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Morphofunctional Characteristics of Mongolian Children and Adolescents Living in Different Ecological Zones

In 2014–2015, 13,477 Mongolian schoolchildren (5833 boys and 7644 girls from different regions of the country), aged 8–17, were subjected to a comprehensive biological study. The program included 50+ anthropometric and anthroposcopic traits. Out of this set, bodily dimensions and functional parameters were used for the present paper. Their analysis was carried out among residents of mountain-taiga, steppe, and desert zones, which are still the main ecological niches of Mongolia. The urban sample (the best known Mongolian population, which included only subjects born and living in Ulaanbaatar) was used as a control group. The urban children and adolescents, as well as those living in the mountain-taiga zone, are characterized by maximal average values of the parameters. In the capital, these parameters are mostly affected by the living conditions, which are the best, confirming the results of previous studies. At the same time, the stressful urban factors account for higher indicators of the hemodynamic system in urban schoolchildren. The resemblance of these characteristics in steppe and desert dwellers results from relatively similar climatic conditions and physical stress patterns.

Keywords: *Anthropology, growth/development processes, Mongolia, ecological zones, functional parameters.*

Introduction

The study of the influence of geographic environment on human growth and development has always been the focus of interest for Russian anthropologists. Among previous studies, the series conducted by team of Moscow auxologists led by N.N. Miklashevskaya, wherein children and adolescents from different regions of the former USSR were studied, stands alone. One of the main conclusions of these works was that varying climatic conditions do not substantially affect growth and sexual maturation as long as the conditions are not extreme (Miklashevskaya, 1985: 270; Miklashevskaya, Solovyeva, Godina, 1988: 66).

Mongolia, owing to its combination of widely varying climatic and geographic features and an ethnically homogeneous population, provides great opportunities for carrying out studies of the ecogeographic variation of human growth and development. The natural zones present in Mongolia

include taiga forests, mountain-steppe forests, steppes, semi-deserts, and deserts. According to the range of temperatures, both diurnal and annual (maximum yearly amplitude in Ulaanbaatar reaches 90 °C), Mongolia displays one of the most sharply continental climates in the world (Natsionalniy atlas…, 1990: 55). Such climatic and landscape diversity makes it possible to perform large-scale surveys of the effect of climate-geographic factors on the formation of the somatic status of children and adolescents.

The first such study was carried out in the 1960s by C. Chultemdorj (1967). He compared the main parameters of the physical development of the 8–18-year-old inhabitants of the Mongolian capital with those of children and adolescents of the Central aimag, and did not find any significant differences between them. Further, a comparative analysis of the physical development of children and youth of Ulaanbaatar, mountainous (Zavkhan aimag) and desert (South Gobi (Ömnögovi) aimag) areas also did not reveal substantial differences in the rates of growth of the inhabitants of different geographic zones (Lkhagvazhav, 1972).

The anthropological features of peoples of Central Asia have been extensively studied by Russian anthropologists (Chikisheva, 1982; Antropoekologiya…, 2005: 6–126). The classic studies by T.I. Alekseeva and V.P. Alekseev addressing the issue of interaction between human populations and the environment have been carried out in different ecological zones of this region, including Mongolia. These studies have shown that the intergroup differentiation of physical parameters is associated with climatic influences. In particular, the desert inhabitants from Bogd sum displayed retardation of growth processes, an elongated trunk, narrow shoulders (while pelvic width was medium), and a flattened chest. The highest growth rates were typical for the steppe population (Khalkhgol sum), while the studied physical parameters in this population were similar to those of the inhabitants of the mountain-taiga zone (Jargalant sum). Children and adolescents from these groups exhibited the largest values of relative arm length, circumference and sagittal diameter of the chest, shoulder and pelvic widths, and trunk length. The population of Bat-Ulzii sum (mountain-taiga zone) displayed more dolichomorphic body proportions, and relatively longer legs, while the trunk and arms in this group were short, and the transverse diameters were minimal (Antropoekologiya…, 2005: 140–147). In terms of their morphological status, children from Bogd sum were assigned to a desert type, children from Khalkhgol and Jargalant to a continental type, and from Bat-Ulzii to an alpine type. These results supported the view according to which the typical features of different adaptive types emerge early in ontogeny (Alekseeva, 1986: 190).

