AN EVALUATION OF THE PREVALENCE OF MALIGNANT NEOPLASMS IN RUSSIA USING AN INCIDENCE-MORTALITY MODEL

RUSTAM TURSUN-ZADE

This paper aims to estimate Russian cancer incidence and mortality derivatives given limited access to medical and demographic data. We use the population model of cancer proposed by J. Duchêne, which is a special case of a well-known multiple-decrement life table that makes it possible to obtain otherwise inaccessible indicators, such as the prevalence of cancer in the population. Applying this model to the publicly available Russian cancer incidence and mortality data, we were able to estimate the following indicators: average age at disease onset, average duration of disease, prevalence of malignant cancer, and average age at death from malignant cancer in Russia. We aimed to determine whether the prevalence of cancer is on the rise in the Russian Federation and, if it is, whether this increase is occurring due to an expansion of morbidity.

It was found that the average age at disease onset and the average age at death from it in Russia are increasing, with the primacy of the latter. These processes are in turn resulting in an increase of the average number of years lived with cancer, thus justifying the hypothesis of an expansion of morbidity. This phenomenon, along with the increase in the incidence of malignant cancer, is what is causing the increased cancer prevalence.

Groups of cancer localizations with the highest and lowest prevalence were identified, as well as localizations with a visible tendency toward an expansion of morbidity. It was found that in Russia the general trend is towards the expansion of morbidity, expressed by an increase in the number of years lived in an imperfect health condition. Malignant neoplasms of the lip, oral cavity and oesophagus (C00-C15) in females is the only localization for which the expansion of morbidity does not occur. For this localization a compression of morbidity is observed that is an antipode to the expansion. The main limitations and drawbacks of the study are discussed in a separate section.

Key words: *multiple decrement life-tables, incidence and mortality from malignant neoplasms, prevalence of malignant neoplasms, cancer incidence and mortality derivatives, oncological statistics, cancer mortality data analysis.*

Malignant neoplasms are the second leading cause of death in the world. According to WHO estimates, in 2015 the number of deaths caused by malignant neoplasms was equal to 8.8 million [WHO 2017], putting it behind only the number of deaths caused by cardiovascular diseases. Many experts believe that malignant neoplasms (hereinafter interchangeably referred to as "cancer") are already the leading cause of death in some high-income countries, and in the coming decades are set to become the main cause of death and disability worldwide [Bray et al. 2012].

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The Russian mortality structure has been mainly determined by the so-called "big four" group of causes: cardiovascular diseases, malignant neoplasms, external causes of death and respiratory diseases [Vishnevsky 2014]. In recent years (since 2006), diseases of the digestive organs have pushed respiratory diseases down to fifth place, thus moving into the fourth position in the Russian cause-specific mortality structure [Rosstat 2017; Shcherbakova 2018]. Since 2003, conditions favoring a life expectancy increase have been formed in Russia [Shkolnikov et al. 2013]. These conditions have been largely determined by declines in excess mortality caused by cardiovascular diseases and external causes of death [Andreev, Kvasha, Kharkova 2014].

In terms of age, this growth is primarily determined by two age groups: children under 15 years of age and adults age 65 and older [Andreev, Kvasha, Kharkov 2014]. For cerebrovascular diseases, the mortality rates are currently at a historical minimum in females and are close to that in males [Grigoriev et al. 2014]. These dynamics are sufficiently stable and sustained so as to speak of the beginning of the first stage of a cardiovascular revolution in Russia.

