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Gender-age peculiarities of disability-adjusted life years (DALYs) in tuberculosis in a high-density region: a retrospective cohort study

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ABSTRACT

Background. Infections associated with socially significant diseases considerably contribute to a decrease in the quality of public health. Tuberculosis, though declining in Russia, is still recognized as a pressing public health problem. Meanwhile, an assessment of the burden of tuberculosis on society, using such comprehensive methods as measuring disability-adjusted life years, is yet to be investigated in Russia. **Objective.** To estimate the tuberculosis burden by calculating the index of disability adjusted life years in a high-density region. **Methods.** The retrospective cohort study involved data on newly-diagnosed and died of tuberculosis cases that corresponded to the annual reporting form of federal statistical surveillance No. 8 "Information on active tuberculosis cases" for the Republic of North Ossetia-Alania; information on patients who died of tuberculosis or tuberculosis combined with infection caused by human immunodeficiency virus, was obtained from the Department of Civil Status Records of the Republic of North Ossetia-Alania and verified with data from the Federal State Statistics Service; data on tuberculosis-associated disability was received from Main Bureau of Medical and Social Expertise in the Republic of North Ossetia-Alania of the Ministry of Labor and Social Protection of the Russian Federation for 2018 and 2022. Following the analytic dataset, 691 people with newly-diagnosed tuberculosis, who received TB-associated disability and died from TB in 2018 (318 people) and 2022 (373 people) were identified. The study involved calculation of gender and age standardized TB morbidity and mortality rates as well as DALY index with its components: Years of Life Lost due to tuberculosis and Years Lost due to Disability**.** The study involved comparing data between 2018 and 2022 and gender/age-specific indicators within the same year. Mathematical data processing was performed using Microsoft Excel 2017 (Microsoft Corporation, USA) and SPSS 26.0 (SPSS Inc., USA). Differences between the compared indicators were evaluated by Chi-square criterion with variations, the initial data were grouped in a contingency table, the significance of differences was expressed by p-value. **Results.** The burden of tuberculosis in the Republic of North Ossetia-Alania refers predominantly to the male population: with a gender difference in the decrease in the disability-adjusted life years in 2018 and 2022 by 4.4 and 9.0 times ($p < 0.05$), respectively; 2.8 times among males, 5.5 times among females ($p < 0.05$). The burden of tuberculosis is mainly associated with premature mortality due to tuberculosis among males aged 35–54 years and among females aged 35–44 years with a pronounced decrease in Years of Life Lost. Years of Life Lost among males aged 20–34 in 2022 appears two times higher than the cohort average. The increase in Years of Life Lost among males aged 60–64 accounted for 1.7 times, in Years Lost Due to Disability — 11.2 times ($p < 0.05$). Years Lost Due to Disability among females aged 20–44 years appeared to be the highest, exceeding the cohort average by more than two times in 2018. **Conclusion.** The burden of tuberculosis is predominantly due to tuberculosis-related premature mortality among the male population. According to the disturbing conclusion, Years of Life Lost among young males aged 20–34 years and tuberculosis-related premature mortality shift towards the male population of pre-retirement age (60–64 years) with an increase in Years Lost Due to Disability among them. Notably, the study reveals high rates of Years Lost Due to Disability among females aged 20–44. The results obtained should be taken into account when developing regional tuberculosis programs with their targeted use in "vulnerable" age and gender groups of the population.

KEYWORDS: tuberculosis, global burden of disease, DALY, morbidity, mortality, gender, age

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Половозрастные особенности потерь жизненного потенциала с поправкой на инвалидность (DALYs) при туберкулезе в регионе с высокой плотностью населения: когортное ретроспективное исследование

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АННОТАЦИЯ

Введение. Социально значимые инфекции вносят существенный вклад в снижение качества общественного здоровья. Туберкулез, несмотря на снижение показателей в России, все еще остается актуальной проблемой здравоохранения. Между тем исследования по оценке бремени туберкулеза, оказываемого на общество, с применением таких комплексных методов, как вычисление индекса Disability adjusted life years (индекс потерянных лет жизни с поправкой на инвалидность), в нашей стране до сих пор весьма ограничены. **Цель исследования —** оценка бремени туберкулеза с вычислением количества потерянных лет жизни с поправкой на инвалидность в регионе с высокой плотностью населения. **Методы.** В когортное ретроспективное исследование включены данные по впервые выявленным случаям и умершим от туберкулеза, соответствовавшие ежегодной отчетной форме федерального статистического наблюдения № 8 «Сведения о заболеваниях активным туберкулезом» по Республике Северная Осетия — Алания; информация по умершим от туберкулеза пациентам, в том числе с сочетанием с инфекцией, вызванной вирусом иммунодефицита человека, полученная из Управления записи актов гражданского состояния Республики Северная Осетия — Алания и сверенная с данными Федеральной службы государственной статистики; данные по инвалидности в связи с туберкулезом, полученные из федерального казенного учреждения «Главное бюро медико-социальной экспертизы по Республике Северная Осетия — Алания» Министерства труда и социальной защиты Российской Федерации за 2018 и 2022 гг. На основе анализа массива данных выделен 691 человек с впервые выявленным туберкулезом; получившие инвалидность в связи с туберкулезом и умершие от него в 2018 (318 человек) и 2022 годах (373 человека). Вычислены стандартизованные половозрастные показатели заболеваемости и смертности от туберкулеза, также индексы Disability adjusted life years с его составляющими: Years of life lost (потерянные годы жизни из-за заболеваемости и преждевременной смертности) от туберкулеза и Years lost due to disability (потерянные годы жизни по причине инвалидности). Сравнивались данные между 2018 и 2022 годами, также половозрастные показатели внутри одного года. Математическая обработка данных выполнена на базе программы Microsoft Excel 2017 (Microsoft Corporation, США) и программы SPSS.26.0 (SPSS Inc., США). Различия сравниваемых показателей оценивались по критерию Хи-квадрат с дополнениями, с группировкой исходных данных в виде таблицы сопряженности, уровень значимости различий выражался по p-value. **Результаты.** Бремя туберкулеза в Республике Северная Осетия — Алания преимущественно несет мужское население: с межгендерным различием снижения показателя индекса потерянных лет жизни с поправкой на инвалидность в 2018 г. и 2022 г. в 4,4 и 9,0 раза ($p < 0,05$) соответственно; среди мужчин — в 2,8 раза, среди женщин в 5,5 раза ($p < 0,05$). Основное бремя туберкулеза обусловлено преждевременной смертностью от туберкулеза, преимущественно среди мужчин возраста 35–54 лет; среди женщин 35–44 лет, с выраженным снижением индекса Years Life Lost среди них. Индекс Years Life Lost среди группы мужчин 20–34 года в 2022 г. был в 2 раза выше средних данных когорты. Рост Years Life Lost среди группы мужчин 60–64 лет составил 1,7 раза, а рост Years Lost Due to Disability — в 11,2 раза ($p < 0,05$). Индекс Years Lost Due to Disability среди женщин возраста 20–44 лет был наиболее высоким, превысив средний показатель когорты более чем в 2 раза в 2018 г. **Заключение.** Бремя туберкулеза преимущественно обусловлено преждевременной смертностью от него среди мужского населения. Настораживают потери жизненного потенциала среди группы мужчин молодого возраста 20–34 лет и смещение преждевременной смертности от туберкулеза в сторону мужского населения предпенсионного возраста 60–64 лет на фоне роста Years Lost Due to Disability среди них. Также обращают на себя внимание высокие показатели Years Lost Due to Disability среди женщин 20–44 лет. Полученные результаты необходимо учитывать при разработке региональных программ по туберкулезу с целенаправленным использованием ресурсов в «уязвимых» половозрастных группах населения.

