ANALYSIS OF BODY MASS INDEX FORMATION IN CHILDREN AND ADOLESCENTS OF THE RUSSIAN FEDERATION

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To prevent health problems in pediatric population, the Russian Federation (RF) is implementing the Complex of measures to combat obesity in children under 18 years of age, approved on December 1, 2023, No. 18824-P12-TG. The study aimed to consider body mass index (BMI) formation in Russian children and adolescents in the regional aspect. As part of the all-Russian monitoring of the physical development of children and adolescents in 2021–2024, BMI of 258,611 boys and 252,629 girls living in 50 constituent entities of the RF was studied. Big data analysis has shown that in most regions there is a harmonious development of the child population and the indicators fit into the BMI 25th–75th centile for the RF as a whole, which is 19.6–22.9 kg/m^2 in boys aged 17 and 18.7–22.3 kg/m^2 in girls. At the same time, there is an influence of socio-economic factors. The analysis of the regional features of BMI formation in children and adolescents aged 7–17 years has shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product.

Keywords: children, adolescents, body mass index, regions, monitoring, physical development

Author contribution: the authors contributed equally to preparation of the paper.

Compliance with ethical standards: the study was approved by the Ethics Committee of the Pirogov Russian National Research Medical University (protocol No. 239 dated 15 April 2024).

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АНАЛИЗ ФОРМИРОВАНИЯ ИНДЕКСА МАССЫ ТЕЛА У ДЕТЕЙ И ПОДРОСТКОВ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Для профилактики нарушения здоровья детского населения в Российской Федерации (РФ) осуществляется исполнение Комплекса мер по борьбе с ожирением у детей до 18 лет от 1 декабря 2023 г. № 18824-П12-ТГ. Целью работы было рассмотреть формирование индекса массы тела (ИМТ) у российских детей и подростков в региональном аспекте. В рамках проведения общероссийского мониторинга физического развития детей и подростков в 2021–2024 гг. был изучен ИМТ 258 611 мальчиков и 252 629 девочек, проживающих в 50 субъектах РФ. Анализ *big data* показал, что в большинстве регионов имеет место гармоничное развитие детского населения и что показатели укладываются в ИМТ в зоне 25–75-го центиля для РФ в целом, который у мальчиков 17 лет составляет 19,6–22,9 кг/м^2, а у девочек — 18,7–22,3 кг/м^2. В то же время присутствует влияние социально-экономических факторов. Анализ региональных особенностей формирования ИМТ у детей и подростков 7–17 лет показал, что ИМТ имеет тем более высокое значение, чем ниже место субъекта РФ по показателю валового регионального продукта.

Ключевые слова: дети, подростки, индекс массы тела, регионы, мониторинг, физическое развитие

Вклад авторов: все авторы внесли равный вклад в подготовку публикации.

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The issue of overweight and obesity is relevant for pediatric population all over the world [1–5].

Currently, the Russian Federation (RF) is implementing the Complex of measures to combat obesity in children under 18 years of age, approved by T.V. Golikova, Deputy Chairman of the Government of the Russian Federation, on December 1, 2023, No. 18824-P12-TG. As part of the screening assessment within the framework of the check-up aimed to allocate groups of overweight children and adolescents at risk, calculation of body mass index (BMI) with estimation is performed in accordance with the guidelines of the World Health Organization (WHO) and clinical guidelines "Obesity in Children" of the Ministry of Health of the RF [6].

Consideration of BMI formation in Russian children and adolescents in the regional aspect taking into account growth and development patterns seems to be a relevant task.

The study aimed to consider BMI formation in children and adolescents of the RF in the regional aspect.

METHODS

When conducting all-Russian monitoring of physical development of children and adolescents in 2021–2024, a cross-sectional study of physical development indicators (body length, body weight) was performed in children and adolescents aged 7–17 years with subsequent BMI (kg/m^2) calculation in 50 constituent entities of the RF. Considering the growth and development patterns, we selected the regions that were different in climate and geographic conditions, ethnic composition of the population, socio-economic and other factors. The sample was calculated using the method by K.A. Otdelnova (95.0%, $p \leq 0.05$): each gender and age group in the studied constituent

entity of the RF was represented by 100 children. The data on body length and body weight of 258,611 boys and 252,629 girls were selected for statistical analysis to calculate BMI (Table 1).

Statistical processing of the data obtained was performed using the Microsoft Office Excel (Microsoft; USA) and Statistica 13.0 (StatSoft; USA) software packages. When processing the results of physical development assessment, the data were tested for normality using the Kolmogorov–Smirnov, Lilliefors, and Shapiro–Wilk tests. The quantitative data acquired were normally distributed, which is in line with the literature data on assessing physical development indicators. We used parametric statistical methods involving the use of the mean (M), error of the mean (m), and standard deviation (σ). To assess significance of differences in mean values, the Bonferroni adjusted Student's *t*-test was used. The differences were considered significant at the significance level not exceeding 0.05.

The data on socio-economic indicators in constituent entities of the RF at the midpoint of the observation period (main economic indicators in 2022: per capita income (per month), average monthly nominal accrued wages of the employees of organizations (per month), gross regional product in 2021, agricultural products, retail trade turnover; place occupied by the constituent entity based on the major socio-economic indicators in the RF in 2022: per capita gross regional product in 2021, agricultural products, per capita retail trade turnover) were taken from official sources [7].

Correlations between BMI of children and adolescents aged 7–17 years and socio-economic indicators were assessed using the Spearman's rank correlation coefficient, since the distribution of socio-economic indicators was non-normal.

RESULTS

BMI formation in children and adolescents of the RF in the regional aspect was considered based on the gender and age BMI curves (Fig. 1–8).