The collaborative works of Mongolian scholars (M. Erdene and D. Tumen) and Russian anthropologists carried out in the 1980s have also detected manifestations of adaptation to different environmental zones in the complex of morpho-physiological features of Mongolian children. A comparison of urban and rural children demonstrated retardation of the latter in values of the morpho-physiological features (Erdene, Tumen, 1998).

This study sets out to explore the association between the morphofunctional characteristics of Mongolian children and adolescents, and environmental conditions, employing vast recently collected samples.

Materials and methods

This study is based on the results of the cross-sectional comprehensive survey of Mongolian children and adolescents from Ulaanbaatar and other regions of Mongolia, carried out in 2014 and 2015. The data were collected in compliance with the rules of bioethics: each of the subjects signed an informed consent protocol, and the data were depersonalized. In total, 13,477 individuals (5833 boys and 7644 girls), from 8 to 17 years of age, representing different ecological zones, were employed in the study (Table 1). The sample was divided into age cohorts according to the conventional anthropological principle: e.g. 7-year-old children included those aged from 6 years and 6 months to 7 years 5 months and 29 days.

All anthropometric measurements were taken according to standard techniques (Bunak, 1941). The protocol included a vast array of measurements (more than 30 in total), including: statures, and heights of main anthropometric points, measured using Martin's anthropometer (precision up to 0.5 mm); transverse diameters of the shoulders, pelvis, and chest; circumferences of the chest, waist, buttocks, shoulder, forearm, hip, and shin, measured using a measuring tape (precision up to 0.5 cm); and bone (joint) diameters, measured by a sliding caliper with a nozzle (precision up to 0.5 mm). Skinfold thickness at eight locations on the trunk and limbs was quantified following a standard protocol (Lutovinova, Utkina, Chtetsov, 1970) using a skinfold caliper with a precision of up to 0.1 mm. Body mass was measured on a digital floor scale with a precision of up to 0.01 kg. As was noted above, only the data on total body dimensions are explored and discussed further. The body mass index (BMI) was calculated following

Table 1. **Age distribution of the studied children and adolescents, depending on environmental conditions**

Age, years	Total	Geographic zone			Urban
		Mountain-taiga	Desert	Steppe	
Boys					
8	310	58	43	40	169
9	442	39	91	69	243
10	478	70	87	37	284
11	592	152	32	60	348
12	678	173	43	57	405
13	773	189	55	54	475
14	777	168	54	56	499
15	595	90	56	55	394
16	684	217	23	26	418
17	504	138	27	29	310
	5833	1294	511	483	3545
Girls					
8	523	89	58	24	352
9	531	61	33	38	399
10	599	88	40	44	427
11	779	139	25	50	565
12	915	176	60	37	642
13	1025	208	65	59	693
14	1155	204	64	72	815
15	868	160	47	42	619
16	669	140	47	35	447
17	580	138	36	34	372
	7644	1403	475	435	5331

Quetlet (1870: 92): BMI = m/h^2, where m – body mass in kilos, h – body height in meters. Some functional parameters were quantified as well: systolic and diastolic blood pressure (SBP and DBP), and heart rate (HR) measured with an electronic tonometer MBO Digimed 16 (Germany); grip strength of each hand, quantified by DK-50 and DK-100 dynamometers; and the peak expiratory flow rate (PEFR), measured with a Spirometric peak flow meter (USA).

Estimates of the main statistical parameters (X, S) of the raw data were performed. In order to compare intragroup differentiation across age cohorts, the original values of the variables were also converted into z-scores for each of the cohorts (Cole, 1997). One-way analysis of variance (ANOVA) was used to assess the significance of intergroup differences in physical development between children and adolescents from different environments. The Holm-Bonferroni method for multiple pair-wise comparisons was employed for controlling for type I errors. All the calculations were carried out with the Statistica 10.0. software package.