КЛЮЧЕВЫЕ СЛОВА: туберкулез, глобальное бремя болезни, DALYs, заболеваемость, смертность, пол, возраст

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ИСТОЧНИКИ ФИНАНСИРОВАНИЯ: авторы заявляют об отсутствии спонсорской поддержки при проведении исследования.
КОНФЛИКТ ИНТЕРЕСОВ: авторы заявляют об отсутствии конфликта интересов, связанных с публикацией настоящей статьи.
ДЕКЛАРАЦИЯ О НАЛИЧИИ ДАННЫХ: данные, подтверждающие выводы настоящего исследования, не являются общедоступными, они получены авторами в ходе проведения исследования; при необходимости их можно запросить у корреспондирующего автора. Данные и статистические методы, представленные в статье, прошли статистическое рецензирование редактором журнала – сертифицированным специалистом по биостатистике.
СООТВЕТСТВИЕ ПРИНЦИПАМ ЭТИКИ: Проведение исследования одобрено локальным этическим комитетом по экспертизе эпидемиологических и социологических исследований в сфере общественного здоровья и здравоохранения при федеральном государственном бюджетном научном учреждении «Национальный научно-исследовательский институт общественного здоровья имени Н.А. Семашко» (ул. Воронцово Поле, 12, стр. 1, г. Москва, Россия), заключение № 15/2023 от 25.01.2023 г.
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INTRODUCTION

In times of increasing global challenges arising due to technology-related, environmental, biological, military, political, and other reasons, the preservation of public health is of particular importance.[1] The integrity and national security of any country largely depend on the level of public health defined as the medical and social resources of a specific state, as well as the potential of its society [1]. In general, the level of public health is assessed using several economic, sociological, demographic, biomedical, and other determinants defined by specific indicators [2].

In measuring the social burden of individual diseases, it is most common to use the epidemiological analysis of intensive and extensive "crude" or standardized morbidity, mortality, and period prevalence rates [3, 4]. It is known that these rates give only a general idea (indication) of the social burden of the disease. For a more profound and comprehensive assessment of the socioeconomic burden of various pathologies, including comorbid conditions, a method is used, primarily abroad, for calculating disability-adjusted life years (DALYs) associated with morbidity and premature mortality from a particular disease by gender and age group [5–9]. The DALYs measure was first developed in the 1990s by Christopher J. Murray and Alan Lopez on the initiative of the World Bank and the World Health Organization (WHO) to systematically assess the burden of various diseases, injuries, and risk factors at the global, regional, and national levels [10].[2] The DALYs calculation procedure, as detailed in the book by Nuria Homedes, presents some difficulties, primarily due to the low availability of information, specifically data on disability, as well as the cumbersome nature of calculations.[3] However, with the current development of digital technologies and the accumulation of large personalized population databases, the significance of these factors is rapidly decreasing, as well as in Russia.[4] In addition, in 2020, WHO developed a simplified way to calculate DALYs, proposing that losses due to disability should be calculated only as the product of disease prevalence and disability weight.[5] The main advantage of DALYs calculation is that, along with the estimation of social and economic losses incurred by the society due to morbidity and premature mortality from various causes in a particular gender and age group of the population, this method provides a means to make and implement management decisions not only in the health care system but also at the political level of the country as a whole.[4]

As we noted above, the DALYs measure is more commonly used in foreign countries than in Russia to assess the burden of a disease; however, in recent years this method has been considered more frequently in the national scientific literature. For example, several studies were conducted in the Tomsk Region

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to calculate the DALYs measure among the entire population of the region and children aged 0–17 years; the social burden of gynecologic oncology disease was also determined [11, 12]. In the Republic of Sakha (Yakutia) the damage caused to the society by alcohol consumption was estimated among the working-age population [13]; health losses of Kemerovo residents from myocardial infarction[6] and health losses of the Russian population from oncology disease, as well as from naturally occurring infections, were determined, as measured by DALYs [14, 15]. Of interest are the recommendations for applying DALYs in the construction industry, where the amount of economic production losses caused by the morbidity and premature mortality of workers is calculated.[7]

The burden of socially significant infectious diseases (SSIDs), which, among others, in Russia include tuberculosis (TB), HIV infection, parenteral viral hepatitis, and sexually transmitted infections,[8] significantly reduces the level of public health both in the world[9] and in Russia [16–18]. Globally, HIV infection has become one of the four reasons behind the rise in DALYs among adolescents and adults, with a 58.5% increase in the measure among the total population in 1990–2019, while in 16 Middle-Eastern and North African countries, the DALYs burden of HIV infection has also increased in all gender and age groups over the same period [19, 20]. Viral hepatitis C and B account for 26% and 23%, respectively, of liver cirrhosis worldwide as measured by DALYs. In Japan, among vaccine-preventable infectious diseases, viral hepatitis B and TB ranked below influenza in 2008–2020, as measured by DALYs [22]. In the Republic of Korea, TB became the second most significant disease following upper respiratory tract infections according to the DALYs measure, with the highest level found among men and elderly patients aged over 80 years [23]. In China, the TB-related DALYs measure was also higher among men and people over the age of 70 years [24]. In Colombia, the TB-related DALYs measure amounted to 56% among the working-age population aged between 15 and 69 years and 68.4% among men [25]. Noteworthy are the results of a study conducted in Kazakhstan to assess the burden of syphilis, one of the sexually transmitted infections; in the study, the DALYs measure calculated per 100,000 population by gender and age group was high among children under five years of age, which the authors attributed to perinatal infection [26].

In Russia, studies assessing the burden of SSIDs with DALYs calculation are very limited. Analyzing the dynamics of mortality from TB, HIV infection, and parenteral viral hepatitis, Sergey Sterlikov et al. note a reduction in the number of years of life lost due to SSIDs in 2015–2020, primarily due to a decrease in TB [27]. Another study, which was conducted in the Orel Region, found that among the HIV-positive population, the DALYs measure was highest in the 30–39 age group [28]. No domestic studies are available on the estimation of years of life lost due to SSIDs and other diseases depending on population density. In foreign publications, such data are also limited; we found only one study reporting a high TB-related DALYs measure among the favela population of Rio de Janeiro, with a high density of informal settlements [29].