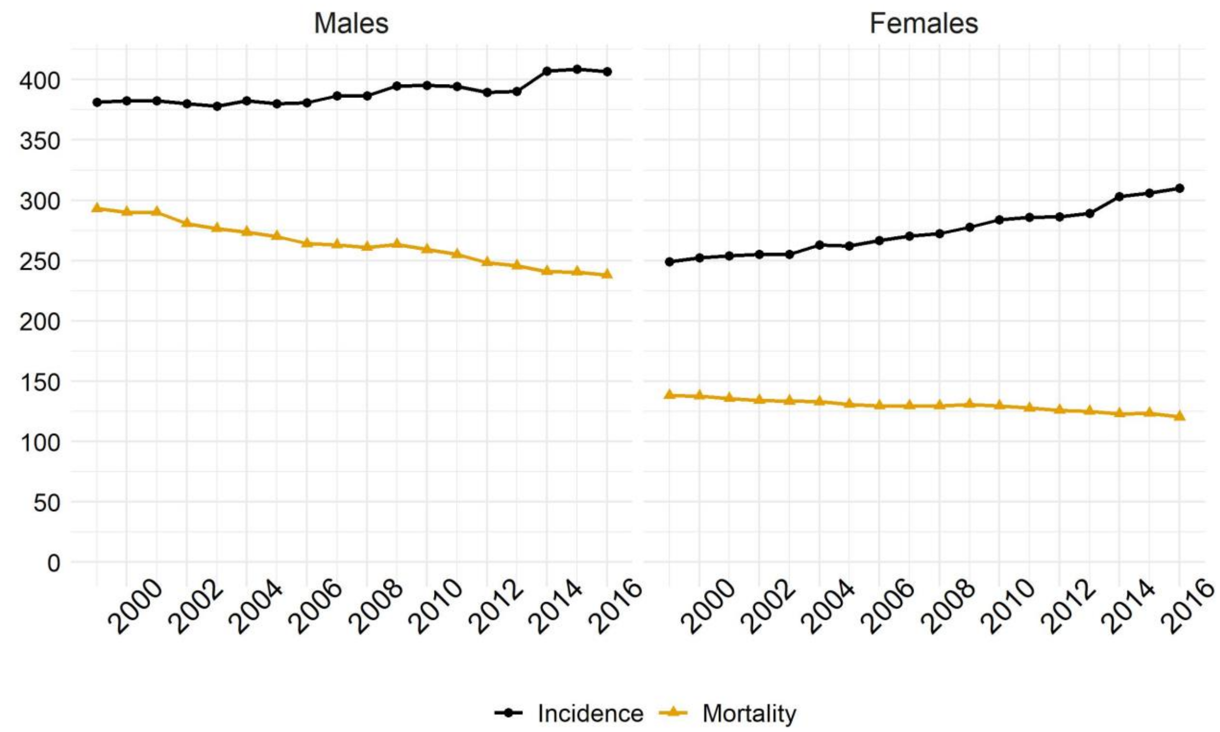

Figure 1. Age-standardized incidence and mortality rates for all malignant neoplasms, per 100,000 population, 1999-2016

Source: Author's calculations based on the data described in the Data and Methods section. Standardization is performed by a direct method using the European standard population.

Malignant neoplasms are the second leading cause of death in Russia. In 2016, 15.6% of all deaths registered in Russia were caused by malignant neoplasms [Kaprin, Starinsky, Petrova 2018a]. Figure 1 shows the dynamics of Russian age-standardized death and incidence rates for all malignant neoplasms combined for 1999-2016.

From Figure 1 the trend towards an age-standardized death rate decrease is evident. But the age-standardized incidence rate was increasing at the same period particularly around 2014.

Since the incidence of cancer is known to be increasing with age and is mainly concentrated among the elderly (the largest number of registered cases in 2016 falls within the 65-69 age group) [Kaprin, Starinsky, Petrova 2018a], given the aging of the Russian population there is no reason to expect a change in the observed cancer incidence trend. This development may cause an increase in cancer prevalence, making cancer an even more important factor of disability in Russia.

Unfortunately, despite a well-developed system for collecting and processing statistical data on cancer incidence in Russia (data have been collected since 1953, and in 1996 an order on the establishment of a Federal Cancer Registry was adopted[1]), contemporary practices do not provide for the full publication of data on the prevalence of cancer in the population. Yearbooks called "The state of oncological care for the population", published since 2007 by the P. A. Gertzen Institute, a supervisory body for the Federal Cancer Registry, contain only the prevalence rates calculated per 100,000 population without the corresponding age and sex distribution [Kaprin, Starinsky, Petrova 2018b]. Cancer prevalence data could be obtained from population-based cancer registries, although some doubts exist regarding the ability of the Russian oncological service to carry out lifelong monitoring of registered patients and to remove them in a timely fashion from the register in the event of their death. The registries' capability to conduct a complete registration of all cases of cancer diagnosed posthumously, as well as to provide a robust link between incidence and mortality data, are also questioned. In particular, to the best of our knowledge, after the ratification of the law "On Personal Data" in 2006[2] the Federal Cancer Register lost the ability to conduct personalized data checks, and currently relies on an array of depersonalized aggregated data[3]. Thus, it has been quite difficult for registries to obtain reliable data on deaths of cancer patients that were previously recorded in the register [Petrova, Starinsky, Gretsova 2016]. This may result in unreliable data on the "contingent's accumulation" (and prevalence) due to the late removal of patients from the register. This problem was particularly acute in the first years after the ratification of the law on personal data; however, currently the situation has improved somewhat. Population-based cancer registries are establishing new ways of coordination, but the problem is still far from being resolved [Petrova, Staritsky, Gretsova 2016].

In its annual statistical reports "Malignant neoplasms in Russia: incidence and mortality" [Kaprin, Starinsky, Petrova 2014, 2015, 2016, 2017, 2018a; Chissov, Starinsky, Petrova 2009, 2010, 2011, 2012, 2013] the P.A. Gerzen Institute indicates that it uses mortality data obtained from Rosstat's statistical table C51, "Distribution of deaths by sex, age group and cause of death", a data source which is de facto independent of the Ministry of Health, while incidence data is gathered by a different state entity (the Ministry of Health). Table C51 is used in spite of the fact that mortality is recorded according to the short version of the ICD-10 list with a limited number of localizations. At the same time, the prevalence of cancer at regional level relies on the database (records on cases of incidence and death) of the registry itself, which may result in an inaccurate estimate of the cancer prevalence due to possible late removals of those patients who either left

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[1] Order of the Ministry of Health of the Russian Federation dated December 23, 1996 No. 420 "On the establishment of the State Cancer Registry"

[2] Federal Law dated July 27, 2006 No.152-F3 "On personal data".

[3] Order of the Ministry of Health of the Russian Federation dated April 19, 1999 No. 135 "On improving the system of the State Cancer Register".

the region or died in a region not accountable to the cancer registry while still being kept in the database. Due to difficulties of comparing the completeness of registration of incidence and mortality data carried out by the two independent entities, as well as the possible underestimation of deaths by cancer registries on a regional level, it can be assumed that the data on cancer prevalence contained in both the Federal and regional population-based registries may be incomplete.

If there is indeed an increase in cancer prevalence, it is important to identify the factors causing this increase. Is it solely an effect of an increase in incidence, or are we dealing with an increase in the duration of disease expressed in an increase in the average number of years lived in a state of ill health (a phenomenon called the expansion of morbidity) [Fries 1980, 2005]?

We use the demographic method of multiple-decrement life tables developed by J. Duchêne [Duchêne 2002] to estimate the unpublished derivatives of cancer incidence and mortality data in the Russian population. These derivatives (average age at disease onset, average duration of disease, the prevalence of cancer and the average age at death from cancer) will allow us to determine whether the prevalence of cancer is increasing in the Russian Federation and whether this increase results from an expansion of morbidity.