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the CFD are provided in Fig. 1.

Fig. 2 presents gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the NWFD.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the SFD are provided in Fig. 3.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the NCFD are provided in Fig. 4.

Fig. 5 presents gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the VFD.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the UFD are provided in Fig. 6.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the SFD are provided in Fig. 7.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the FEFD are provided in Fig. 8.

The analysis of gender and age BMI curves shows that in the majority of regions there is a smooth increase in BMI with age in both boys and girls — usually without crossovers, which is in line with such biological patterns, as directionality, gradualism, irreversibility and heterochrony. Indicators of boys are superior to that of girls, which is consistent with such pattern, as sex-specific growth and development (sexual dimorphism). In general, harmonious development is observed in the majority of regions.

There are regional BMI differences observed by growth termination. Thus, the following maximum and minimum BMI values are reported for the CFD: in boys aged 17 years living in the Kursk Region, the value is 21.97 ± 0.17 kg/m^2, while in boys aged 17 years living in the Ivanovo Region it is 20.95 ± 0.34 kg/m^2, i.e. the difference is 1.02 kg/m^2 (Student's *t*-test: 2.68; $p = 0.007746$). In girls living in the Oryol Region, BMI is 21.51 ± 0.39 kg/m^2, while in those living in the Kursk Region it is 20.55 ± 0.39 kg/m^2, i.e. the difference is 0.96 kg/m^2 (Student's *t*-test: 2.19; $p = 0.029425$).

No significant differences are reported for the NWFD ($p > 0.05$).

The following maximum and minimum BMI values are reported for the SFD: in boys aged 17 years living in the Republic of Kalmykia, the value is 22.57 ± 0.59 kg/m^2, while in boys aged 17 years living in the Krasnodar Krai it is 21.41 ± 0.06 kg/m^2, i.e. the difference is 1.16 kg/m^2 (Student's *t*-test: 2.00; $p = 0.005000$). In girls living in the Republic of Kalmykia, the value is 21.34 ± 0.34 kg/m^2, while in those living in the Rostov Region it is 20.16 ± 0.14 kg/m^2, i.e. the difference is 1.18 kg/m^2 (Student's *t*-test: 2.34; $p = 0.018815$).

The following maximum and minimum BMI values are reported for the NCFD: in boys aged 17 years living in the Republic of North Ossetia–Alania, the value is 21.98 ± 0.15 kg/m^2, while in boys aged 17 years living in the Karachayevo-Circassian Republic it is 21.16 ± 0.21 kg/m^2, i.e. the difference is 0.82 kg/m^2 (Student's *t*-test: 3.18; $p = 0.001600$). In girls living in the Karachayevo-Circassian Republic, BMI is 21.80 ± 0.23 kg/m^2, while in those living in the Chechen Republic it is 20.25 ± 0.29 kg/m^2, i.e. the difference is 1.55 kg/m^2 (Student's *t*-test: 4.19; $p = 0.000042$).

The following maximum and minimum BMI values are reported for the VFD: in boys aged 17 years living in the Republic of Mordovia, BMI is 21.68 ± 0.32 kg/m^2, while in boys aged

Table. Size of samples to form big data for analysis by the constituent entities of the Russian Federation, *n*

Federal District	Observations, boys, *n*	Observations, girls, *n*	Total observations, *n*
Central Federal District (CFD)	42 042	40 003	82 045
Northwestern Federal District (NWFD)	13 401	12 911	26 312
Southern Federal District (SFD)	66 935	64 923	131 858
North Caucasus Federal District (NCFD)	19 110	17 290	36 400
Volga Federal District (VFD)	51 535	48 769	100 304
Urals Federal District (UFD)	27 902	26 493	54 395
Siberian Federal District (SFD)	14 593	19 443	34 036
Far Eastern Federal District (FEFD)	23 093	22 797	45 890
Total observations, *n*	258 611	252 629	511 240