The critical analysis of scientific publications shows that the use of DALYs is very limited in our country in the comprehensive assessment of the impact that the burden of SSIDs has on public health in Russia, and no such studies taking into account population density are available. Of note is that SSIDs, specifically TB, HIV infection, and their comorbidity, remain relevant, reducing the level of public health (in Russia for 2015–2020). Among the infectious and parasitic diseases contributing to years of life lost, HIV infection accounts for 70.5%, while TB comorbid with HIV infection accounts for 21.3% [27]. In 2019, TB was among the top ten global causes of high disease burden, as measured by DALYs.[9]

The study **aims** to assess the socioeconomic burden of socially significant infectious diseases on the example of TB by calculating the number of disability-adjusted life years (DALYs) in a high-density region.

METHODS

Study design

A retrospective cohort study was conducted.

Study conditions

The study was conducted at the premises of the N.A. Semashko Research Institute of Public Health and the Republican Clinical Republican Clinical Center of Phthisiopulmonology of the Ministry of Health of the Republic of North Ossetia-Alania. The study analyzed and compared data for 2018 and 2022.

Eligibility criteria

Inclusion criteria

The study included data on all TB cases newly diagnosed in the population of the Republic of North Ossetia-Alania, as well as patients who died from TB, including those with TB comorbid with HIV infection, for 2018 and 2022. Only the patients aged 15 and older were included in the DALYs calculation.

Exclusion criteria

The DALYs calculation study excluded the pediatric population aged between 0 and 14 years due to the absence of TB-related deaths and disabilities among them in 2018 and 2022.

Removal criteria

Removal criteria are not provided in this study.

Description of the eligibility criteria

Data on newly diagnosed TB cases corresponded to the annual reporting form of federal statistical surveillance No. 8

[6] Tabakaev MV, Shapovalova EB, Maksimov SA, Artamonova GV. Population health losses from myocardial infarction estimated with index DALY in Kemerovo in 2006–2012 years. *Complex Issues of Cardiovascular Diseases.* 2014;1:21–25 (In Russ.).

[7] Burtseva AA, Gomazov FA. Recommendations for the use of DALY in the construction industry. *Information technologies and systems: management, economics, transport, and law.* 2022;52;164–165. (In Russ.).

[8] Resolution of the Government of the Russian Federation No. 715 of December 1, 2004 "On Approval of the List of Socially Significant Diseases and the List of Diseases that Constitute a Danger to the Public" (as amended and supplemented).

[9] Global health estimates: life expectancy and leading causes of death and disability. WHO. https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates

"Information on active tuberculosis cases" for the Republic of North Ossetia-Alania; information about patients who died of TB or TB comorbid with HIV infection, was obtained from the Department of Civil Status Records of the Republic of North Ossetia-Alania and verified with data from the Federal State Statistics Service; data on tuberculosis-related disability were consistent with those received from Main Bureau of Medical and Social Expertise in the Republic of North Ossetia-Alania of the Ministry of Labor and Social Protection of the Russian Federation for 2018 and 2022.

Selection of group members

The selection of study participants is presented in the description of eligibility criteria.

Target parameters in the study

Main parameters in the study

The target parameters of the study included standardized gender- and age-specific indicators of TB morbidity and mortality, as well as the DALYs measure and its components: YLL — years of life lost due to TB morbidity and premature mortality; YLD — years of life lost due to TB-related disability in the analyzed period in the Republic of North Ossetia-Alania.

Additional parameters in the study

Additional parameters are not provided in this study.

Methods for measuring the target parameters

TB morbidity and mortality rates are standardized by gender and age using the European gender-and-age standard per 100,000 population.[10] Average standardized TB morbidity and mortality rates for Russia are given in general, without division into age groups.

DALYs are calculated as follows[4, 5]:

$$DALYs = YLL+YLD. \quad (1)$$

Years of Life Lost due to premature mortality are calculated according to Eq. (2):

$$YLL=KCe^{ra}/(r+в)^2x\{e^{-(r+в)\,x\,б}x[1+(r+в)xб]-e^{-(r+в)x\,(L+б)}x[1+(r+в\,x(L+б))]\}+1-K/r\,x(1-e^{-rl}), \quad (2)$$

where: б — age of death in years; *L* — years not lived (difference between the standardized life expectancy at birth and age at death. Life expectancy at birth was in agreement with the annual data of the Federal State Statistics Service for the Republic of North Ossetia-Alania[11]; *r* — discount rate (3% or 0.03); *K* — age weight modeling constant (varying within the range of 0–1); в — age weight category (в = 0.04); *C* — constant age weight correction (*C* = 0.1658); Dw — disability weight, TB = 0.3 in case of disease, 1 — in case of death; *e* — logarithmic constant = 2.71.

Years Lost Due to Disability (years of life lost due to disability related to the TB) are calculated according to Eq. (3):

$$YLD=Dwx(KCe^{ra}/(r+в)^2x\{e^{-(r+в)\,x\,б}x[1+(r+в)xб]-e^{-(r+в)\,x\,(L+б)}x[+(r+в)x(L+б)]\}+1-K/r\,x(1-e^{-rl}), \quad (3)$$

where: б — age at onset in years; L — duration of disability in years; r — discount rate (3% or 0.03); K — age weight modeling constant (varying within the range of 0–1); в — age weight category (в = 0.04); C — constant age weight correction (C = 0.1658); Dw — disability weight, TB = 0.3 in case of disease, 1 — in case of death; e — logarithmic constant = 2.71.

Variables *(predictors, confounders, and effect modifiers)*

Changes in the gender and age composition of the region's population can act as confounders in the study; to reduce this modifying effect, all indicators were obtained from the official sources of the Federal State Statistics Service and relevant regional government agencies.

Statistical procedures

Principles behind sample size determination

By design, the study was a cohort study analyzing data for 2018 and 2022, which did not require sample size determination.

Statistical methods

Data entered into an Excel spreadsheet was mathematically processed using Microsoft Excel 2017 (Microsoft Corporation, USA) and SPSS.26.0 software (SPSS Inc., USA). The negative DALYs values, as well as values exceeding 100.0%, obtained for the group aged 65 years and over since the age of people in this group exceeded the life expectancy at birth were not interpreted due to the lack of their significance. Differences between the compared morbidity and mortality rates were evaluated using the chi-square test with extensions; the input data were grouped in the form of a contingency table; the significance level of differences was expressed as a p-value.

RESULTS

Sampling

The study included 691 patients with newly diagnosed and died of TB in the Republic of North Ossetia-Alania: 318 people in 2018 and 373 people in 2022. These included patients whose disability was TB-related (230 in total): 120 in 2018 and 110 in 2022; and those who died of TB (19 people in total): 13 in 2018 and 6 in 2022. Patients who died of TB could be identified prior to the study period. The study compared the DALYs measure and its components for 2018 and 2022, as well as evaluating differences between the measures by gender and age within the same year. Children were not included in the DALYs calculation study due to the absence of TB-related deaths and disability.

