ there were not significant differences in percent predicted values.

The results from the cardiopulmonary exercise test in the studied groups are presented in Table 3. There were no significant differences between the two ethnic groups regarding ventilatory variables (tidal volume (V_T), breathing frequency (BF), and minute ventilation (V_E)), V_E/VO_2, equivalents for carbon dioxide at anaerobic threshold (V_E/VCO_2AT), VO_2 at peak exercise (VO_2peak), as well as in its "normalized" derivatives (oxygen uptake per kg (VO_2/kg), oxygen uptake/body surface area (VO_2/BSA) and oxygen pulse (VO_2/HR)). It is worthy to note the significantly higher heart rate in Bulgarian children. The level of physical exertion is almost the same in the studied groups (comparable RER) but the perception of exertion was significantly higher in Bulgarian children as seen from the Borg score.

Only two Romany children (3.5%) did not complete the test whereas 12 (7.8%) Bulgarians discontinued the standardized protocol prematurely ($P = 0.423$). Eleven of these children appeared to be overweight or obese according to the cut off values of Cole et al (13). Children who did not complete the test (n = 14) had significantly higher Borg score compared to the rest of the subjects (7.5 ± 0.7 vs 4.2 ± 1.5; $P < 0.001$).

Significant gender differences were established simultaneously in two ethnic groups with regard to the following parameters: V_E/VO_2 and V_E/VCO_2AT (higher in girls), PI_{max} and PE_{max} (higher in boys), and FAT% (higher in girls). Romany boys had significantly higher values for VO_2 peak and its derivatives (VO_2/kg, VO_2/HR), whereas for Bulgarians had significantly higher lung function parameters (VC, FEV_1 and $T_{L,CO}$).

A box-plot of birth weight of 83 Bulgarian (45 boys/38 girls) and 41 Romany (20 boys/21 girls) children from the whole group is presented in Figure 1. We took into consideration only those infants delivered in term whose birth weight and gestational age were known. Bulgarian children had significantly higher birth weight in comparison with Romanies (3,358 ± 513 vs 3,095 ± 435 g; $P = 0.006$). The children's birth weight correlated

Table 4. Determinants of the main studied parameters and equations characteristics*

Variable	Predictors	β-coefficient	SE	t	P	Model characteristics F, significance
Vital capacity	constant	-3.159	0.469	-6.74	<0.001	88.0, <0.001
	height	0.041	0.003	12.79	<0.001	
	gender	-0.160	0.045	-3.54	0.001	
FEV_1	constant	-2.613	0.362	7.21	<0.001	99.2, <0.001
	height	0.034	0.002	-13.89	<0.001	
	gender	-0.076	0.034	-2.25	0.026	
$T_{L,CO}$	constant	-7.103	2.067	-3.44	0.001	35.7, <0.001
	height	0.094	0.014	6.68	<0.001	
	parents' smoking	-0.737	0.172	-4.28	<0.001	
VO_2peak	constant	260.422	44.049	5.91	<0.001	609.8, <0.001
	weight	28.033	1.135	24.70	<0.001	

*Abbreviations: SE – standard error of β-coefficient; FEV_1 – forced expiratory volume in 1 s; $T_{L,CO}$ – carbon monoxide diffusion capacity (transfer factor).

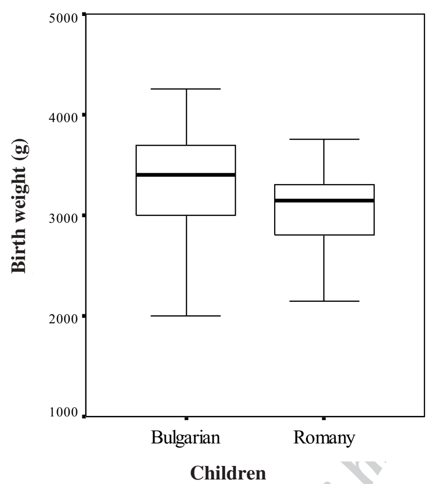

Figure 1. Box-plot of birthweight of Bulgarian and Romany newborns. The box represents the interquartile range which contains the 50% of values. The whiskers are bars that extend from the box to the highest and lowest values, excluding outliers. The line across the box indicates the median.

significantly and positively with VC (r=0.299; P=0.001), FEV_1 (r=0.229; P=0.010), $T_{L,CO}$ (r=0.375; P<0.001), VO_2 peak (r=0.280; P=0.012), as well as with the main anthropometric parameters – height (r=0.379; P<0.001), weight (r=0.298; P=0.001), BSA (r=0.333; P<0.001), and CCI (r=0.263; P=0.003). However, following application of stepwise regression analysis it became apparent that despite these significant correlations, birth weight was not a determinant of any of the main cardiopulmonary parameters (Table 4). Table 4 represents the determinants of the main studied parameters and equation characteristics.

It is clearly seen from Table 4 that height and gender are the main determinants of children's lung function indices. Body weight, but not height, was identified as a main determinant of peak exercise oxygen uptake (VO_2 peak). According to this analysis, parents' smoking has a significant effect on the transfer factor. It is worthy to note the absence of ethnic belonging as a determinant in these equations.

We found a higher prevalence of indoor smoking by parents of Romanies in comparison with Bulgarians (59.6% vs 17.6%, respectively; P<0.001). Another important environmental concern is the use of fossil fuels for heating without adequate ventilation in the majority of Romany homes (64.9% vs 23.5% in Bulgarian; P<0.001).