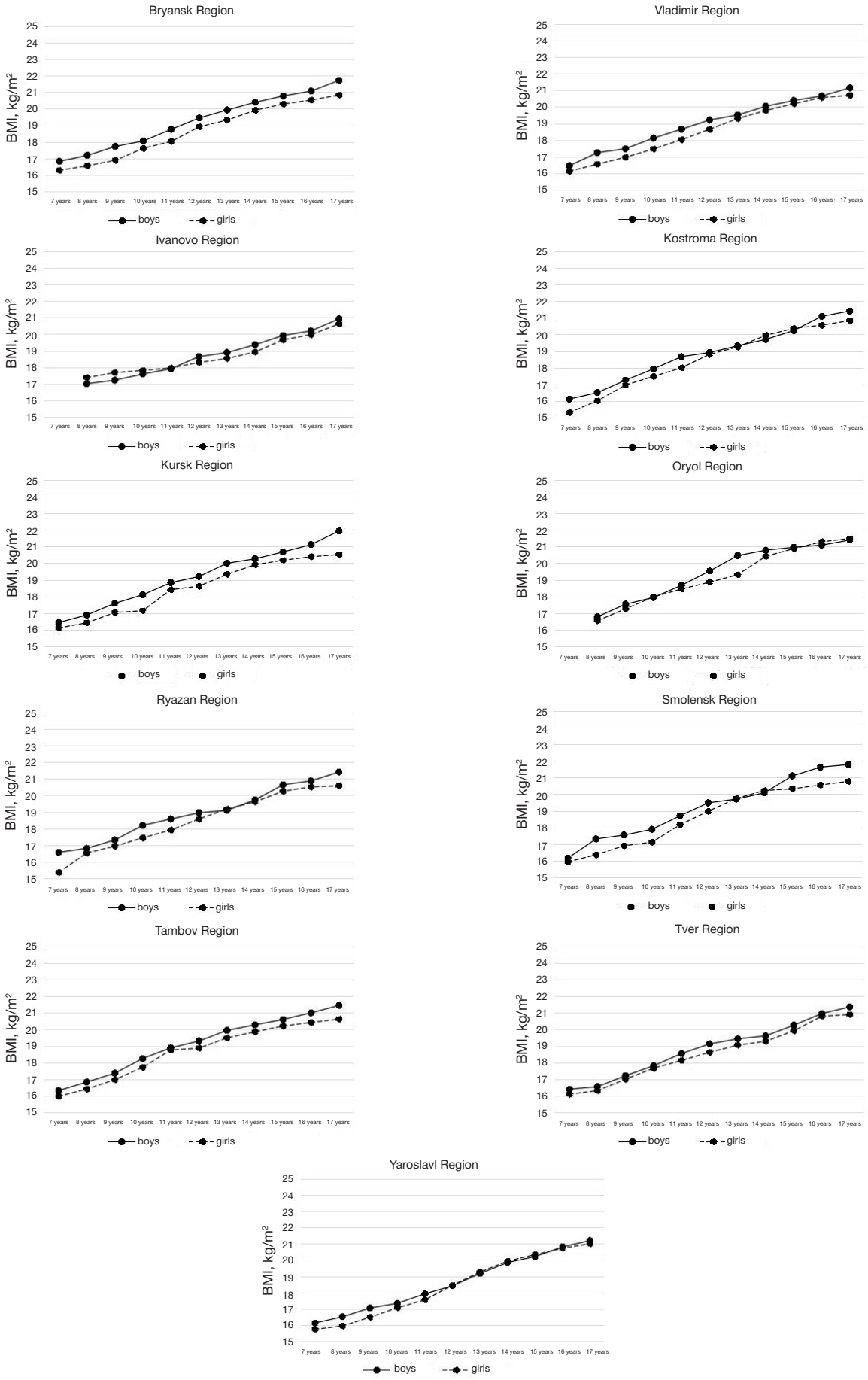

Fig. 1. Body mass index (BMI) formation in children and adolescents of the Central Federal District (CFD), kg/m^2

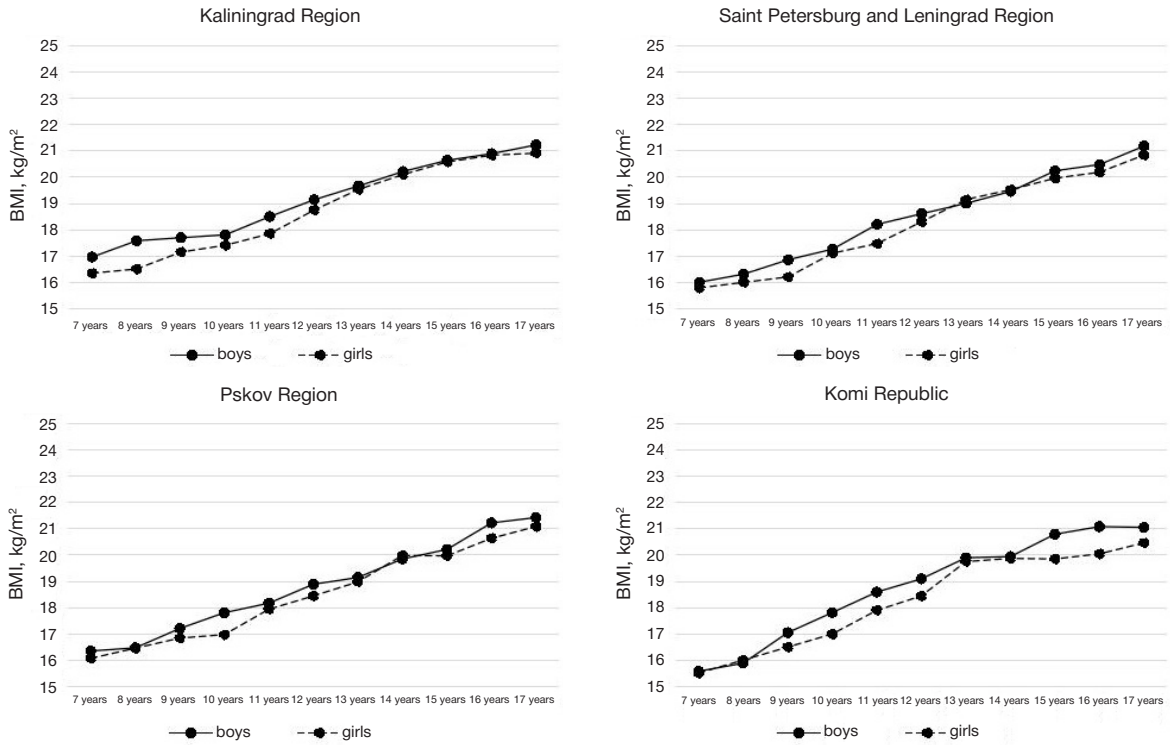

Fig. 2. Body mass index (BMI) formation in children and adolescents of the Northwestern Federal District (NWFD), kg/m^2