The block diagram of the study design is presented in Fig. 1.

Characteristics of the study sample (groups)

In the conducted study, the mean age of the patients and other characteristics of the participants, including socioeconomic, were not significant enough to describe them separately. The present study was aimed at assessing the burden of TB using a method for estimating the DALYs measure by gender and

[10] Sterlikov SA, Belilovskii EM, Golubev NA, Kucheryavaya DA. *Calculation of gender-age and standardized morbidity rates. Version 1.21.* Available: https://t.me/+ANfiYvtocj8wYmY6

[11] Federal State Statistics Service. *Demographics*. Available: https://rosstat.gov.ru/folder/12781

age group. Below we present a general characterization of the region where the study was conducted.

The Republic of North Ossetia-Alania is a federal entity of the Russian Federation, part of the North Caucasian Federal District, with a total area of 8,000 square kilometers; as of the beginning of January 2023, it had a population of 680,748, with a predominance of women (55.2%) and urban residents (63.2%)[11]. The main feature of the republic is its high population density amounting to 85.23 people/km^2, which ranks it right below the cities of Moscow and St. Petersburg, the Moscow Region and the Republic of Ingushetia, with the average indicator for Russia amounting to 8.55 people/km^2. In terms of gross regional product per capita, which was 527.8 thousand rubles in 2021, the Republic of North Ossetia-Alania belongs to the federal subjects characterized by an average economic level of development.

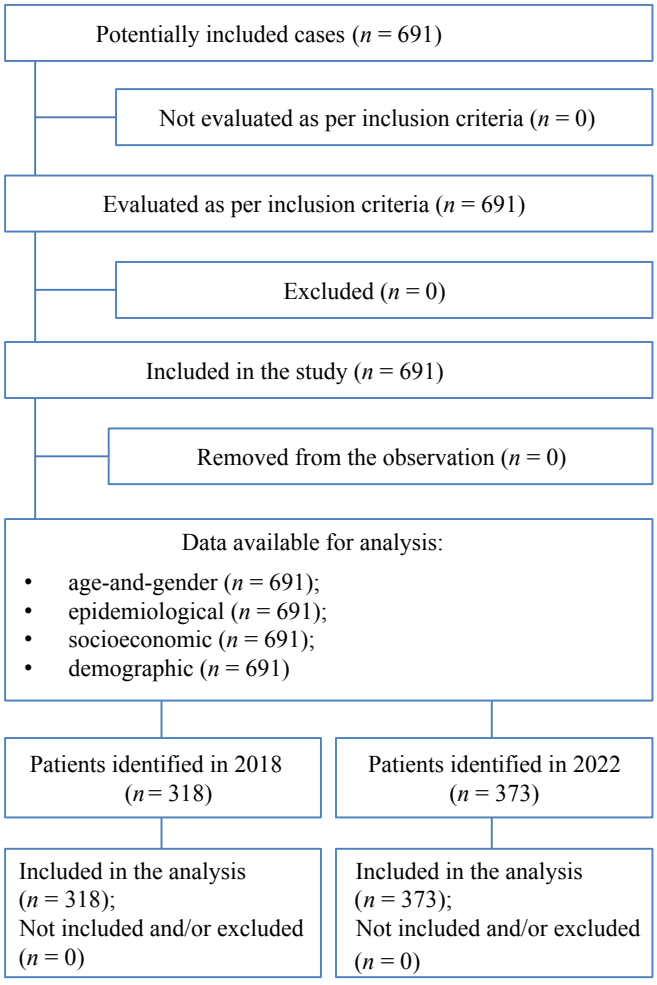

Fig. 1. DALY calculation: schematic diagram of the research design

Note: performed by the authors (according to STROBE recommendations).

Рис. 1. Блок-схема дизайна исследования по вычислению DALYs

Примечание: блок-схема выполнена авторами (согласно рекомендациям STROBE).

Main study results

As indicated in the table below, the standardized TB morbidity rates in the Republic of North Ossetia-Alania for 2018 and 2022 decreased in almost all age groups, except for the critical ages (0–6 years; 55 years and over), in which the rates tended to increase, especially among children. In general, the 35–44 year old population, predominantly males, were most affected by TB, with the indicator exceeding the study cohort average by 1.7–1.2 times in 2018 and 2022, respectively.

Among men aged 35–44 in 2018, the indicator was more than twice the cohort average. Men aged 45–54 years were also affected by TB, with the indicators exceeding the average by 1.6 and 2.4 times in 2018 and 2022, respectively. The TB morbidity rate of men aged 55–64 years, while moderately above average, was lower than in previous age groups but higher than in the group of people aged 65 years and over. In the 18–34 age group, the indicators did not exceed the average morbidity rate in the male cohort.

Among women, the standardized TB morbidity rate was lower than among men aged 25–64 years; however, it was higher in the groups of people aged between 0 and 24 years and 65 years and over. Women aged 65 years and over were most commonly affected by TB, with the indicators exceeding the average by nearly two times in 2022. Also, 15–17 year old adolescents and 18–24 year old adults were most affected by TB in the female cohort, with the indicator exceeding the average by 1.3 and 1.5 times, respectively, in 2018. Among women aged 25–64 years, the TB morbidity rate was lower or slightly higher than the corresponding average.

A gender comparison of the overall standardized TB morbidity rate in the Republic of North Ossetia-Alania with the average rates in Russia shows a 1.7 times higher TB morbidity rate among the male population in 2018 and a 1.4 times higher TB morbidity rate among the female population in 2022 in the Republic of North Ossetia-Alania as compared to the general Russian population. For the Republic of North Ossetia-Alania, the standardized TB morbidity rate was lower or slightly higher than that reported across Russia, with a 1.2-fold downward trend observed in 2018–2022.; in Russia, the TB morbidity rate decreased by 1.5 times during the analyzed period.

TB mortality in the Republic of North Ossetia-Alania was high in the same gender and age groups as TB morbidity, with a predominance of unfavorable outcomes among men. TB mortality among males aged 35–44 and 45–54 years was particularly high in 2018, exceeding the cohort averages by 2.0 and 2.5 times, respectively. Men aged 55 years and over also died frequently of TB, exceeding the average rate by 1.2–3.0 times in the study period. In 2018, no TB-related deaths were registered in the 25–34 age group; in 2019 and subsequent years, the TB mortality rate in this age group of men was lower or did not exceed the cohort average. No TB mortality in the groups aged 0–24 was reported in the region for 2018 and 2022.