While we recognize that data modeled for a life-table stationary population cannot be considered a full-fledged substitute for real data, these data can nevertheless be used to assess the dynamics of population processes.

DATA AND METHODS

We use the population model of cancer (hereinafter referred to as the “Duchêne model” [Duchêne 2002]) to estimate the unpublished cancer incidence and mortality derivatives in the Russian population. This model is based on the balance between age-specific incidence and mortality rates and is calculated by the multiple-decrement life table method. We use the Duchêne model to obtain the prevalence of cancer and other indicators: average age at disease onset, average age at death from cancer, and the average duration of disease. Note that this method was further developed and described in detail in a technical report of the Max Planck Institute [Andreev, Shkolnikov, Jasilionis 2018].

Assuming that incidence and mortality before a certain year *x* were equal to those observed in year *x*, we can calculate the prevalence of cancer in the stationary life-table population in year *x*. To do so, we calculate the proportion of the life-table population living with cancer in a certain age interval *x* using the following formula:

$$Pi_x = \frac{L_x^c}{Lx}, \quad (1)$$

where L_x^c is the number of years lived with cancer in the age interval *x* and L_x the number of years lived by the entire life-table population in the same age interval.

By multiplying the obtained coefficients Pi_x and the real mid-year population living in the corresponding age interval, we estimate the prevalence of cancer in the population living in the same age interval:

$$C_{pr} = Pi_x * P_x, \tag{2}$$

where Pi_x is the proportion of the population living with cancer in the age interval *x* and P_x is the mid-year population living in the same age interval.

To calculate the model, we used the age-specific (by 5-year intervals) death rates for all causes of death combined, M_x, the cause and age-specific death rates for the disease under study, M_x^c, and the age-specific incidence rates for the disease under study, I_x^c. The model is calculated for 5-year age intervals, ranging from 15-19 to the open age interval of 85+ years.

In this paper, the following groups of localization are considered (corresponding codes of the International Classification of Diseases, 10th revision (ICD-10), are given in parentheses):

- All malignant neoplasms (C00-C97);
- Malignant neoplasms of lip, oral cavity, pharynx and oesophagus (C00 - C15);
- Malignant neoplasms of stomach (C16);
- Malignant neoplasms of intestine and rectum (colorectal cancer) (C17 - C21);
- Malignant neoplasms of trachea, bronchus and lungs (C33 - C34);
- Malignant neoplasms of female breast (C50);
- Malignant neoplasms of female genital organs (C51 - C58);
- Malignant neoplasms of prostate (C61);
- All other malignant neoplasms.

Data on cancer incidence were extracted from state statistical reports form No. 7, “Report on Malignant Neoplasm Incidence,” published in the statistical yearbooks of the P.A. Gerzen Institute, “Malignant neoplasms in Russia” [Kaprin, Starinsky, Petrova 2014, 2015, 2016, 2017, 2018a; Chissovsky, Petrova 2009, 2010, 2011, 2012, 2013], as well as in the statistical review “Malignant neoplasms in Russia in 1993-2013” [Petrova et al. 2015]. Data on cancer mortality was derived from table C51 of Rosstat. Data on mid-year population by 5-year age intervals was used for the calculation of rates. Note that before 2014 the incidence and mortality data do not take into account the Republic of Crimea and the city of Sevastopol.

This paper examines the time period of 1999-2016. The choice of 1999 is justified by Russia’s transition to the International Classification of Diseases of the 10th revision (ICD-10), hence we face no possible inaccuracies due to reclassification of causes when switching from one revision of ICD to another. It should also be noted that incidence and mortality for almost all localizations considered is virtually nonexistent at ages below 15-19, which justifies the choice of this interval as the starting point for the model. All events occurring at ages below 15-19 are not taken into account when calculating the population model of cancer.

RESULTS

The dynamics of the average age at cancer onset in Russia are exhibited in Figure 2. It should be noted that for “all other malignant neoplasms” in males the Duchêne model gives uninterpretable results for the average age at disease onset and death from it, as well as for the average duration of disease prior to 2007, due to the features of the input data.

From Figure 2 we see that for “all malignant neoplasms” the average age at diagnosis in males is higher than in females. In recent years (after 2004), there has been a pronounced tendency towards divergence, resulting from the continuing increase in the average age at cancer onset in males and a plateau observed in females. For this diagnostic category the average age at onset in males was approximately equal to that in females prior to 2004, but from 2005 to 2007 males experienced a sharp increase in the average age at onset, which slowed down in 2007 and 2008 and subsequently increased until 2016. After 2004 the average age at cancer onset in females continued to grow, but with a slower pace compared to that in males. This gap further widened starting in 2008. In recent years no significant increase in the average age at cancer onset has been observed in females. Given that for all other diagnostic categories the average age at cancer onset in females exceeds that in males, it can be concluded that this difference can be determined by localizations that are not characteristic of the male sex.