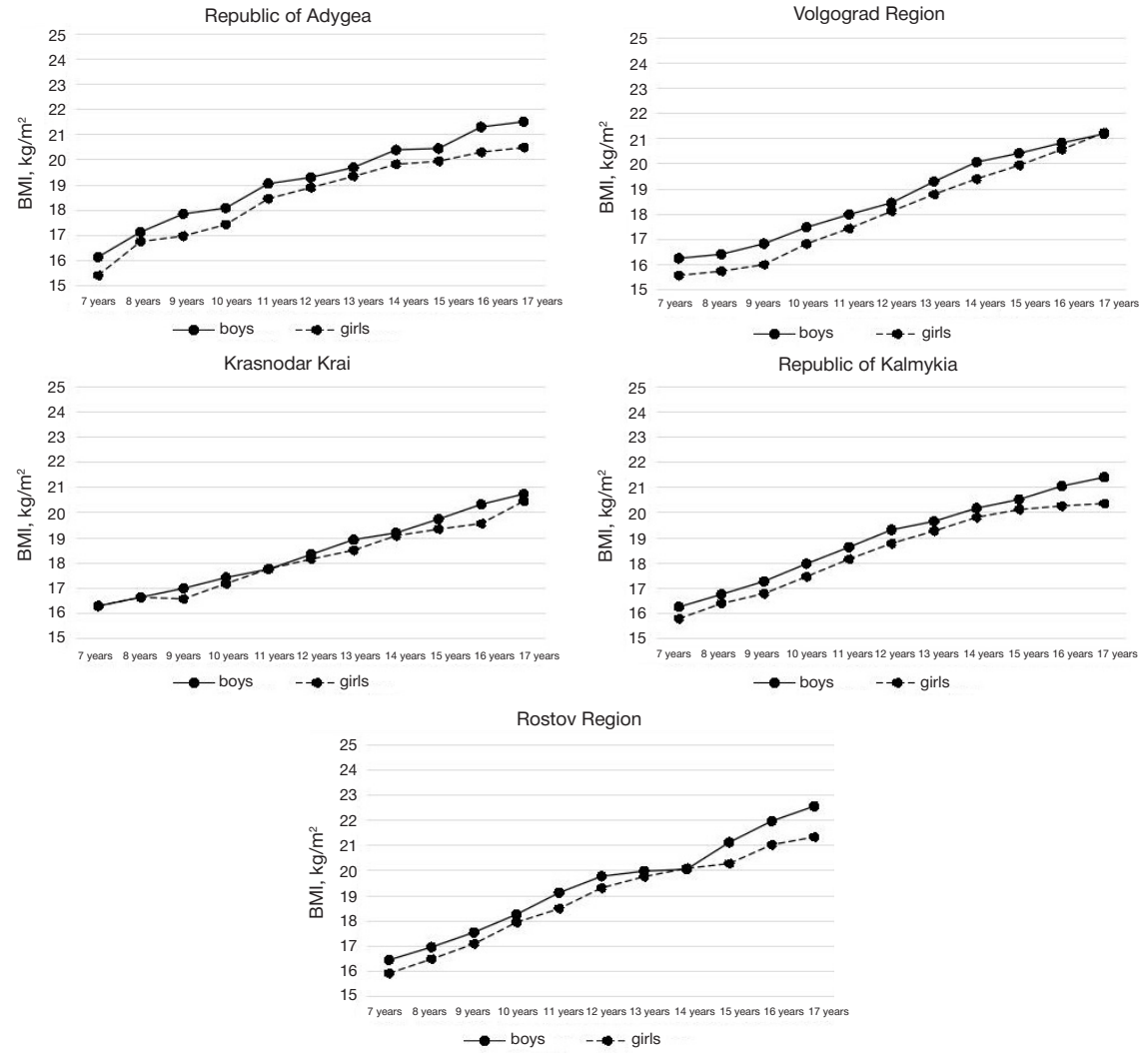

Fig. 3. Body mass index (BMI) formation in children and adolescents of the Southern Federal District (SFD), kg/m^2

