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A Retrospective Analysis of 100-Year Trends in the Physical Development of Moscow Schoolgirls

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ABSTRACT

BACKGROUND: Healthy biological maturation in young girls is crucial for their future reproductive health. The continuous monitoring of their physical development is critical for early identification of any health problems.

AIM: This study aimed to identify the 100-year trend of girls' growth and development in the city of Moscow.

METHODS: The study focused on the physical characteristics of Moscow schoolgirls over a period of 100 years (1920–2020), including their body height and weight, chest circumference, right-hand grip strength, and time of menarche. In this study, a total of 4581 girls aged 8–17 years were observed from 2003 to 2020. The obtained data were compared with those documented in "Materials on the Physical Development of Children and Adolescents in Urban and Rural Areas of the USSR (Russia)," covering the period from 1920 to 2013. The Kolmogorov–Smirnov normality test was used to determine the normality of distribution. The differences were considered significant at $t \geqslant 2.0$ ($p < 0.05$).

RESULTS: Comparative analysis of the physical development of Moscow schoolgirls across decades showed an increase of 3–5 cm in the body height and a significant increase in the chest circumference among all age groups of girls at the beginning of the 21st century compared with their peers in the 1960s and 1980s, indicating the completed processes of gracilization that had been observed since the 1980s. The mean body height of 8-year-old schoolgirls in 2003 was 129.12 ± 0.47 cm compared to 125.66 ± 0.32 cm in those in the 1960s ($p < 0.001$). Additionally, the mean chest circumference was 62.34 ± 0.44 cm in 2003 and 60.50 ± 0.22 cm in the 1960s ($p < 0.008$). Moreover, a decrease in the right-hand grip strength has been noted in all age groups (9-year-old girls: 13.2 ± 0.2 kg in the 1960s and 6.9 ± 0.1 kg in 2003; $p < 0.001$). Earlier menarche has been documented in modern Moscow schoolgirls, with an average age of 12 years and 9 months. This phenomenon is accompanied by a shift in the chronology of growth patterns toward earlier stages. The age of first menstruation (menarche) varies with family income.

CONCLUSION: Over a century-long period, Moscow schoolgirls have shown increased total body size and earlier biological maturation.

Keywords: physical development; schoolgirls; body weight; body height; grip strength; menarche; 100-year trend.

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Ретроспективный анализ вековых тенденций в физическом развитии московских школьниц

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АННОТАЦИЯ

Обоснование. Здоровое биологическое созревание в детском возрасте формирует в будущем репродуктивное здоровье женщины, в связи с чем особого внимания требует динамическая оценка физического развития школьниц как показателя для ранней диагностики преморбидных состояний.

Цель исследования. Выявить вековую тенденцию процессов роста и развития девочек в мегаполисе Москве.

Методы. Изучено физическое развитие (длина и масса тела, окружность грудной клетки, мышечная сила правой кисти и становление менструальной функции) московских школьниц за период с 1920 по 2020 год. Объём собственных наблюдений, проводившихся с 2003 по 2020 год, составил 4581 девочку 8–17 лет. Полученные данные сравнивались с «Материалами по физическому развитию детей и подростков городов и сельских местностей СССР (России)» (1920–2013). Для определения нормальности распределения показателей использовали тест на нормальность по Колмогорову–Смирнову. Различия считали статистически значимыми при $t \geqslant 2{,}0$ ($p < 0{,}05$).

Результаты. Сравнительный анализ физического развития московских школьниц разных 10-летий выявил статистически значимое увеличение длины тела на 3–5 см и достоверное увеличение окружности грудной клетки во всех возрастных группах девочек начала XXI века по сравнению со сверстницами 1960-х и 1980-х годов, что свидетельствует о завершении процессов грациализации, отмечавшихся с 1980-х годов. Так, длина тела школьниц 8 лет в 2003 году составила 129,12±0,47 см, в 1960-х — 125,66±0,32 см ($p < 0{,}001$), окружность грудной клетки — 62,34±0,44 см и 60,50±0,22 см ($p < 0{,}008$) соответственно. При этом во всех возрастных группах продолжается снижение мышечной силы правой кисти (девочки 9 лет: 13,2±0,2 в 1960-х и 6,9±0,1 кг в 2003 году, $p < 0{,}001$). Установлены более ранние сроки наступления менархе у современных московских школьниц (в среднем 12 лет 9 мес) и сдвиг ростовых скачков на более ранние сроки. Показано, что возраст наступления менструаций зависит от уровня достатка семьи.