Results

An analysis of the anthropometric and physiological parameters was performed to explore the influence of environmental conditions on the formation of the morphofunctional status of Mongolian children and adolescents from the ecological zones, contrasted in terms of climate-geographic features: mountain-taiga, steppe, and desert (Natsionalniy atlas…, 1990). The most thoroughly studied urban sample of the Mongolians, from Ulaanbaatar, was employed as a reference. Only the individuals born in the city and

Table 2. **ANOVA results for total body dimensions**

Parameter	Zone	♂				♀			
		1	2	3	4	1	2	3	4
Body height	1		0.000	0.000	0.118		**0.000**	**0.000**	**0.000**
	2	**0.000**		0.007	**0.000**	**0.000**		**0.031**	**0.000**
	3	**0.000**	0.007		**0.000**	**0.000**	**0.031**		0.633
	4	0.118	**0.000**	**0.000**		**0.000**	**0.000**	0.633	
Body mass	1		0.000	0.000	0.077		**0.004**	0.660	0.076
	2	**0.000**		0.050	**0.000**	**0.004**		0.323	**0.000**
	3	**0.000**	0.050		**0.000**	0.660	0.323		**0.024**
	4	0.077	**0.000**	**0.000**		0.076	**0.000**	**0.024**	
BMI	1		0.000	0.000	0.281		0.170	0.377	**0.000**
	2	**0.000**		0.571	**0.000**	0.170		0.990	0.223
	3	**0.000**	0.571		**0.000**	0.377	0.990		0.116
	4	0.281	**0.000**	**0.000**		**0.000**	0.223	0.116	
Chest circumference	1		0.000	0.000	0.534		0.053	0.310	0.181
	2	**0.000**		0.726	**0.000**	0.053		0.936	**0.000**
	3	**0.000**	0.726		**0.000**	0.310	0.936		**0.009**
	4	0.534	**0.000**	**0.000**		0.181	**0.000**	**0.009**	

Note. 1 – mountain-taiga zone, 2 – desert, 3 – steppe, 4 – urban. Parameters that differ in inhabitants of different zones and reach the level of statistical significance are marked in bold.

living there at the moment of the study were included in the analysis*.

Total body dimensions. According to the results of the ANOVA (Table 2), the boys from Ulaanbaatar and the mountain-taiga zone display significantly larger values of all total body dimensions. Pair-wise comparisons between these two, as well as between the two other samples (from the desert and steppe zones), did not reveal any significant differences. The results for the female sample were not as clear. For example, the girls from the mountain-taiga and desert zones exhibit significantly the largest and the smallest values of stature, respectively, while between the other groups no significant difference was detected. The maximum values of body mass and BMI are found in the urban girls. The difference between them and girls from desert and steppe zones is significant for body mass, and between them and girls from mountain-taiga zone for BMI. The largest values of chest circumference were observed in urban and mountain-taiga schoolgirls, though intergroup differences were not significant (Table 2, Fig. 1).

Functional parameters. According to the ANOVA results (Table 3), the boys from the city and mountain-taiga zone demonstrate the highest values of PEFR. The differences between the two groups mentioned above, as well as between the samples from the desert and steppe zones, were not statistically significant. The same applies to the values of grip strength of each hand. Turning to the hemodynamic parameters, the urban boys exhibit the highest blood pressure as compared to the rural samples from various zones, but none of the intergroup differences were significant. The hemodynamic parameters, PEFR, and grip strength of each hand display the highest values in the urban girls. Other parameters do not exhibit intergroup differences (Table 3, Fig. 2).

Discussion

The effect of ecological factors on the biological status of the Mongolian sample becomes evident during the growth and development of the most biologically vulnerable population group—children and adolescents. Our results confirm the conclusions arrived at by T.I. Alekseeva and co-authors (Antropoekologiya…, 2005: 140–147): urban and mountain-taiga schoolchildren display the maximum average values of

*A general comparison between urban and rural Mongolian children and adolescents, disregarding environmental conditions, can be found elsewhere (Godina, Gundegmaa, Permyakova, 2019).