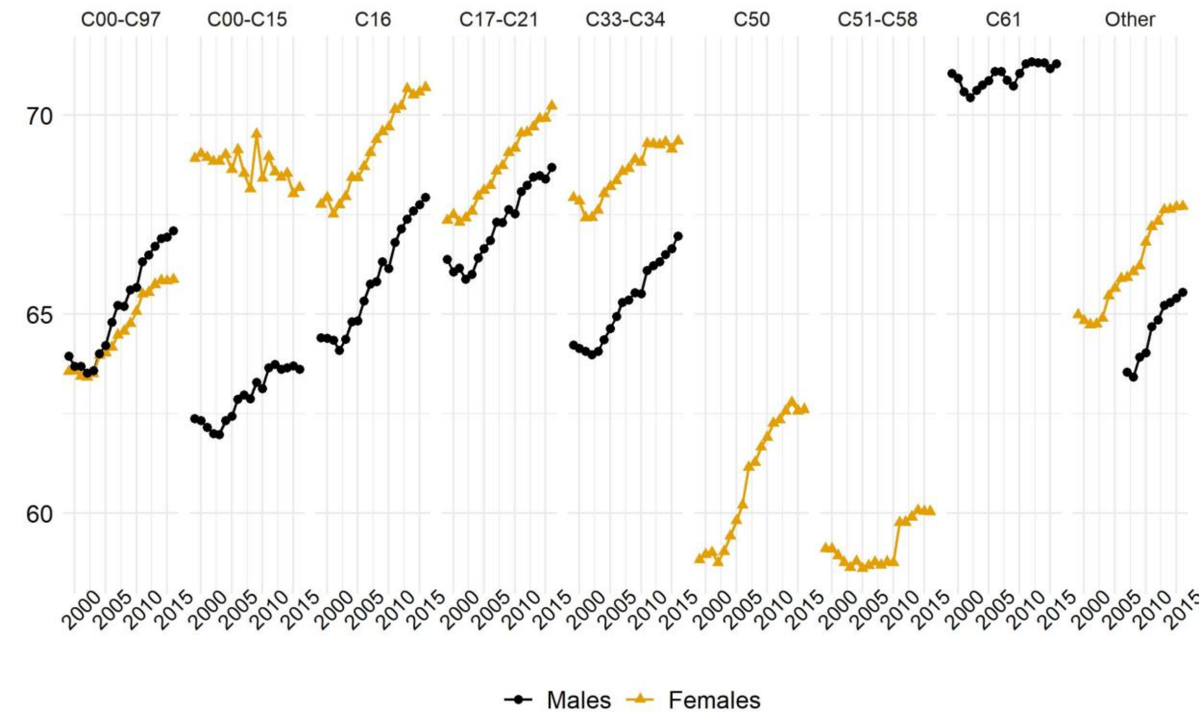

Figure 2. Average age at cancer onset, 1999-2016

C00-C97– all localizations; C00 - C15 - MN of lip, mouth, pharynx and oesophagus; C33 - C34 - MN of trachea, bronchus and lungs; C16 - MN of stomach; C17 - C21 – MN of intestines and rectum (colorectal cancer); C50 - MN of female breast; C51 - C58 - MN of female genital organs; C61 – MN of prostate.

Source: Author’s calculations based on the data described in the Data and Methods section.

For stomach cancer, average age at onset begins to grow in 2003 in males and in 2002 a noticeable increase can be observed in females, followed by a slight decrease in 2014.

For “colorectal cancer”, age at onset increases starting in 2003 in males and in 2001 in females. In females a steady growth follows a slight decline observed between 2000 and 2001, while in males a steady increase has been observed since 2002.

For cancer of the trachea, bronchus and lungs, an increase among males has been observed since 2003, while in females - since 2001. For female breast cancer there has been a significant increase since 2002. For all other cancers an increase is observed since 2002 in females and since 2008 in males.

Attention should be paid to cancer of the female genital organs and to prostate cancer, since their dynamics are different from those observed for other groups of localizations considered. The average age at onset for cancer of the female genital organs decreased until 2003, then after some increase in 2004 and a subsequent decrease in 2005 it reached a plateau, fluctuating at around 58.7 years up to 2011, when significant growth followed by yet another plateau is observed. The average age at onset for prostate cancer grew slightly, fluctuating at around 71 years.

For cancer of the lip, oral cavity, pharynx and oesophagus in males, after a period of decline observed in 1999-2003 a consistent increase is observed up until 2016. In females the dynamics of the average age at onset for this diagnostic category are an exception to the general upward trend. Prior to 2006 it fluctuates at around 69 years, then in 2007-2008 there was a sharp decrease followed by a significant increase in 2009, when it reached 69.5 years, and a further decrease to 68.2 years in 2016. This value is lower than that registered in 1999 (68.9 years).

The most significant increase in the average age at cancer onset in males is observed for stomach cancer, cancer of the trachea, bronchus and lungs, colorectal cancer, all other cancers and cancer of the lip, oral cavity, pharynx and oesophagus. The smallest growth is observed for prostate cancer; however, it should be noted that this diagnostic category was initially the category with the highest recorded age at disease onset, while the localization with the lowest recorded age at onset in males is cancer of the lip, oral cavity, pharynx and oesophagus. The most significant increase in the average age at cancer onset in females is observed for cancer of the female breast and stomach, for colorectal cancer, all other cancers, cancer of the trachea, bronchus and lungs, and for cancers of the female genital organs. For cancer of the lip, oral cavity, pharynx and oesophagus in females, a decrease in the average age at disease onset is observed. The localization with the lowest recorded age at onset is cancer of the female breast, while the localization with the highest age is stomach cancer.

The increase in the average age at disease onset in males was generally more significant than in females for almost all groups of localization considered, with the exception of colorectal cancer and all other cancers. This growth is largely determined by stomach cancer and by cancer of the trachea, bronchus and lungs. In females, cancer of the female breast, stomach and colorectal cancers are leaders in terms of growth. The greatest difference in the average age at onset in males and females is observed for cancer of the lip, oral cavity, pharynx and oesophagus, stomach cancer and cancer of the trachea, bronchus and lungs, while the smallest is observed for colorectal cancer.