Заключение. У московских школьниц за столетний период выявлена тенденция к увеличению тотальных размеров тела и сдвиг сроков биологического созревания на более ранние.

Ключевые слова: физическое развитие; школьницы; масса тела; длина тела; мышечная сила; менархе; столетняя динамика.

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ЭКО•ВЕКТОР

INTRODUCTION

Currently, there is high prevalence of non-communicable diseases among children and adolescents in Russia and worldwide, which is largely due to global lifestyle changes, including the spread of unbalanced nutrition and sedentary lifestyle, uncontrolled use of electronic devices, decreased medical activity, and many others [1, 2]. Consequently, early diagnosis of premorbid conditions by indicators that are sensitive to the effects of risk factors for the development of diseases is critical [3, 4].

One of these indicators in the child population is the level of physical development, as a criterion of their health status, including the assessment of harmony and the level of biological development [4–6].

Healthy biological maturation also forms a woman's future reproductive health, depending on genetic predisposition, the presence of somatic pathology, and the impact of behavioral and other factors [5]. The risk factors for violations of physical and biological development of girls include the level of family wealth, the quality of medical care and development of the health system in the country, and conditions and lifestyle [7–11]. Thus, it is crucial to observe the physical development of girls in Moscow over a 100-year period.

This study aimed to assess the centenary trend of physical development of school-age girls in Moscow.

METHODS

This retrospective study included an analysis of the results of the authors' own research and archival data [12–15]. A total of 4581 schoolgirls were observed. Body length and weight, chest circumference, and muscle strength of the right arm were measured using standard certified medical instruments (e.g., anthropometer, medical scales, centimeter tape, and hand dynamometer) according to the standard anthropometric method [16]. Additionally, the formation of menstrual function was studied in 893 female students born in the 1990s–2000s and studying at Moscow Universities in 2008–2023.

A standardized questionnaire was used to collect data on reproductive health and identify menstrual disorders among girls [17].

The questionnaire allowed for determining the age of menstruation, regularity of the menstrual cycle, duration of the menstrual cycle, and presence of menstrual disorders.

To assess the socioeconomic status of the girls' families, the Family Affluence Scale was employed according to the Health Behavior in School-aged Children (HBSC) questionnaire [18].

Statistics analysis

Obtained data were statistically processed using Statistica 10.0 (StatSoft, USA). Descriptive statistics were used; the arithmetic mean values, squared errors of means, and mean square deviations were calculated. In determining the normality of the distribution of indicators, a single-sample Kolmogorov–Smirnov normality test was used, and asymmetry, kurtosis, and their standard errors were analyzed. All quantitative indicators in the studied subgroups demonstrated a normal distribution. The Student's t-test was utilized to assess the significance of differences in average values. The differences were considered significant when $t \geqslant 2.0$–($p < 0.05$); $t \geqslant 2.6$–($p < 0.01$); and $t \geqslant 3.3$–($p < 0.001$).

Conjugacy tables were created to describe the statistical relationship of qualitative indicators with a small number of discrete variants, and the relationships between the indicators were described by the Pearson conjugacy coefficient, ranging from 0 to 1. An increase in the coefficient indicated an increase in the degree of connection.

The relative risk calculation was used to determine the probability of a certain outcome depending on a certain factor.

RESULTS

At the beginning of the 21st century, a significant increase was observed in the body length of Moscow schoolgirls in all age groups by an average of 3–5 cm compared to their peers in the 1960s, and a significant increase in body length by an average of 2–3 cm was observed in the age groups of 9–15 years compared with their peers in the 1980s (Table 1).

Furthermore, at the beginning of the 21st century, Moscow schoolgirls aged 10–14 years were significantly ahead by 2–4 kg of their peers in the 1960s and those aged 10–13 years by 2–3.5 kg of their peers in the 1980s.

The chest circumference of Moscow schoolgirls in the 1980s was smaller than that of Moscow schoolgirls in the 1960s, indicating a gracilized physique. Additionally, at the beginning of the 21st century, Moscow schoolgirls of all age groups showed a significant increase in chest circumference by 3–6 cm compared to their peers in the 1980s and by 2–4 cm compared to schoolgirls in the 1960s.