Women died of TB significantly less often than men in the Republic of North Ossetia-Alania. The highest TB mortality rate was among women aged 35–44 years in 2018, which exceeded the female cohort average by 7.5 times. In 2022, wom-

Table. Gender-age standardized morbidity and mortality rates in tuberculosis, the Republic of North Ossetia-Alania and Russia* for 2018 and 2022 (per 100,000)
Таблица. Половозрастные стандартизованные показатели заболеваемости и смертности от туберкулеза в Республике Северная Осетия — Алания и России* за 2018 г. и 2022 г. (на 100 000 населения)

Age (years)	TB morbidity (per 100,000)						TB mortality (per 100,000)					
	2018			2022			2018			2022		
	Total	M	F	Total	M	F	Total	M	F	Total	M	F
0–4	11.1	10.2	12.1	21.6	16.9	27.0	0.0	0.0	0.0	0.0	0.0	0.0
5–6	4.3	8.1	0.0	16.2	10.1	23.1	0.0	0.0	0.0	0.0	0.0	0.0
7–14	19.6	16.9	22.4	6.7	5.0	8.6	0.0	0.0	0.0	0.0	0.0	0.0
15–17	31.8	29.2	34.4	16.3	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18–24	28.6	18.5	40.5	19.3	11.3	29.3	0.0	0.0	0.0	0.0	0.0	0.0
25–34	37.0	46.4	26.8	18.5	23.5	13.2	0.0	0.0	0.0	2.2	4.3	0.0
35–44	62.4	104.9	26.2	36.0	40.3	32.1	10.9	16.7	6.0	1.9	4.0	0.0
45–54	45.7	78.6	20.2	44.4	86.3	11.1	9.4	21.4	0.0	2.1	4.7	0.0
55–64	34.3	56.8	19.1	40.4	59.2	27.5	4.2	10.3	0.0	4.8	11.8	0.0
65+	42.1	38.7	44.2	45.2	44.4	46.2	3.8	11.9	0.0	2.8	5.5	1.4
Total	36.5	48.1	27.1	29.9	36.5	24.6	3.7	8.4	0.8	1.9	3.9	0.3
Russia	42.9	28.3	26.7	28.3	42.4	18.2	5.0	9.0	1.9	2.9	5.4	0.9

*Notes: compiled by the authors; *standardized mean TB incidence rates unrelated to age. Abbreviation: TB — tuberculosis; M — men; F — women.*
*Примечания: таблица составлена авторами; * приведены средние стандартизованные показатели заболеваемости ТБ без разделения на возрастные группы. Сокращение: ТБ — туберкулез; М — мужчины; F — женщины.*

en are reported to more frequently die of TB at ages of 65 or over, as well as contract the disease, exceeding the cohort average by 4.7 times in that year.

Region-wide, the standardized TB mortality rate was below the national average both among men and women, decreasing by 1.9 times in 2018–2022; in Russia, this indicator decreased by 1.7 times in this period.

Figure 2 shows that the socioeconomic burden of TB as measured by the DALYs measure tended to decrease in the Republic of North Ossetia-Alania in 2018–2022, with an overall 3.1-time reduction in the measure: by 2.8 times among men and by 5.5 times among women ($p < 0.05$). The social burden of TB was predominantly carried by the male population, with a 4.4-time gender difference in the DALYs measure in 2018 and a nearly 9-time difference in 2022 ($p < 0.05$).

Both among men and women, socioeconomic losses caused by TB in 2018 were mostly attributable to premature TB-related deaths. During the year, the YLL measure exceeded the YLD value in the cohort as a whole, by more than 2 times among men ($p < 0.05$) and by 1.4 times among women. By 2022, the YLL/YLD ratio has significantly changed: in the cohort, the number of years of potential life lost due to TB has

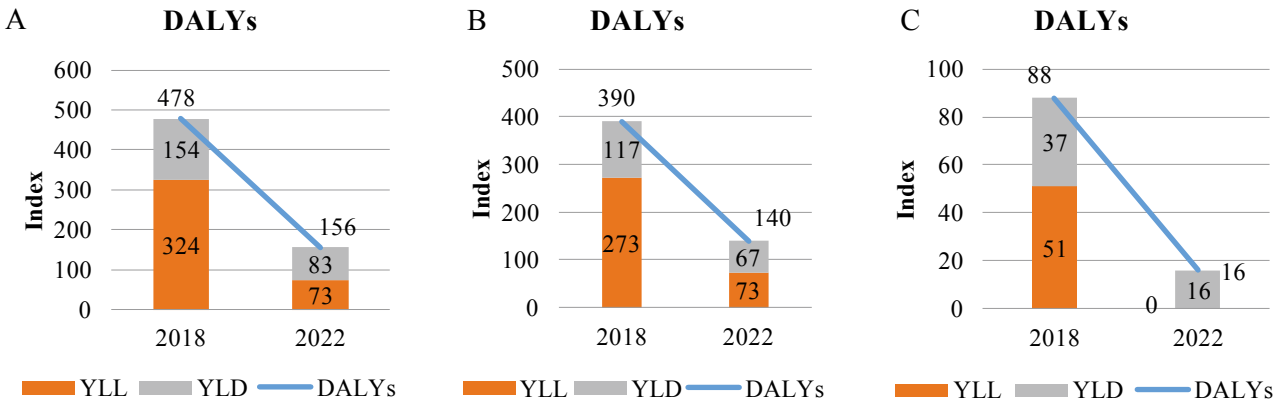

Fig. 2. DALYs associated with tuberculosis in the Republic of North Ossetia-Alania for 2018 and 2022: A — total for the region; B — males; C — females
Note: performed by the authors. Abbreviations: DALYs — Disability-Adjusted Life Years; YLL — Years Life Lost; YLD — Years Lost Due to Disability
Рис. 2. Потерянные годы жизни с поправкой на инвалидность (DALYs), связанные с туберкулезом, в Республике Северная Осетия — Алания за 2018 и 2022 гг.: А — всего по региону; В — мужчины; С — женщины
Примечание: рисунок выполнен авторами. Сокращения: DALYs — индекс потерянных лет жизни с поправкой на инвалидность (Disability adjusted life years); YLL — годы потерянной жизни в результате заболеваемости и преждевременной смертности (Years Life Lost); YLD — годы жизни, потерянные по причине инвалидности (Years Lost Due to Disability).

become lower than the YLD measure (years lost due to disability). Among men, the YLL/YLD ratio was nearly equalized at 1:1.1. Among women, the burden of TB was only associated with years lost due to disability in 2022.

During the study period, the DALYs measure per 100,000 population by gender and age group was highest among men aged 35–59 years and among women aged 35–44 years, with a marked tendency for the indicator to decrease by 2–5 times ($p < 0.05$), respectively (Fig. 3). In the 20–34 age group and the 60–64 age group, a trend was found toward an increased burden of TB with a 2.3- and 4.0-time increase ($p < 0.05$) in the DALYs measure, respectively, which was attributable to changes only among men. Among women, the DALYs measure decreased in all age groups in 2018–2022, except for the 15–19 age group, in which the measure that was non-existent in 2018 amounted to 3.4 per 100,000 population in 2022. The contribution of the group aged 65 years and over to the burden of TB was not significant.