The dynamics of the average age at death from cancer are exhibited in Figure 3.

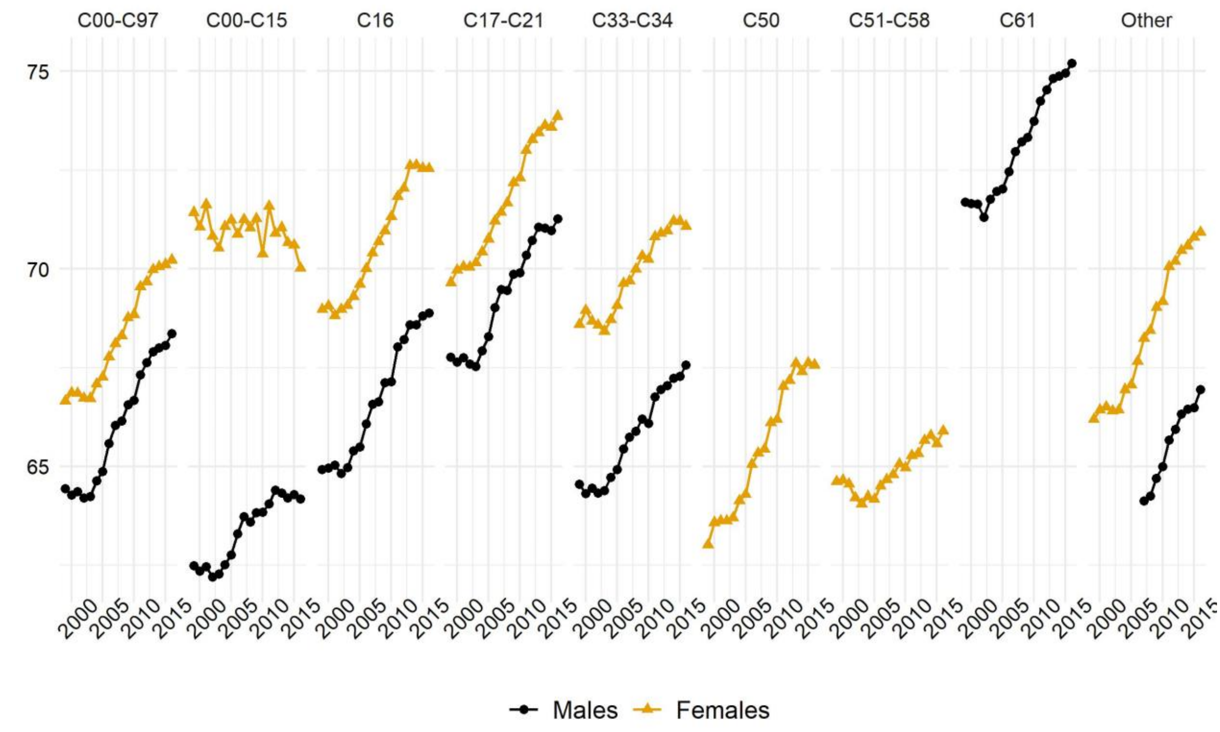

Figure 3. Average age at death from cancer, 1999-2016

C00-C97– all localizations; C00 - C15 – MN of lip, mouth, pharynx and oesophagus; C33 - C34 - MN of trachea, bronchus and lungs; C16 - MN of stomach; C17 - C21 – MN of intestine and rectum (colorectal cancer); C50 - MN of female breast; C51 - C58 - MN of female genital organs; C61 – MN of prostate.

Source: Author's calculations based on the data described in the Data and Methods section.

Figure 3 shows that the average expected age at death from cancer in females exceeds that in males for all groups of localizations considered. A steady upward trend is observed. The only exception to this trend is cancer of the lip, oral cavity, pharynx and esophagus in females. Localizations with the highest recorded age at death include prostate cancer in males and colorectal cancer in females, while the lowest values are observed for cancer of the lip, oral cavity, pharynx and esophagus in males, and for the female genital organs.

An increase in the average age at death from cancer in males is observed since 2002 and since 2003 in females. For stomach cancer this growth has been taking place since 2002 in males and since 2001 in females; for colorectal cancer - since 2003 in males and since 1999 in females; for cancer of the trachea, bronchus and lungs - since 2003 in males and since 2004 in females; for all other cancers an increase has been observed starting with the first years of observation for both males and females; for female breast cancer, an increase has been observed since 1999, and for cancer of the female genital organs, it began after a period of decline in 2000–2003. The average age at death from prostate cancer has increased since 2002. The average age at death from cancer of the lip, oral cavity, pharynx and oesophagus in males increased up to 2012, reaching a plateau. In females, the dynamics of this indicator are an exception to the general trend towards an increase in the average age at death from cancer; it fluctuated at around 71 years with two periods of sharp decline observed in 2001-2003 and in 2010, with an increase in 2011 and a subsequent decrease until 2016. In 2016, the indicator reached a value of 70.1 years, which is lower than the value observed in 1999 (71.4 years). The greatest difference in the average age at death between males and females is observed for cancer of the lip, oral cavity, pharynx and oesophagus and cancer of the trachea, bronchus and lungs, and the smallest - for colorectal cancer. The localization with the highest observed average age at death in males is prostate cancer, and in females - colorectal cancer. The lowest values are observed for cancer of the lip, oral cavity, pharynx, and oesophagus in males, and for the female genital organs.