However, muscle strength of the right hand continued to decrease ($p < 0.001$). The difference in values between the Moscow schoolgirls of the early 21st century and contemporaries of the 1980s did not exceed 9 kg, and in comparison to peers of the 1960s, a significant difference was up to 11.4 kg by age 17 years.

In the 1920s, the maximum annual increases in body length were observed in Moscow girls aged 14–15 years (Figure 1), whereas at the beginning of the 21st century, the maximum annual increases shifted to earlier periods. The maximum increase in body length was recorded in Moscow schoolgirls aged 11–12 years, and growth processes in most girls were complete by aged 16 years (the average value of weight gain from 16 to 17 years was <1 cm) (Table 2).

One of the main indicators of biological maturation is the formation of menstrual function. Archival data and the present study show a significant decrease in the age of menarche (from 15.3 to 12.9 years old) from 1920 to 2020.

Table 1. Indicators of physical development of Moscow schoolgirls aged 8–17 years in different decades: 1960–1969 [13], 1982–1991 [14–15], and 2003–2012 (our results), M ± m

Age	Year of observation	n	Body length (cm)	Body weight (kg)	Chest circumference (cm)	Muscle strength of the right hand (kg)
8 years	1960	288	125.66 ± 0.32	25.54 ± 0.28	60.50 ± 0.22	10.4 ± 0.2
	1982	125	127.78 ± 0.51	26.23 ± 0.41	58,27 ± 0.33	13.3 ± 0.2
	2003	143	129.12 ± 0.47	25.48 ± 0.46	62.34 ± 0.44	5.5 ± 0.2
	p 1960–2003		<0.001	=0.911	=0.008	<0.001
	p 1982–2003		=0.054	=0.225	=0.003	<0.001
9 years	1961	291	130.64 ± 0.34	29.17 ± 0.29	62.74 ± 0.26	13.2 ± 0.2
	1983	125	132.83 ± 0.55	29.48 ± 0.49	61.49 ± 0.34	15.8 ± 0.3
	2004	181	134.60 ± 0.52	29.62 ± 0.52	65.10 ± 0.45	6.9 ± 0.1
	p 1961–2004		<0.001	=0.451	=0.004	<0.001
	p 1983–2004		=0.021	=0.586	<0.001	<0.001
10 years	1962	287	136.47 ± 0.38	32.63 ± 0.36	64.26 ± 0.29	13.9 ± 0.2
	1984	125	137.63 ± 0.57	32.45 ± 0.56	63.41 ± 0.38	17.3 ± 0.3
	2005	182	140.47 ± 0.47	34.71 ± 0.62	67.51 ± 0.55	9.7 ± 0.2
	p 1962–2005		<0.001	=0.004	=0.003	<0.001
	p 1984–2005		=0.008	=0.004	<0.001	<0.001
11 years	1963	248	142.88 ± 0.45	36.38 ± 0.44	67.80 ± 0.33	17.0 ± 0.3
	1985	125	144.10 ± 0.65	36.67 ± 0.65	64.65 ± 0.47	18.1 ± 0.3
	2006	167	146.59 ± 0.56	39.87 ± 0.78	70.28 ± 0.60	13.4 ± 0.2
	p 1963–2006		<0.001	=0.003	=0.004	=0.002
	p 1985–2006		=0.003	=0.003	<0.001	<0.001
12 years	1964	148	147.20 ± 0.60	41.30 ± 0.60	70.80 ± 0.40	21.2 ± 0.3
	1986	125	150.20 ± 0.60	41.90 ± 0.70	68.80 ± 0.50	20.4 ± 0.4
	2007	118	153.20 ± 0.64	44.40 ± 0.97	74.60 ± 0.79	14.7 ± 0.3
	p 1964–2007		<0.001	=0.003	<0.001	<0.001
	p 1986–2007		<0.001	=0.004	<0.001	<0.001
13 years	1965	148	154.80 ± 0.50	46.80 ± 0.70	75.00 ± 0.40	25.9 ± 0.4
	1987	125	156.40 ± 0.60	47.20 ± 0.80	73.70 ± 0.50	23.3 ± 0.4
	2008	119	159.40 ± 0.60	50.70 ± 0.97	78.40 ± 0.66	16.7 ± 0.4
	p 1965–2008		<0.001	<0.001	<0.001	<0.001
	p 1987–2008		<0.001	=0.004	<0.001	<0.001
14 years	1966	148	158.00 ± 0.50	50.60 ± 0.60	76.70 ± 0.40	29.4 ± 0.5
	1988	125	160.00 ± 0.50	52.20 ± 0.80	76.40 ± 0.50	24.8 ± 0.4
	2009	86	162.60 ± 0.64	53.20 ± 1.09	80.40 ± 0.67	20.9 ± 0.5
	p 1966–2009		<0.001	=0.021	<0.001	<0.001
	p 1988–2009		<0.001	=0.069	<0.001	<0.001
15 years	1967	148	159.70 ± 0.50	54.10 ± 0.60	78.40 ± 0.30	31.4 ± 0.4
	1989	125	162.00 ± 0.50	54.80 ± 0.80	79.20 ± 0.50	25.9 ± 0.4
	2010	120	164.25 ± 0.50	56.20 ± 1.02	82.10 ± 0.60	21.9 ± 0.4
	p 1967–2010		<0.001	=0.065	<0.001	<0.001
	p 1989–2010		=0.003	=0.057	<0.001	<0.001
16 years	1968	148	160.20 ± 0.50	56.30 ± 0.60	79.5 ± 0.40	31.4 ± 0.4
	1990	125	163.10 ± 0.50	56.90 ± 0.70	80.0 ± 0.40	26.2 ± 0.4
	2011	118	164.63 ± 0.53	57.41 ± 0.99	82.71 ± 0.61	21.4 ± 0.4
	p 1968–2011		<0.001	=0.058	<0.001	<0.001
	p 1990–2011		=0.061	=0.073	<0.001	<0.001
17 years	1969	148	160.80 ± 0.50	58.10 ± 0.60	80.80 ± 0.30	33.3 ± 0.5
	1991	125	163.40 ± 0.50	57.60 ± 0.70	81.00 ± 0.50	26.2 ± 0.3
	2012	95	164.52 ± 0.63	58.05 ± 1.35	83.47 ± 0.80	21.9 ± 0.4
	p 1969–2012		<0.001	=0.097	<0.001	<0.001
	p 1991–2012		=0.057	=0.083	=0.004	<0.001