The predominant association of TB burden with TB mortality, specifically among men, is supported by YLL data per 100,000 population by gender and age group (Fig. 4). The measure of years of potential life lost due to TB in the study period, while remaining highest in the 35–54 age group, tended to decrease in almost all age groups, except for the 55–59 age group, in which it remained stable (fig. 4A). Among people aged 20–34 years, the YLL measure, which was non-existent in 2018, amounted to 16.9 per 100,000 population in 2022. Overall, the YLL measure decreased by 4.4 times in 2018–2022 ($p < 0.05$).

In accordance with general trends, the YLL measure per 100,000 population among men was highest in the 35–44 and 45–54 age groups, with a marked 6.6- and 8.8-time decrease ($p < 0.05$), respectively, in 2018–2022 (Fig. 4B). Noteworthy is the 1.7-time increase in the YLL measure in the pre-retirement group of men[12] aged 60–64 in 2018–2022. In the 20–34 age group, the YLL measure, which was non-existent in 2018, amounted to 35.8 per 100,000 population in 2022, which is twice the male cohort average. Overall, the number of years of potential life lost due to TB decreased by 3.7 times ($p < 0.05$) among the male population in the Republic of North Ossetia-Alania in 2018–2022.

Among women, the burden of TB morbidity and premature mortality was lower than among men: in the 35–44 age group, the YLL measure was 95.7 per 100,000 corresponding population in 2018, which is 1.7 times lower than that of men (Fig. 4C). The overall YLL measure amounted to 12.9 per 100,000 population among women in 2018, which is more than five times lower than that among men ($p < 0.05$).

We also analyzed the burden of TB associated with YLD per 100,000 population by gender and age group as one of the socioeconomic factors reducing the level of public health (Fig. 5).

It is clear that the contribution of years lost due to TB-related disability, as compared to the role of years of potential life lost due to premature TB mortality, is much smaller, with its prevalence in the 55–59 age group rather than in the 35–54 age group as in the case of YLL (fig. 5A). Nevertheless, the YLD measure per 100,000 population is quite high among the group of people aged 34–54 years, while exhibiting a significant decrease in most age groups, except for the group aged 60–64 years, in which a 1.8-time increase in the measure was observed in 2018–2022 ($p < 0.05$). In the 15–19 age group, the measure, which was non-existent in 2018, amounted to 1.7 per 100,000 population in 2022. In 2018–2022, the YLD measure decreased by nearly half in the Republic of North Ossetia-Alania ($p < 0.05$).

The socioeconomic burden of TB associated with years lost due to disability is expectedly higher among men than among women, especially in the 55–59 age group, in which the YLD measure per 100,000 population is the highest among the male cohort, with a nearly 9-time gender difference between the indicators ($p < 0.05$). Among men aged 35–54 years, the YLD measure per 100,000 population is also high. In the analyzed period, a decrease in indicators was noted in all age groups, except for the pre-retirement group aged 60–64 years in the male cohort (similar to YLL), in which the YLD measure increased by 11.2 times during the study period. Overall, the YLD measure per 100,000 population among the male cohort decreased by 1.7 times in the region in 2018–2022 ($p < 0.05$).

Unlike the male cohort, the burden of TB associated with years lost due to disability was highest in the female cohort among the 20–34 age group and the 35–44 age group, exceeding the cohort average by more than 2 times in 2018 ($p < 0.05$). The decrease in the YLD measure per 100,000 population in 2018–2022 was reported in all age groups of the female cohort, specifically in the pre-retirement group aged 55–59 years, as well as in the 60–64 age group: by 6.5 and 5.2 times, respectively ($p < 0.05$). Overall, the YLD measure per 100,000 population among women in the Republic of North Ossetia-Alania decreased by 2.4 times during the study period ($p < 0.05$).

Additional research results

No additional results were obtained during the study.

DISCUSSION

Main findings of the study

In the present retrospective cohort study, we have assessed the socioeconomic burden of TB in a single high-density region with the correct application of a comprehensive and more sensitive method—DALYs calculation. The study results show that the main socioeconomic burden of TB on public health is associated with TB-related mortality in all the age groups (starting from the age of 20 years), with a tendency toward equalization between indicators and the data on years lost due to disability and shift toward the group of people aged 60 years and over among the male population. In the 35–44 age group, the number of years of potential life lost due to TB is highest among both men and women; however, a pronounced downward trend is observed in 2018–2022.

[12] Federal Law No. 400-FZ of December 28, 2013 (revised on December 25, 2023) "On Insurance Pensions."