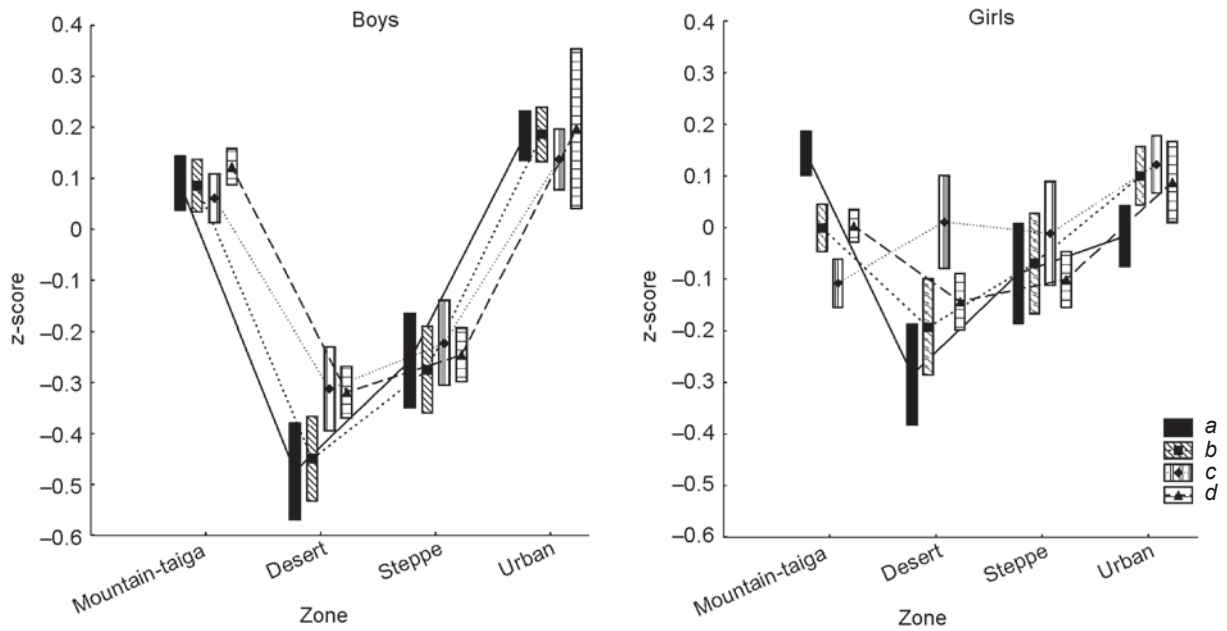

Fig. 1. ANOVA results for total body dimensions.
a – stature; *b* – body mass; *c* – BMI; *d* – chest circumference.

Table 3. **ANOVA results for z-scores of the functional parameters***

Parameter	Zone	♂				♀			
		1	2	3	4	1	2	3	4
PEFR	1		0.000	**0.000**	0.418		0.256	0.942	**0.000**
	2	**0.000**		0.798	**0.000**	0.256		0.756	**0.000**
	3	**0.000**	0.798		**0.000**	0.942	0.756		**0.000**
	4	0.418	**0.000**	**0.000**		0.000	0.000	0.000	
Grip strength of the right hand	1		0.000	**0.000**	0.502		0.418	0.480	**0.000**
	2	**0.000**		0.832	**0.000**	0.418		0.079	**0.000**
	3	**0.000**	0.832		**0.000**	0.480	0.079		**0.000**
	4	0.502	**0.000**	**0.000**		0.000	0.000	0.000	
Grip strength of the left hand	1		0.000	**0.000**	0.154		0.855	**0.000**	**0.000**
	2	**0.000**		0.879	**0.000**	0.855		0.048	**0.000**
	3	**0.000**	0.879		**0.000**	**0.000**	0.048		**0.000**
	4	0.154	**0.000**	**0.000**		**0.000**	**0.000**	**0.000**	
SBP	1		0.566	0.897	**0.000**		0.062	0.622	**0.000**
	2	0.566		0.955	**0.000**	0.062		0.769	**0.000**
	3	0.897	0.955		**0.000**	0.622	0.769		**0.000**
	4	**0.000**	**0.000**	**0.000**		**0.000**	**0.000**	**0.000**	
DBP	1		0.669	0.337	**0.000**		0.062	0.622	**0.000**
	2	0.669		0.979	**0.000**	0.062		0.769	**0.000**
	3	0.337	0.979		**0.000**	0.622	0.769		**0.000**
	4	**0.000**	**0.000**	**0.000**		**0.000**	**0.000**	**0.000**	
HR	1		0.696	0.342	0.999		0.126	0.219	**0.000**
	2	0.696		0.974	0.767	0.126		0.998	**0.000**
	3	0.342	0.974		0.420	0.219	0.998		**0.000**
	4	0.999	0.767	0.420		0.000	0.000	0.000	