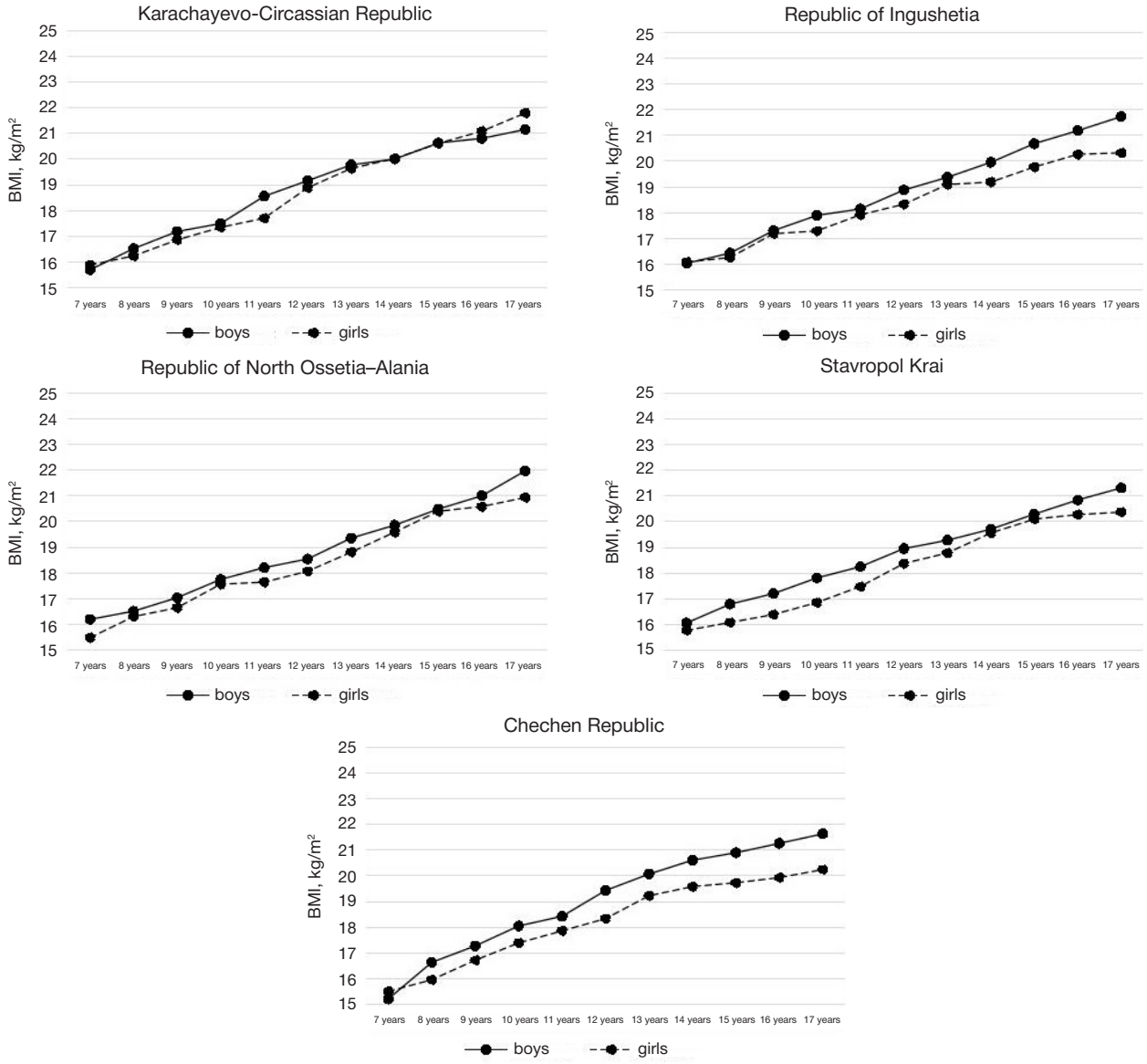

Fig. 4. Body mass index (BMI) formation in children and adolescents of the North Caucasus Federal District (NCFD), kg/m²

17 years living in the Chuvash Republic it is 20.49 ± 0.14 kg/m², i.e. the difference is 1.19 mg/m² (Student's *t*-test: 3.41; *p* = 0.000708). In girls living in the Chuvash Republic, BMI is 21.46 ± 0.34 kg/m², while in those living in the Republic of Tatarstan it is 19.79 ± 0.15 kg/m², i.e. the difference is 1.67 kg/m² (Student's *t*-test: 4,49; *p* = 0.000011).

The following maximum and minimum BMI values are reported for the UFD: in boys aged 17 years living in the Kurgan Region, the value is 21.74 ± 0.22 kg/m², while in boys aged 17 years living in the Tyumen Region it is 20.03 ± 0.18 kg/m², i.e. the difference is 1.71 kg/m² (Student's *t*-test: 6.02; *p* = 0.000001). In girls living in the Yamalo-Nenets Autonomous Okrug, BMI is 21.34 ± 0.25 kg/m², while in those living in the Tyumen Region it is 20.37 ± 0.21 kg/m², i.e. the difference is 0.97 kg/m² (Student's *t*-test: 3.28; *p* = 0.001182).

The following maximum and minimum BMI values are reported for the SFD: in boys aged 17 years living in the Altai Krai, BMI is 21.95 ± 0.39 kg/m², while in boys aged 17 years living in the Omsk Region it is 20.82 ± 0.14 kg/m², i.e. the difference is 1.13 kg/m² (Student's *t*-test: 2.73; *p* = 0.006711). In girls living in the Irkutsk Region, BMI is 21.53 ± 0.20 kg/m², while in those living in the Omsk Region it is 20.33 ± 0.15 kg/m², i.e. the difference is 1.20 kg/m² (Student's *t*-test: 4.80; *p* = 0.000002).

The following maximum and minimum BMI values are reported for the FEFD: in boys aged 17 years living in the Amur Region, the value is 21.61 ± 0.24 kg/m², while in boys aged 17 years living in the Khabarovsk Krai it is 20.85 ± 0.22 kg/m², i.e. the difference is 0.76 kg/m² (Student's *t*-test: 2.33; *p* = 0.020329). In girls living in the Amur Region, BMI is 20.95 ± 0.27 kg/m², while in those living in the Khabarovsk Krai it is 20.18 ± 0.17 kg/m², i.e. the difference is 0.77 kg/m² (Student's *t*-test: 2.41; *p* = 0.016486).

In general, the following maximum and minimum BMI values have been revealed in the regional aspect: in boys aged 17 years living in the Republic of Kalmykia, BMI is 22.57 ± 0.59 kg/m², while in boys aged 17 years living in the Tyumen Region it is 20.03 ± 0.18 kg/m², i.e. the difference is 2.54 kg/m² (Student's *t*-test: 4.02; *p* = 0.000077). In girls living in the Karachayevo-Circassian Republic, BMI is 21.80 ± 0.23 кг/м², kg/m², while in those living in the Republic of Tatarstan it is 19.79 ± 0.15 kg/m², i.e. the difference is 2.01 kg/m² (Student's *t*-test: 7.32; *p* = 0.000001).

Assessment of the impact of socio-economic indicators in the constituent entities of the RF on BMI formation in boys and girls aged 7–17 years in the regional aspect has shown that integral indicators of the subject of the RF were significant, i.e.