Discussion

This study showed that there were significant differences between Bulgarian and Romany children with regard to anthropometric parameters, including birth weight, lung function indices, and perception of exertion. The children's birth weight correlated significantly with main anthropometric and cardiopulmonary parameters, but it was not a determinant of the latter.

The limitations of our study were that we did not measure some specific anthropometric variables, such as sitting height and all thoracic dimensions, and we cannot comment on different body proportions, such as trunk/leg length ratio. Yet, according to Cotes (9), this ratio is similar in Caucasians and Indian subjects.

Another limitation of this trial was that the investigation was cross-sectional and covered only a narrow age interval. Despite the imperfections of the study, the results convincingly indicated that stated differences between Bulgarian and Romany children really existed and were not a mere result of differences in body proportions.

According to Crapo et al (7), the best way to document ethnic differences is to confront the functional parameters obtained in the frame of one trial performed by means of standardized methods and design, applied by one and the same team of researchers to the different ethnic groups. Our study was fully compliant with these recommendations and the children were of the same age, so we assume that stated differences really exist. The core of the problem is that, besides genetic factors, some other factors, such as environmental and economic factors could significantly contribute to these differences, and it is difficult to weigh precisely the impact of each of them.

Data in the literature prove that racial variations determining genetic differences in anthropometric characteristics lead to significant differences in lung functional parameters (9,21). Significantly lower values of anthropometric and lung function parameters, found in the Romany children, coincide with the findings of lower values of the same parameters in the North Indian population which is the origin of the Romanies, compared with the white population (2). Yang et al (22) found that the values of lung function parameters for Caucasians are higher than those for Chinese and Indian populations of all ages and heights. Gourgoulianis et al (23) found the lower values of lung function parameters in Gypsies aged 14-70 years in Greece. Having in mind these facts, we have to assume that lower anthropometric and absolute spirometric values of Romany children did not result from some kind of physical retardation but represented at least partially genetically determined lower anthropometric characteristics, among which are stature and body mass.

The results of this study and the data in the literature (22,23) suggest that specific reference values should be used for lung function parameters of Romany population. The general reference values for spirometric measurements in Caucasians can be used for Romany children in case they are built solely on anthropometric variables and not age. The lack of differences in percent predicted spirometric values suggests that standing height is a proxy for lung dimensions in this very narrow age interval (10-11 years). Still, there is general agreement that parameters of lung growth during childhood and adolescence are not determined only by height. Theoretically, not only height and age, but also stages of pubertal development should be included in the predictions to improve the quality of pediatric pulmonary reference equations (24).

Despite the genetic factors determining stature and body mass, another reason for lower anthropometric parameters in Romany population can be undernourishment determined by their poor economic status, low educational level, and unsettled lifestyle (23). We found that 4 of the Romanies (7%) had BMI values below the 90th centile according to Cole et al (13), being underweight and presumably inadequately nourished (25). In addition, the percentage of fat in Romany children was significantly lower in comparison with Bulgarians.

Harik-Khan et al (26) point out that factors probably accounting for the racial or ethnic difference may be prenatal or childhood factors such as low birth weight, maternal smoking during pregnancy, allergy, indoor air pollution, and exposure to environmental toxins. The majority of these factors are also found in Romanies.

Based on the questionnaire data obtained by the participants, we can indicate the poorer housing and the use of fossil fuels for heating without adequate ventilation in the majority of Romanies' homes. There was also a higher prevalence of indoor smoking by their parents. In another study we found that more Romany women continued to smoke during pregnancy, compared with Bulgarian women (27). The Romany children in our sample were born by very young mothers (mean age 19.5 ± 3.1 years) which is a consistent sign of social immaturity. Higher degree of indoor air pollution, including exposure to tobacco smoke, in Romanies' homes may at least partially explain significantly lower values (absolute and percent predicted) of their diffusion capacity.

Our results also showed that Romany mothers gave birth to babies with lower birth weight in comparison with Bulgarian mothers. There is a consensus about Romany babies being consistently smaller, although the data on this problem are scarce (28,29). On the other hand, there is a lot of conflicting evidence about the impact of birth weight on health status and lung function parameters (30). We found that birth weight correlated significantly with anthropometric characteristics and some cardiopulmonary parameters, which corresponds to the findings of Rona et al (31).

It is difficult to interpret the significant difference in perceived exertion between the two groups because of a lack of similar data in the literature. A possible explanation is that Romany children who live in harder socioeconomic conditions had higher tolerance towards physical exertion and stress. Ethnic differences are described with regard to the perception of angina pectoris during exercise (32) and perception of dyspnea evoked by bronchial challenge tests (33) but in trials including only adult population.

In line with Cotes (9), who considered exercise parameters as independent of ethnic group, we found that VO_2 peak and its standardized indices VO_2/kg and VO_2/BSA did not differ between Romany and Bulgarian children. Trowbridge et al (34) found that there were no ethnic differences only with regard to resting and submaximal VO_2, and they are apparent for VO_2 peak. The finding that 96.5% of the Romany children completed the standardized test (vs 92.2% in Bulgarian), their significantly lower score of perception to exercise, and especially significantly lower heart rate, suggest that their functional capacity might be even better than that of their Bulgarian counterparts.

In conclusion, there were significant differences between Bulgarian and Romany children with regard to anthropometric parameters including birth weight, lung function indices, and perception of exertion. These differences appear to be a combined result of biological and environmental factors.

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