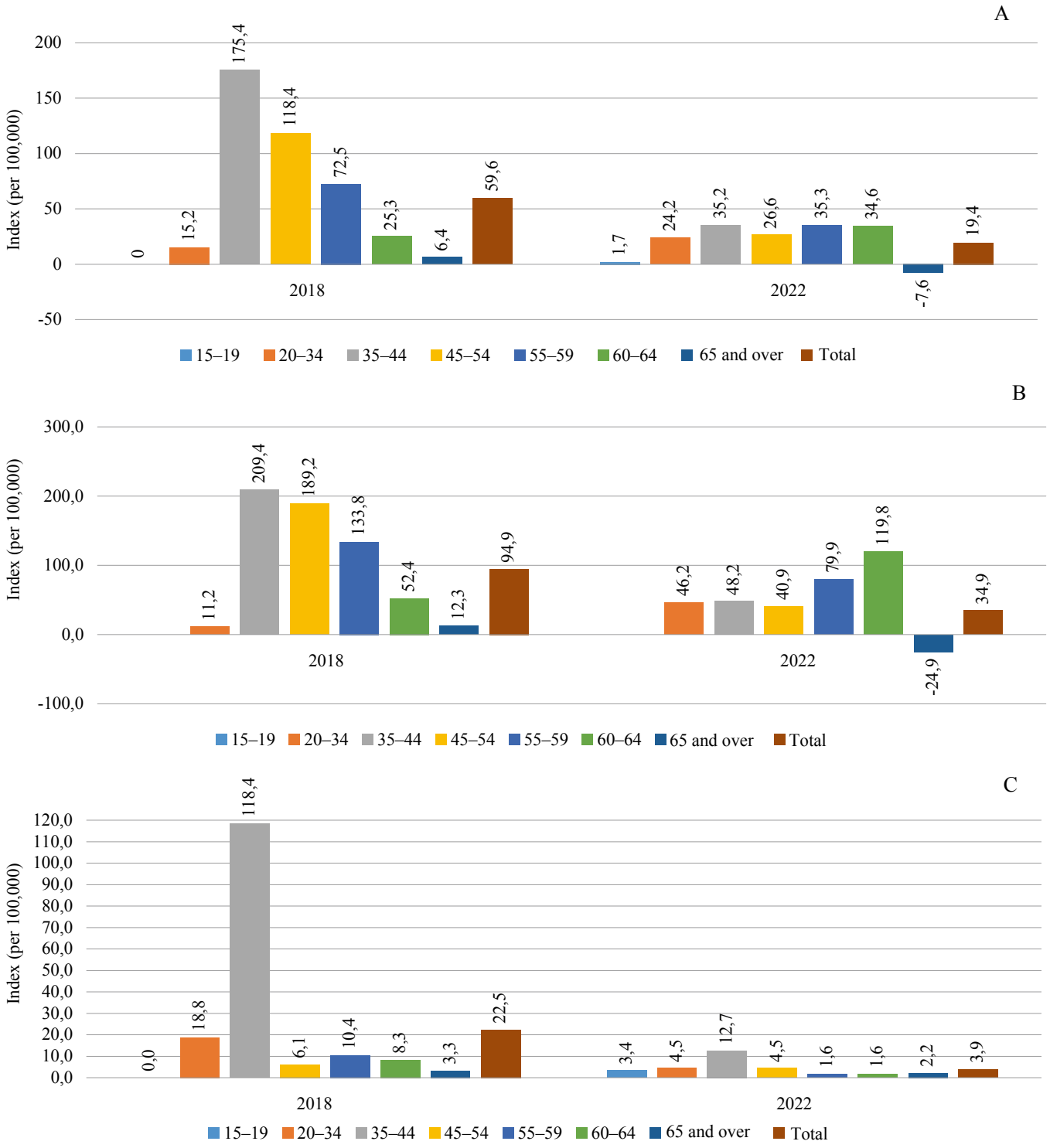

Fig. 3. Tuberculosis-related DALY in the Republic of North Ossetia-Alania for 2018 and 2022: A — total; B — males; C — females

Note: performed by the authors. Abbreviation: DALY — Disability-Adjusted Life Years.

Рис. 3. Потерянные годы жизни с поправкой на инвалидность (DALYs), связанные с туберкулезом, на 100 000 половозрастного населения Республики Северная Осетия — Алания в 2018 и 2022 гг.: А — всего; В — мужчины; С — женщины

Примечание: рисунок выполнен авторами. Сокращение: DALYs — индекс потерянных лет жизни с поправкой на инвалидность (Disability adjusted life years).

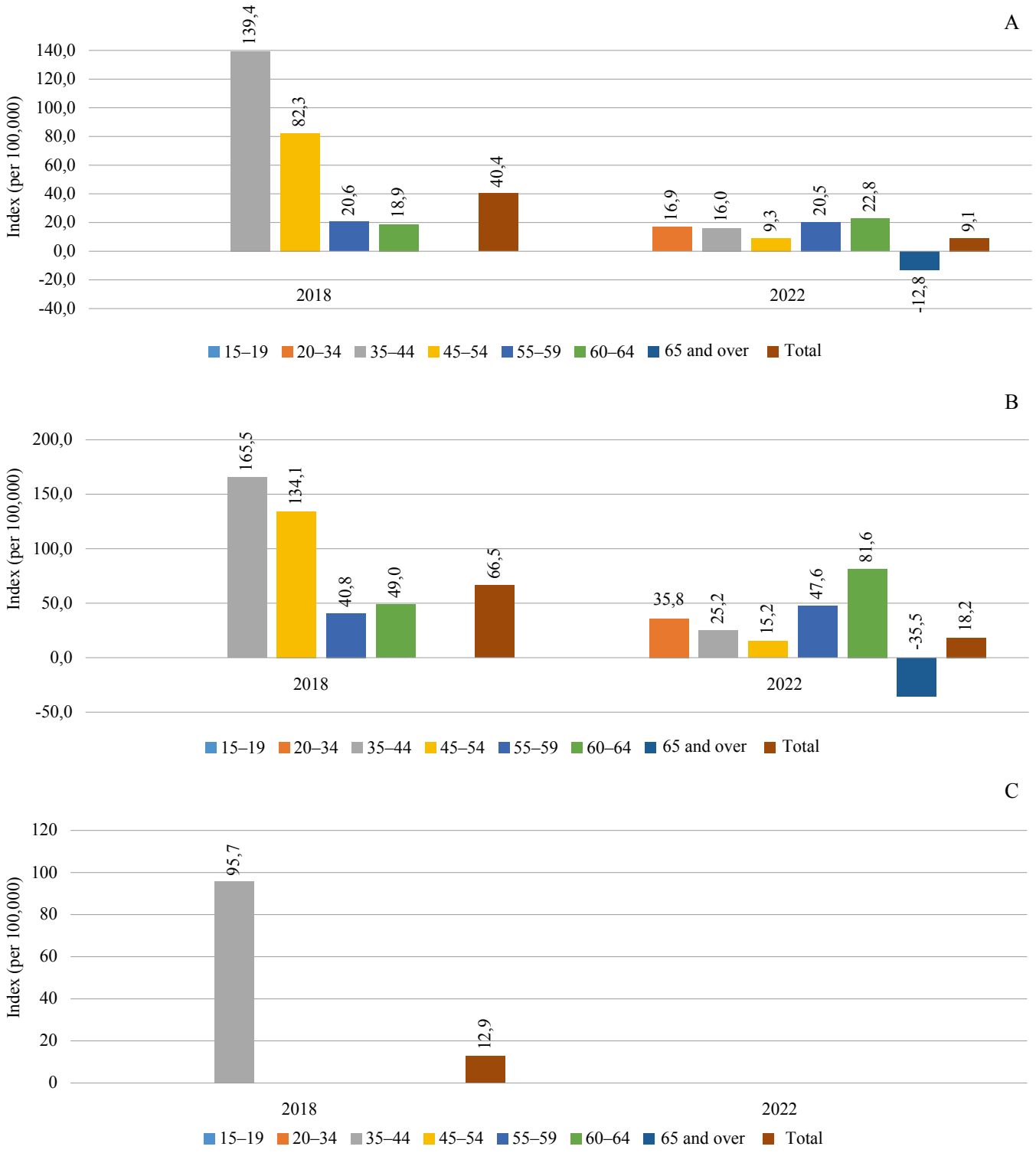

Fig. 4. YLL related to premature mortality per 100,000 gender/age population of the Republic of North Ossetia-Alania in 2018 and 2022: A — total; B — males; C — females

Note: performed by the authors. Abbreviation: YLL — Years Life Lost as a result of morbidity and premature mortality.

Рис. 4. Потери жизненного потенциала, связанные с преждевременной смертностью (YLL) от туберкулеза, на 100 000 половозрастного населения Республики Северная Осетия — Алания в 2018 и 2022 гг.: А — всего; В — мужчины; С — женщины.

Примечание: рисунок выполнен авторами. Сокращение: YLL — годы потерянной жизни в результате заболеваемости и преждевременной смертности (Years Life Lost).