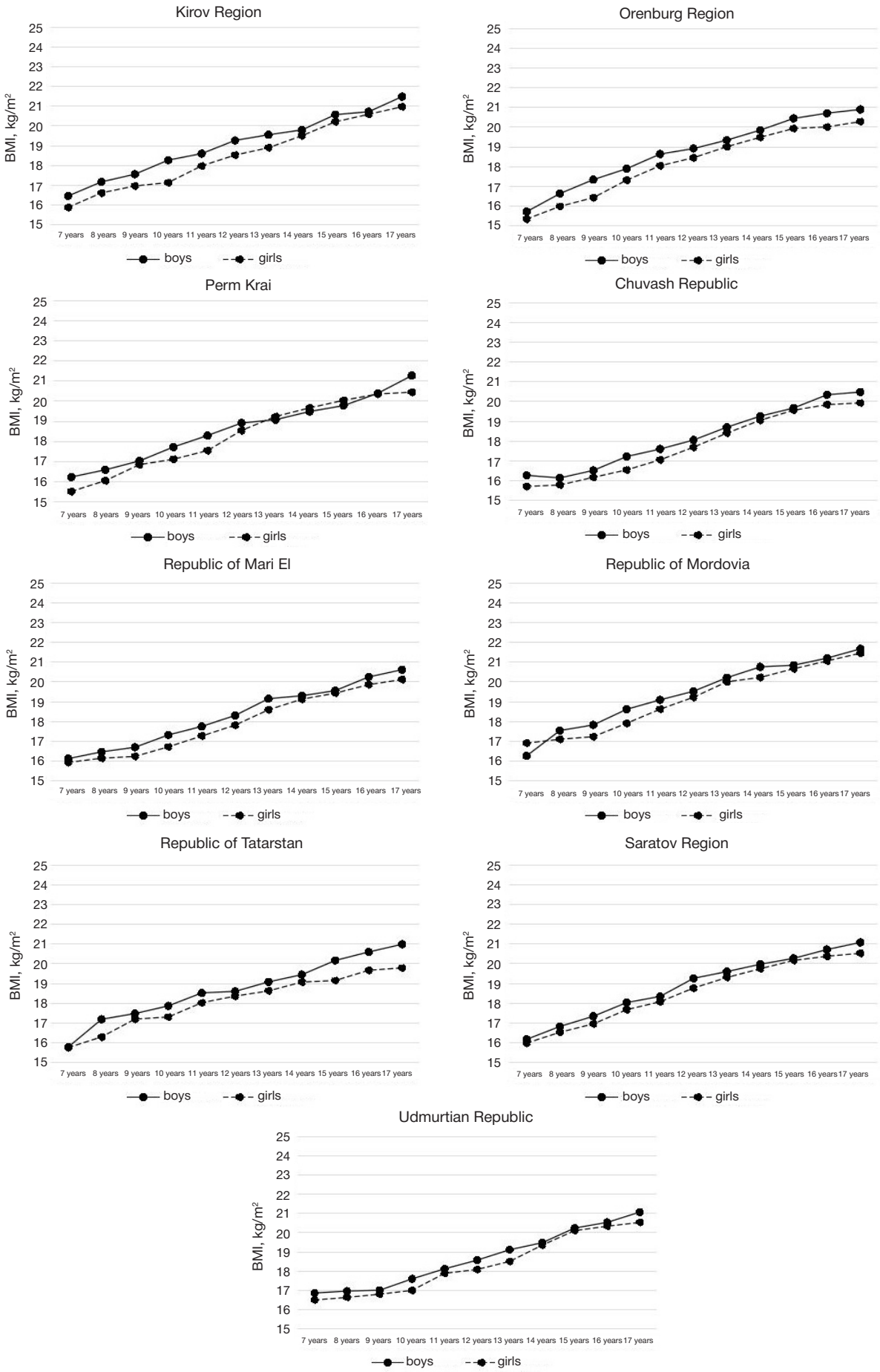

Fig. 5. Body mass index (BMI) formation in children and adolescents of the Volga Federal District (VFD), kg/m²