An increase in the average age at death exceeded that of the average age at onset. However, if the average age at onset for all cancers in males was higher than in females, for the average age at death from cancer the opposite is true. Despite the fact that the average age at death in males has increased more than in females, females nevertheless die from all cancers 1.9 years later than males. In males, the increase in the average age at death is largely determined by stomach cancer, colorectal cancer and cancer of the trachea, bronchus and lungs, while in females - by all other cancers, cancer of the female breast, colorectal cancer and stomach cancer. Similar to the age at cancer onset, the maximum age at death for almost all locations is observed in 2014-2016. However, the significant exception here (as in the case of onset age) is cancer of the lip, oral cavity, pharynx and oesophagus in females, for whom there is a tendency towards a decreasing average age at death.

The average duration of disease represents the difference between the average age at death and the average age at onset and is shown in Figure 4. The logical consequence of the increase in the average age at death, which grew faster than the average age at onset, is an increase in the average expected duration of disease, or in other words, an increase in the number of years lived in a state of incomplete health (in our case, of illness with cancer). From Figure 4 it follows that the duration of disease increases for all groups of localizations considered, with the exception of cancer of the lip, oral cavity, pharynx and oesophagus in females. The duration of disease in males is much shorter than in females, and for “all malignant neoplasms” there is a tendency towards a further convergence in the values of this indicator between males and females. A significant increase in the average number of years lived with prostate cancer is observed. The shortest average duration of disease in males is observed for cancer of the lip, oral cavity, pharynx and oesophagus, as well as for cancer of the trachea, bronchus and lung, with mean values of about 0.5 years, while in females the shortest duration is observed for cancer of the trachea, bronchus and lungs (1.3 years) and for stomach cancer (1.5 years). Localizations with the most fluctuations are cancer of the female breast and female genital organs; for cancer of the female genital organs the greatest values are observed in 2009-2010. In males, for all groups of localizations considered there is a tendency towards an increase in the number of years lived with cancer. The most significant increase in this indicator in males is observed for prostate cancer, while in females, with the exception of “all other malignant neoplasms”, for colorectal cancer. However, it should be noted that a tendency to a slight decrease in the average duration of disease has emerged in recent years, most pronounced in females for the following groups of localizations: stomach cancer, colorectal cancer, cancer of the trachea, bronchus and lungs.

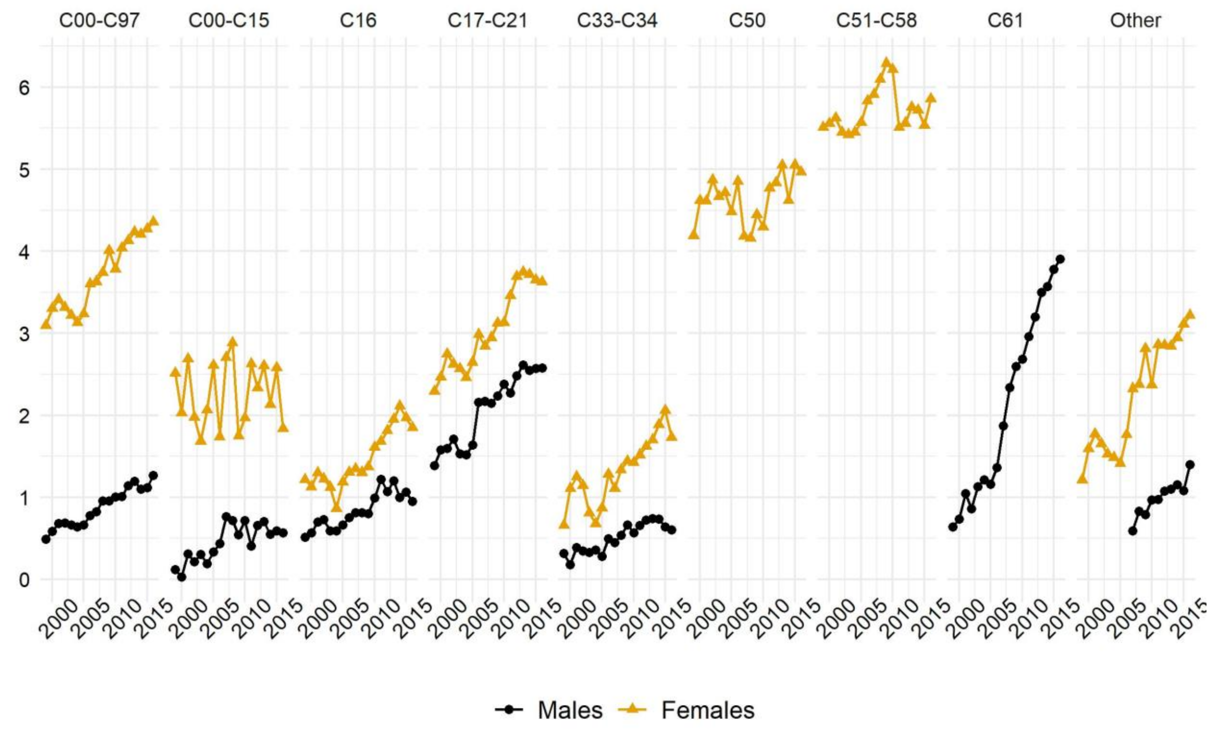

Figure 4. Expected duration of disease, 1999-2016, in years

C00-C97– all localizations; C00 - C15 - MN of lip, oral cavity, pharynx and oesophagus; C33 - C34 - MN of trachea, bronchus and lungs; C16 - MN of stomach; C17 - C21 – MN of intestines and rectum (colorectal cancer); C50 - MN of female breast; C51 - C58 - MN of female genital organs; C61 – MN of prostate.

Source: Author's calculations based on the data described in the Data and Methods section.