*See note to Table 2.

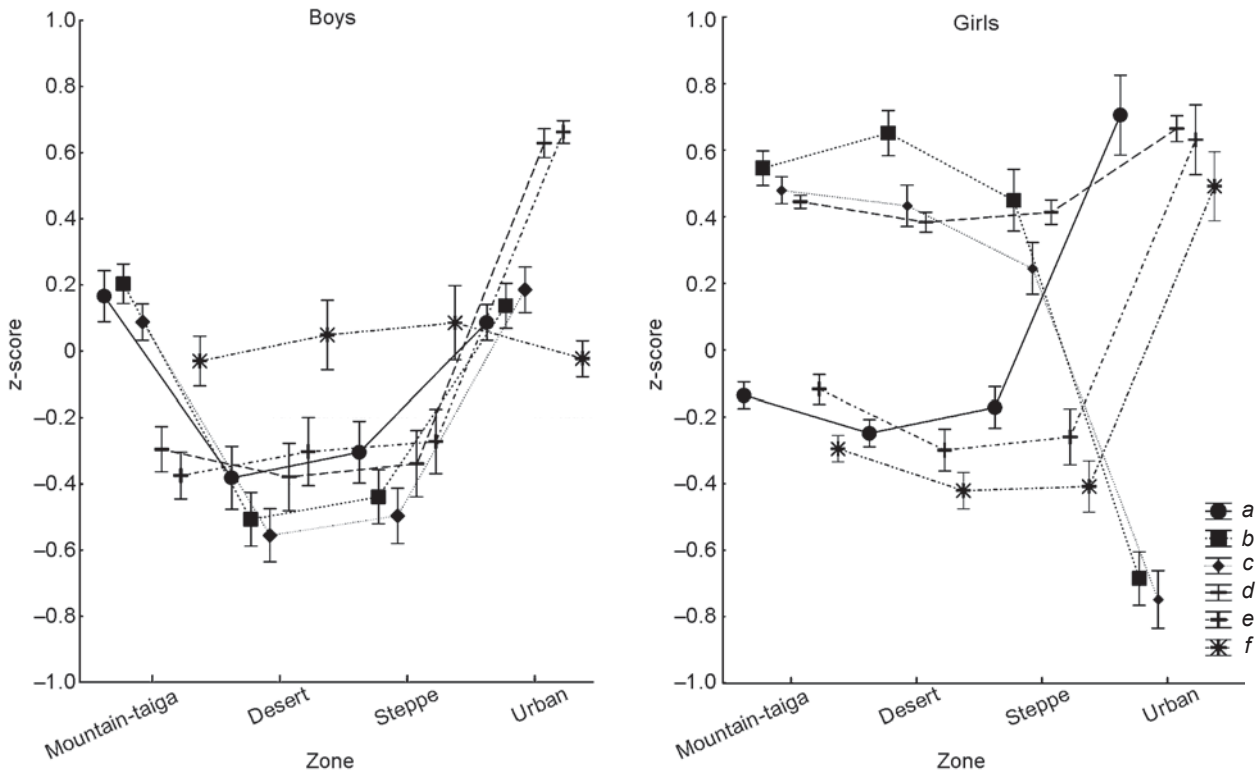

Fig. 2. ANOVA results for z-scores of the functional parameters
a – PEFR; *b*, *c* – grip strength of the right and left hands, respectively; *d* – SBP; *e* – DBP; *f* – HR.