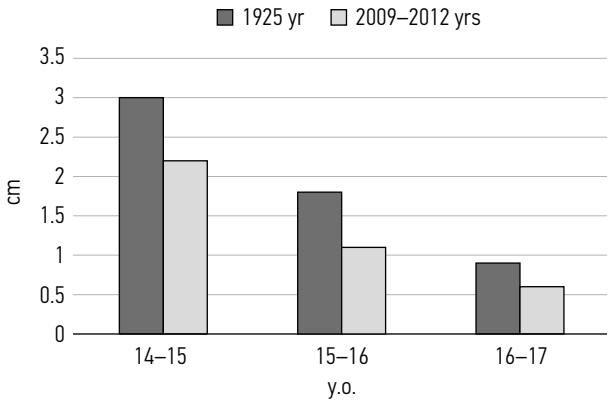

Fig. 1. Annual increase in body length in Moscow girls in the 1920s and early 21st century, cm.

Table 2. Annual increase in body length in Moscow schoolgirls at the beginning of the 21st century (2008–2023), M ± m

Age	Annual increase (cm)	
	n	M±m
8 to 9 years	111	5.51±0.12
9 to 10 years	150	5.64±0.12
10 to 11 years	135	5.96±0.16
11 to 12 years	115	6.54±0.18
12 to 13 years	94	4.84±0.23
13 to 14 years	92	3.78±0.21
14 to 15 years	84	2.15±0.19
15 to 16 years	78	1.06±0.14
16 to 17 years	58	0.60±0.13