An increase in the average duration of disease, expressed in an increase in the number of years lived with cancer, may lead to an increase in the prevalence of cancer in the population. Figure 5 presents the age-standardized prevalence rates for all groups of localizations considered. In males, with the exception of "all other malignant neoplasms", which has the highest prevalence in the Russian population, the most common localization is prostate cancer, followed by colorectal cancer, cancer of the trachea, bronchus and lungs, and cancer of the lip, oral cavity, pharynx and oesophagus. Stomach cancer is the least common form of cancer in males, due to its high lethality. The only localization in males for which a slight decrease in prevalence is observed is cancer of the lip, oral cavity, pharynx and oesophagus. The highest increase in cancer prevalence is observed for prostate cancer and colorectal cancer, while for the prevalence of stomach cancer and cancer of the trachea, bronchus and lungs the dynamics are relatively stable.

Cancer prevalence dynamics in females, also presented in Figure 5, are more stable than in males. An increase in cancer prevalence in females occurs for all of the localizations considered. Apart from "all other malignant neoplasms" the most common are cancers of the female breast and female genital organs, for which the highest growth rate is observed, followed by colorectal cancer, stomach cancer and cancer of the trachea, bronchus and lungs. The lowest prevalence is observed for cancer of the lip, oral cavity, pharynx and oesophagus.

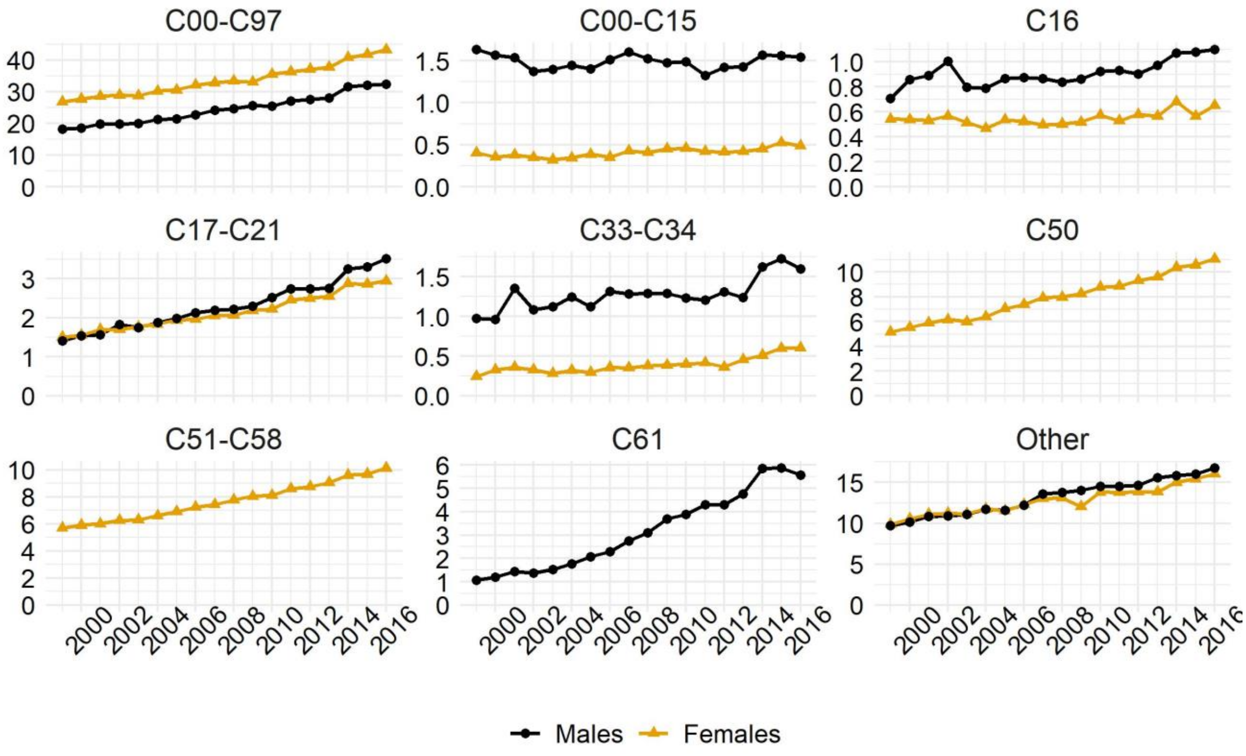

Figure 5. Age-standardized cancer prevalence rates of in the Russian population, per 1000 population, 1999-2016

Standardization is performed by a direct method using the European standard population.

C00-C97– all localizations; C00 - C15 - MN of lip, oral cavity, pharynx and oesophagus; C33 - C34 - MN of trachea, bronchus and lungs; C16 - MN of stomach; C17 - C21 – MN of intestine and rectum (colorectal cancer); C50 - MN of female breast; C51 - C58 - MN of female genital organs; C61 – MN of prostate.

Source: Author's calculations based on the data described in the Data and Methods section.

Apart from localizations unspecific to both sexes, we observe the following structural differences in prevalence of malignant neoplasms in males and in females. While among males cancer of the trachea, bronchus and lungs is more common than cancer of the lip, oral cavity, pharynx and oesophagus, and stomach cancer is the least common localization, among females the most common localization is stomach cancer, followed by cancer of the trachea, bronchus and lungs, with the least common being cancer of the lip, oral cavity, pharynx and oesophagus. In general, the prevalence of cancer in females exceeds that in males, despite the fact that the incidence of cancer in males is much higher than in females. In recent years a trend towards acceleration in growth of the age-standardized prevalence of cancer has been observed in Russia and is more pronounced in males. Cancer of the trachea, bronchus and lungs and prostate cancer are good illustrations of this phenomenon.