most anthropometric parameters. Our study has revealed the same picture for total body dimensions. Our results also corroborate the conclusions based on the study of Mongolian schoolchildren in the early 1990s, before the positive economic changes in the country (Choibalsan, 1991). An assessment of harmony in the development of urban and rural Mongolian children during following decades reveals the same trend: lower values of stature, mass, and BMI are more often observed in less urbanized regions: in particular, in boys (Amgalan, Pogorelova, 2015: 89; Pogorelova, Amgalan, 2016: 1200). However, brachymorphic proportions of adolescents from rural regions determine their denser physique irrespective of body weight and sex. Among the rural groups, the inhabitants of the Gobi desert display the smallest total body dimensions, while the population of the mountain-taiga zone exhibits the largest (Gundegmaa, 2009: 15).

The most interesting trend for the functional parameters is a higher level of grip strength observed in the urban and mountain-taiga samples as compared to other groups. A possible explanation for this trend is the changes in living conditions of rural children, which leads to the loss of their main peculiar feature—physical strength (Liu et al., 2012: 446). But this observation is only true for the boys, while the urban schoolgirls display minimal grip strength of each hand, which can be explained by the retention of the traditional gender labor division in less urbanized regions. The similarity in the parameters in the populations from the steppe and desert zones might be due to the similarity of climatic conditions of their habitats. The environment can affect physique in this case not only directly, but also indirectly: the populations of both parts of the country are predominantly nomadic.

The distribution of the hemodynamic and respiratory parameters in the Mongolian schoolchildren from various climate-geographic conditions demonstrates that SBP is higher in urban children of both sexes, which is undoubtedly explained by a higher stress load in more urbanized areas (Kalyuzhny, 2017: 92; Smagulov, Azhimetova, 2013: 58; Sukhanova, Maksimov, Vdovenko, 2014: 13; Negasheva et al., 2018: 47). The intergroup differences for DBP and HR are not significant, but both parameters are higher in the urban population. The results for the 17-year-old urban schoolchildren can be compared with the outcomes of previous studies, according to which, average SBP and DBP in males from Ulaanbaatar were 116.4 and 76.5 mm Hg, respectively (Dashdavaa, 1991). In our sample of young males, the respective values were

115.6 and 70.5 mm Hg, i.e. fairly close to that of the males from Ulaanbaatar. This means that substantial differences between urban and rural Mongolian schoolchildren existed before the acceleration of urbanization in the country. Higher values of PEFR are also found in the urban and mountain-taiga populations. This observation can be explained as a compensatory reaction of the respiratory system on low temperatures in the mountain-taiga zones and air pollution in the capital (Altantsetseg, 2015: 94).

Conclusions

The results of the present study confirm the hypothesis about a substantial influence of ecological conditions on the growth and physical development of Mongolian children and adolescents. Schoolchildren from the mountain-taiga zone display maximum mean values for total body dimensions and functional indicators, while their peers from the steppe and desert zones lag behind in most parameters. Children and adolescents from the Mongolian capital display the highest level of physical development as well. But in this case, socioeconomic rather than ecogeographic conditions play the lead role, as confirmed by the results of previous research (Godina, Gundegmaa, Permyakova, 2019). At the same time, the stressful urban factors account for a higher indicators of the hemodynamic system in urban schoolchildren. The elevated values of PEFR observed in the urban and mountain-taiga samples can be explained as a compensatory mechanism of the respiratory system providing an adaptive response to environmental conditions: air pollution or cold. The similarity of most studied parameters in the populations of the steppe and desert zones is a result of both similar climatic conditions and the pattern of physical activities in these predominantly nomadic regions of the country.

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