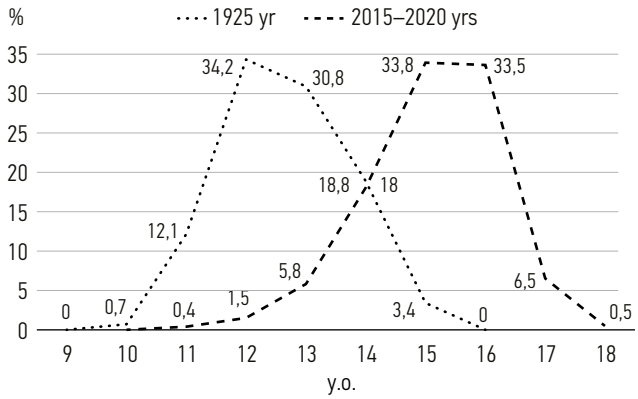

Fig. 2. Distribution of Moscow girls by age of menarche in the 1920s and early 21st century, %.

The average values of the age of menarche in girls and their distribution by age of menarche were of interest (Figure 2).

In 1925, menarche occurred at age 11 years in 0.4% of girls in Moscow and at age 10 years in 0.7% in 2015–2020. Moreover, in 1925, 33.8% of menarche cases occurred at the age of 15 and 33.5% of cases at the age of 16, and some girls experienced late menarche (delayed biological development). In 2015–2020, there was a significant shift in the age of menarche to earlier periods. In 34.2% of cases, menarche occurred at the age of 12 and in 30.8% at the age of 13 ($p = 0.0357$)

Over the past century, the standard of living of families in the metropolis such as Moscow has undergone significant changes. Unfortunately, historical data were not included in this study; however, the standard of living of families of modern Moscow girls was studied. The standard of living of a family reflects the amount of real income per capita and the degree to which the family is provided with spiritual and material goods. This indicator includes both economic and social factors that can influence the formation of menstrual function in girls. Analysis of the socioeconomic status of families using the Moscow girls' responses to the international HBSC questionnaire showed that 22.2% live in families with low income, 33.3% in families with average income, and 44.5% in families with high income.

Only 20.9% of families did not have a car; the remaining families had one, two, or more cars. Each family had two or more computers. Only 17.5% of girls in the last 12 months did not leave their country for holidays/vacations with their family, and 38.1% of girls did not have their own room.

Furthermore, the age of menstruation in Moscow girls from families with low income and those from families with medium and high income was compared. The average age of the onset of menstruation in girls from low-income families was 153.79 ± 11.29 months and 146.95 ± 9.26 months in girls from middle- and high-income families, which showed no significant differences. However, the Student's t-test result was 1.91 at $p = 0.689$, indicating a later onset of menstruation in girls from low-income families. Accordingly, menarche occurred at age between 11 years 9 months and 13 years 8 months in girls from families with a low level of income and between 11 years 5 months and 13 years 0 months in girls from families with a medium and high level of income.

According to the survey results, 11.8% of the girls surveyed had a menstrual cycle disorder, namely, irregular menstrual cycle. Moreover, polymenorrhea (the duration of the menstrual cycle is less than 21 days) was noted in 1.9% of girls.

In addition, opsomenorrhea (the duration of the menstrual cycle is longer than 35 days) was observed in 6.7% of girls. The correlation between the presence of menstrual disorders in girls by the type of irregular menstrual cycle and the duration of the menstrual cycle was investigated (Pearson's conjugation coefficient was 0.52 at $p < 0.001$).

In general, various menstrual disorders were detected in 22.7% of girls. The relative risk value was 1.39 (DI = 1.2–1.5), indicating that girls from a family with a low level of income have increased risk of developing menstrual disorders.

DISCUSSION

The physical development of children and adolescents in Russia has been studied for over 100 years; the present study proves that it depends on various factors [2, 8, 16]. The physical development of children, adolescents, and youth in Moscow has been studied since the 1920s; the results of the studies were regularly published, particularly in the collection of P.I. Kurkin, "Moscow working youth. Issue II," published in 1925 [12].

Further, data on the physical development of the child population were published in seven collections, "Materials on the physical development of children and adolescents in cities and rural areas of the USSR (Russia)," published in 1962, 1965, 1977, 1986, 1998, 2013, and 2019 [13–15, 19, 20].

The cyclical nature of changes in the physical development of children in the 20th century was shown: overcoming the post-war lag in physical development in the mid-1950s, acceleration of growth and development from the 1960s to the mid-1970s, and slowing down of physical development from the late 1980s with gracilization of the physique until the early 2000s (Table 1) [21, 22].