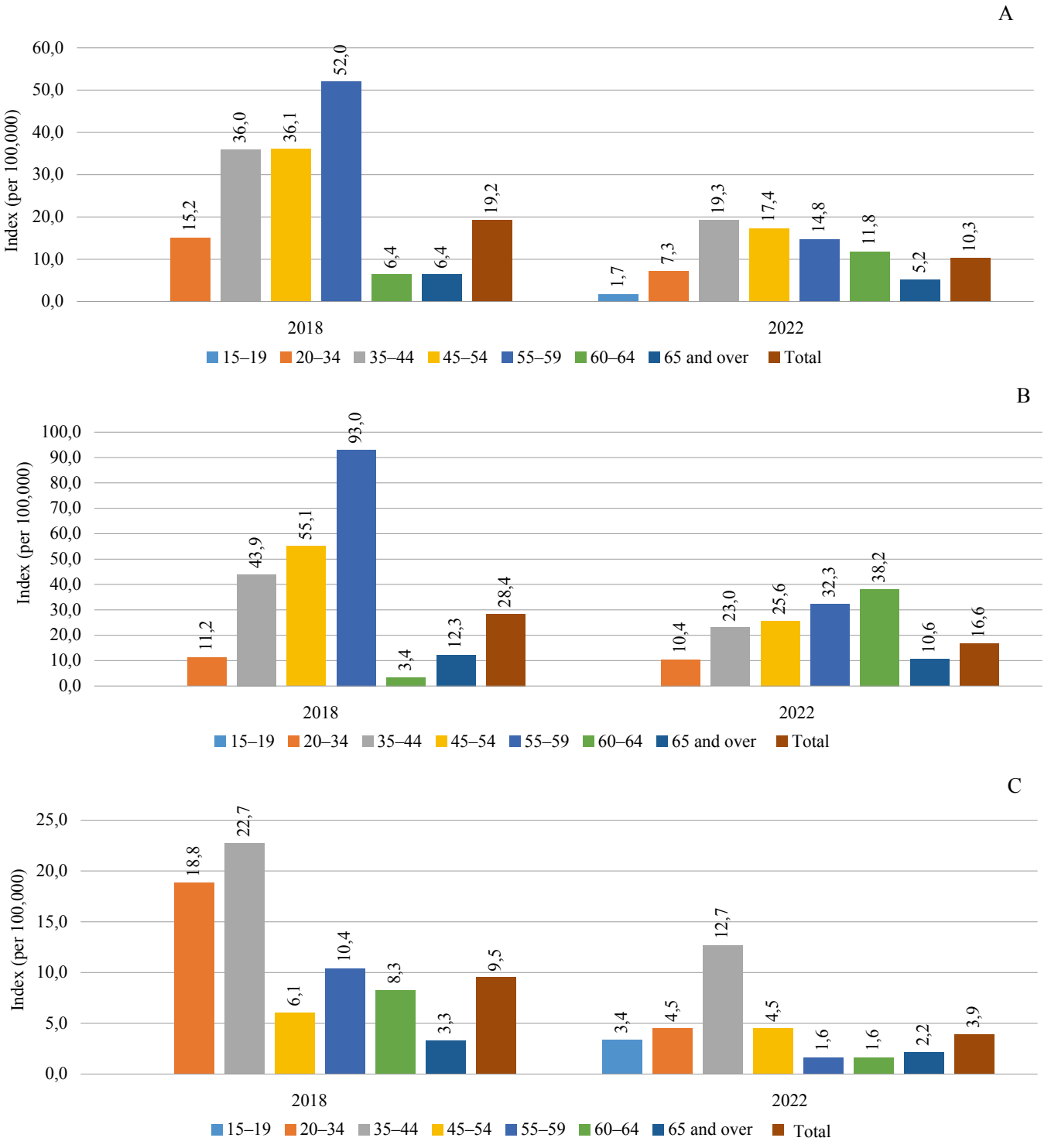

Fig. 5. Tuberculosis-related YLD per 100,000 gender/age population of the Republic of North Ossetia-Alania in 2018 and 2022: A — total; B — males; C — females

Note: performed by the authors. Abbreviation: YLD — Years Lost Due to Disability.

Рис. 5. Потери трудового потенциала, связанные с заболеваемостью и инвалидностью (YLD) по туберкулезу, на 100 000 половозрастного населения Республики Северная Осетия — Алания в 2018 и 2022 гг.: A — всего; B — мужчины; C — женщины

Примечание: рисунок выполнен авторами. Сокращение: YLD — годы жизни, потерянные по причине инвалидности (Years Lost Due to Disability).

Research limitations

The study is limited by the fact that the comorbidity of TB and HIV infection was only taken into account in the analysis of the years of potential life lost, without factoring it into the calculation of years lost due to disability, which could possibly have had some impact on the YLD level in the study cohort. In future studies, we plan to compare the DALYs measure among patients with TB without HIV infection and those with TB comorbid with HIV infection.

Interpretation of the study results

Domestic studies indicate a shift in TB mortality toward older age groups in Russia; conversely, in the 20–34 age group, a decrease in TB mortality rates is observed [27]. Researchers from other countries (Korea, China, and Colombia) also report a high burden of TB-related premature mortality in groups aged over 70 and 80 years, predominantly among men [23–25]. In its reports and recommendations, WHO identifies children and adolescents, as well as people aged over 65 years, as critical age groups in terms of TB[5] morbidity and mortality [16].

This study yields an alarming number of years of potential life lost among the group of young men aged 20–34 years in the Republic of North Ossetia-Alania, which exceeded the cohort average by two times in 2022; thus, a more thorough analysis of the obtained data is required. The high number of years lost due to TB-related disability among the female population aged 20–44 years and among pre-retirement men aged 60–64 years also indicate the need to strengthen the targeting of TB prevention and TB case finding resources to this age group in the region.

In general, the results of this study indicate a decreasing burden of TB associated with years of life lost and years lost due to disability among the population of the Republic of North Ossetia-Alania in 2018–2022, which is in agreement with the general TB epidemiology in the country, where a clear downward trend in all disease indicators has been observed over the last 10–12 years [17, 18].

CONCLUSION

The results of this study are consistent with the general trends in the development of the TB epidemic process in Russia: a decrease in the burden of TB associated with TB disability and premature mortality in the Republic of North Ossetia-Alania in 2018–2022, with a decrease in the DALYs measure across the region (by 3 times among the male population and by 5.5 times among the female population). The main socioeconomic burden of TB is associated with TB-related mortality, predominantly among men aged 35–54 years and women aged 35–44 years, with a tendency toward equalization between indicators and data on years lost due to TB-related disability. Noteworthy is the shift of premature TB mortality towards the older age group of men aged 60 and over, specifically the 60–64 age group, i.e., the expected pre-retirement age among the male population of Russia. In the same age group (60–64 years), a a 11.2 times increase in the YLD measure was observed among men in 2018–2022. The years of potential life lost among men aged 20–34 years, which exceeded the cohort average by 2 times, and the high number of years lost due to disability among women aged 20–44 years also indicate the need to adopt targeted measures for the specified gender and age groups when developing regional TB control programs in the Republic of North Ossetia-Alania.

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