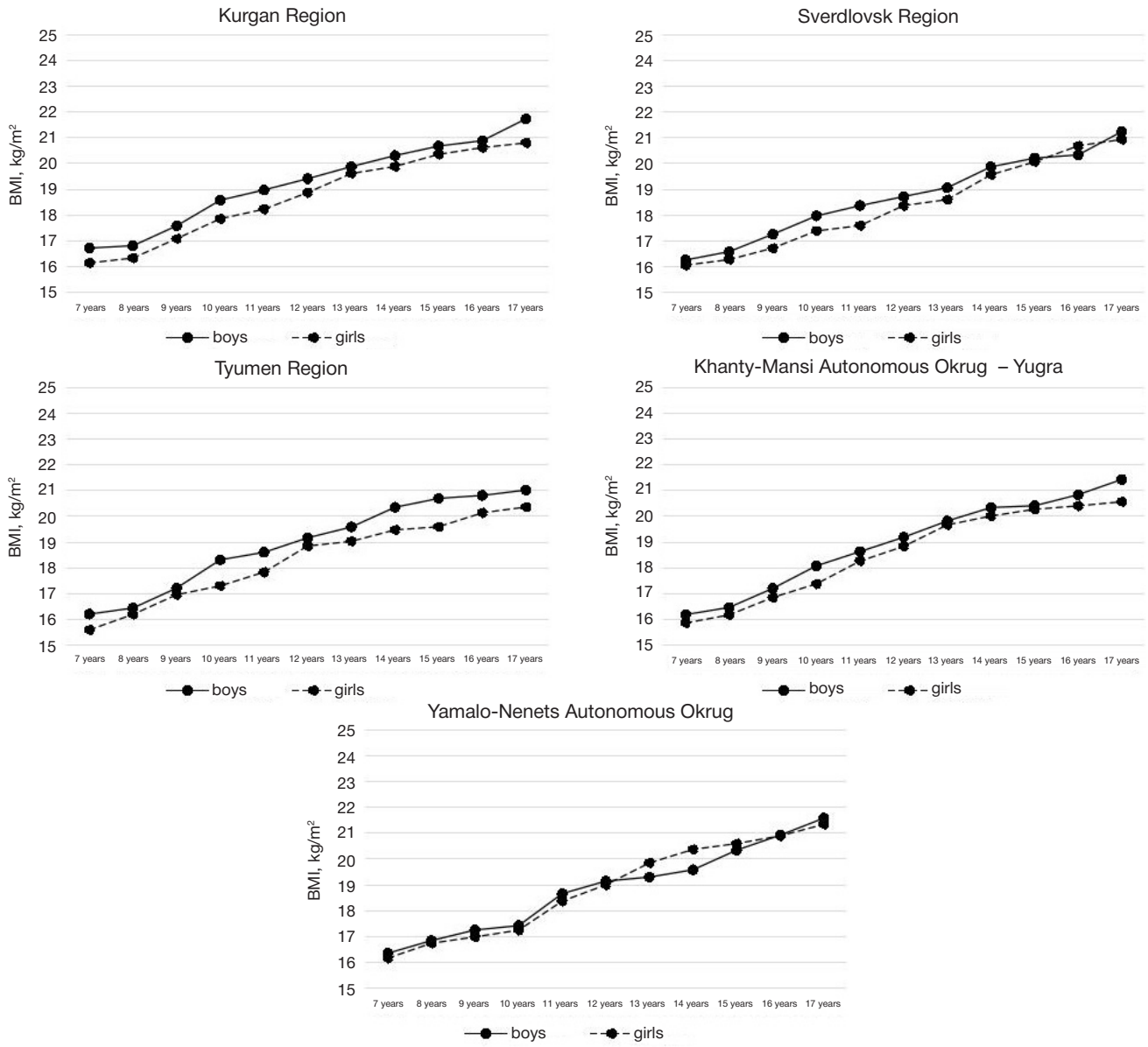

Fig. 6. Body mass index (BMI) formation in children and adolescents of the Urals Federal District (UFD), kg/m^2

per capita gross regional product, by which all the constituent entities were ranked in descending order (moderate correlation based on the Spearman's rank correlation coefficient: 0.519; $p \leq 0.05$), and the related indicators, such as supply of agricultural products 0.659 ($p \leq 0.05$) and per capita retail trade turnover 0.577 ($p \leq 0.05$).

DISCUSSION

Assessment of BMI formation in children and adolescents performed based on big data analysis has shown that there is harmonious development of pediatric population in the majority of regions, and the regional indicators of boys and girls fit into the BMI 25th–75th centile for the RF as a whole, which is 19.6–22.9 kg/m^2 in boys aged 17 years and 18.7–22.3 kg/m^2 in girls. At the same time, there are effects of socio-economic factors and, probably, climate and geographic, ethnic, and other factors.

The impact of climate and geographic factors and the regional differences in indicators of physical development of children and adolescents have been previously reported by many researchers [8–10]. There are earlier reports showing the effects of socio-economic factors on physical development of children and adolescents, as well as BMI [11].

The Pearson correlation coefficient calculated for the BMI of schoolchildren and the distribution of the number of children, who spent their summer vacations in children's recreation and health organizations in the year preceding the study, was –0.68 ($p \leq 0.05$) [12].

It has been also shown that Pearson correlation coefficients for BMI in schoolchildren aged 11 and 15 years and the value of availability of physicians and nurses per 10,000 population were –0.63 and –0.39 ($p \leq 0.05$) [13].

Our study has shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product. The regions that require special attention are the Republic of Kalmykia (66th place) and Karachayevo-Circassian Republic (82nd place).

To date, the numerically significant data have been accumulated: 511,240 observations acquired at once over a short time that make it possible to develop national nomograms for gender-and-age-based assessment of BMI in pediatric population, as well as to update the previously developed standards of this kind [14].