Gracilization was accompanied by a decrease in muscle strength of the right hand [23, 24].

This study showed the centenary dynamics of physical development of Moscow schoolgirls, which is characterized by various trends in differences between anthropometric characteristics and indicators of biological development of schoolgirls. Long-term trends of changes in physical development indicators were also noted in other studies [1, 3, 13, 25–29]. In most European countries, stabilization of physiological and growth processes with a simultaneous increase in body weight was noted at the end of the 20th century—the beginning of the 21st century. In recent years, several studies have shown that weight gain is related to physical fitness. As body weight increased, BMI also increased, which influenced this trend in China, Sweden, and New Zealand [30–32]. Weight gain was becoming widespread among European countries that many researchers spoke of an "obesity epidemic." During puberty, there were trends similar to the Russian ones [4, 5, 19, 26]. The present study is the first to investigate age-old changes in the dynamics of the physical development of girls in Moscow in connection with the main biological feature of girls and the influence of a social factor.

Social and hygienic monitoring includes the systematic monitoring of the physical development and health status of children, which contributes to the timely development and implementation of priority preventive and health measures [11]. Moreover, analysis of the centenary trend revealed global changes in the development of girls, which is crucial for making decisions for the long term.

CONCLUSION

Modern Moscow schoolgirls demonstrate significant differences in body length in all age groups compared with their peers in the 1960s. Moscow girls in the 1990s and 2010s entered adulthood with almost the same body length.

Furthermore, the leading indicator of the biological development of girls shows the opposite trend. In the centenary dynamics, the trend line shows a significant downward trend in the age of menarche. Analysis of the age of menarche showed that in 30% of cases, modern Moscow girls menstruate 3 years earlier than their peers in the 1920s. It is also revealed that the age of menarche depends on the level of wealth of the family of the girl.

Thus, in the dynamics of 100 years of observation in Moscow schoolgirls, an increase in total body size, a decrease in functional indicators, and a shift in biological development to earlier terms were observed.

ADDITIONAL INFORMATION

Author contributions: O.Yu.M.: conceptualization, writing—review & editing, resources, supervision; N.A.S.: methodology, validation, investigation, resources; O.V.S.: visualization, validation, project administration; M.Yu.G.: investigation, formal analysis, writing—original draft; E.V.S.: investigation, resources, data curation. All authors approved the version of the manuscript to be published and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Statement of originality: This work was created using data from previous publications ([12–15] distributed under the terms of the CC-BY 4.0 license).

Data availability statement: The authors declare that access to the data is limited and can be obtained upon request. The request must be adequately substantiated in a free form and supported by the protocol of the designed study and approval from the ethics committee.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. О.Ю.М. — разработка концепции, пересмотр и редактирование рукописи, обеспечение исследования, руководство исследованием; Н.А.С. — разработка методологии, валидация результатов, проведение исследования, обеспечение исследования; О.В.С. — визуализация, валидация результатов, администрирование проекта; М.Ю.Г. — проведение исследования, анализ данных, написание черновика рукописи; Е.В.С. — проведение исследования, обеспечение исследования, работа с данными. Все авторы одобрили рукопись (версию для публикации), а также согласились нести ответственность за все аспекты работы, гарантируя надлежащее рассмотрение

и решение вопросов, связанных с точностью и добросовестностью любой её части.

Этическая экспертиза. Проведение исследования одобрено локальным этическим комитетом при Самарском государственном медицинском университете (протокол № 196 от 07.11.2018). Все участники исследования добровольно подписали форму информированного согласия до включения в исследование.

Источники финансирования. Отсутствуют.

Раскрытие интересов. Авторы заявляют об отсутствии отношений, деятельности и интересов за последние три года, связанных с третьими лицами (коммерческими и некоммерческими), интересы которых могут быть затронуты содержанием статьи.

Оригинальность. При создании настоящей работы были использованы данные, опубликованные ранее ([12–15], распространяется на условиях лицензии CC-BY 4.0).

Доступ к данным. Авторы заявляют об ограниченном доступе к данным — по запросу, обоснованному в свободной форме с предоставлением протокола планируемого исследования и одобрения этического комитета.

Генеративный искусственный интеллект. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовали.

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