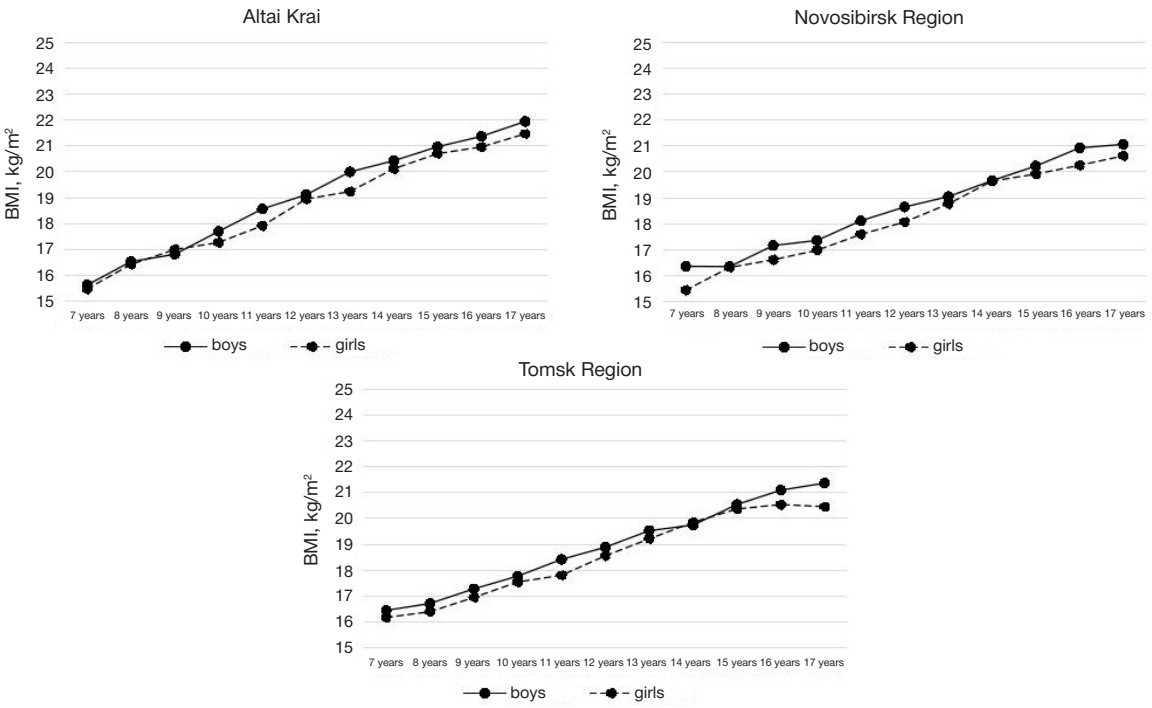

Fig. 7. Body mass index (BMI) formation in children and adolescents of the Siberian Federal District (SFD), kg/m²

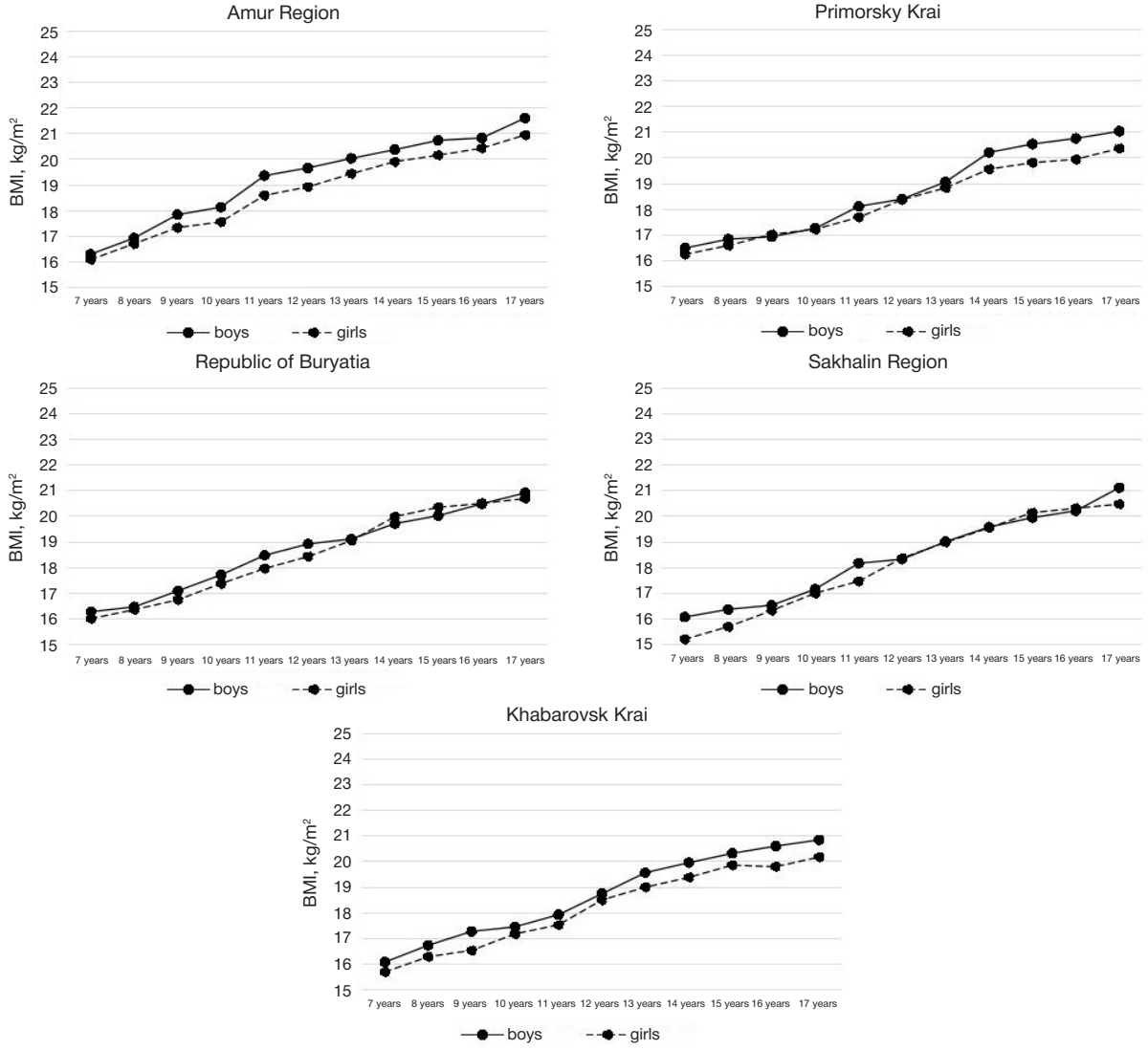

Fig. 8. Body mass index (BMI) formation in children and adolescents of the Far Eastern Federal District (FEFD), kg/m²

CONCLUSIONS

During the study the regional features of body mass index (BMI) formation in children and adolescents aged 7–17 years have been considered for the first time based on the big data analysis in 50 constituent entities of the Russian Federation (RF). It has been shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product.

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