Let us examine prevalence rates by comparing the figures for 2016 and 1999. In this period, the dynamics of age-standardized prevalence rates were as follows.

In males:

- All malignant neoplasms - an increase of 1.8 times;
- All other malignant neoplasms – an increase of 1.7 times;
- Malignant neoplasms of the prostate - an increase of 5.2 times;
- Colorectal cancer - an increase of 2.5 times;
- Malignant neoplasms of lip, oral cavity, pharynx and oesophagus - a decrease of 0.1 times;
- Malignant neoplasms of trachea, bronchus and lungs and MN of stomach – an increase of 1.6 times.

In females:

- All malignant neoplasms and all other malignant neoplasms – an increase of 1.6 times;
- Malignant neoplasms of female genital organs - an increase of 1.8 times;
- Malignant neoplasms of female breast - an increase of 2.1 times;
- Colorectal cancer - an increase of 2 times;
- Malignant neoplasms of stomach - an increase of 1.2 times;
- Malignant neoplasms of trachea, bronchus and lungs - an increase of 2.5 times;
- Malignant neoplasms of lip, oral cavity, pharynx and oesophagus - an increase of 1.2 times.

Based on the model's output we conclude that an increase in the prevalence of cancer for all groups of localizations considered is occurring in Russia. The only exception is the prevalence of cancer of the lip, oral cavity, pharynx and oesophagus in males, for which a slight decrease in values is observed.

DISCUSSION

The prevalence of cancer in Russia is on the rise, thus cancer is becoming a more important factor of disability. In recent years in Russia there has been a tendency towards an acceleration of age-standardized cancer prevalence increase that is more pronounced in males. Illustrative examples are cancer of the trachea, bronchus and lungs (C33-C34), cancer of the prostate (C61) and stomach cancer (C16). Within this period there has been no significant acceleration in average duration of disease increase, but for all cancers there was a tendency towards the age-standardized incidence increase (Figure 1) that is more pronounced in males. Thus, it can be assumed that in Russia the increase in incidence has an important role in prevalence increase, at least in the context of the localizations considered. Despite the fact that the average duration of disease in females is longer than in males, the prevalence of for some cancers such as those of the trachea, bronchus and lungs (C33 – C34) and stomach cancer (C16) in males is higher than in females.

The highest prevalence increase is observed for prostate cancer (C61), although this is most likely caused by overdiagnosis following the introduction of the PSA (Prostate Specific Antigen) test [Bray, Parkin 2009]. The only localization for which a slight decrease in prevalence observed is cancer of the lip, oral cavity, pharynx and oesophagus (C00-C15) in males. Despite the fact that the incidence in males is significantly higher than in females, the prevalence of cancer in females is higher, testifying in favor of the hypothesis of better female cancer survival. It should also be noted that there is a threat of future increase in female cancer mortality. Since the number of deaths from cancer is partly a function of an increase in incidence, the growth of the latter observed in females could later on lead to an increase in cancer mortality.

The average age at cancer onset and the average age at death seem to have grown independently of each other. Male age at disease onset has shifted to older ages, exceeding that of females and confirming the hypothesis regarding the possible shift of the modal age at cancer onset to older ages. At the same time, an increase in the average age at death is observed that is more significant than the increase in the average age at disease onset. Consequently, modal values of the age at death are also shifted towards the older ages. In this regard, males and females display similar dynamics. Average age at disease onset growth is inferior to that of the average age at death. The only localization for which the reverse dynamics are observed is cancer of the lip, oral cavity, pharynx and oesophagus (C00-C15) in females, for which a decrease is observed in both the age at death and the age at onset, with a greater decrease in the age at death. Despite the fact that the minimum age at cancer onset falls on certain periods, the maximum value in all cases considered occurred either in 2016 or one of the years just before. The result of the dynamics of the observed processes is an increase in the average duration of disease that is recorded for all the localizations considered in both males and females, with the exception of cancer of the lip, oral cavity, pharynx and oesophagus (C00-C15) in females.

Nowadays, the compression of morbidity concept is popular in papers aiming to study chronic disease onset and subsequent mortality. The author of the concept [Fries 1980, 2002, 2005] puts forward the following assumption: if a population experiences an increase in life expectancy, a so-called compression of morbidity should also occur. This will be expressed in a reduction in the number of years lived in a state of imperfect health. According to this concept, a decline in incidence of chronic diseases should occur by analogy with the previously observed decline in mortality. The author also suggests that there will be a shift in the average age at disease diagnosis towards the older ages - in other words, the time between the disease onset and death will be decreased (a compression of morbidity will occur) [Crimmins, Beltrán-Sánchez 2011]. We see that in Russia the average age at cancer diagnosis is indeed increasing. At the same time there is a much more pronounced increase in the average age at death from it. These developments, reinforced by decreases in cancer mortality and by increases in cancer incidence, are driving the increase in cancer prevalence, which is determined by an increase in the duration of disease or better survival of cancer patients, and by an increase in standardized incidence rates for the diagnostic category “all malignant neoplasms”. This allows us to conclude that in Russia for all localizations considered the phenomenon of compression of morbidity is not occurring. In contrast, an expansion of morbidity expressed in the increase in the average number of years lived in a state of ill health due to cancer is occurring. An exception is cancer of the lip, oral cavity, pharynx and oesophagus (C00-C15) in females, for which a compression of morbidity expressed in a decrease in the number of years lived with the disease is occurring. In males, no compression of morbidity is observed for this localization, despite a slight decrease in the standardized prevalence, since at the same time the average number of years lived with cancer is increasing.

A further increase in cancer prevalence may be a consequence of the observed dynamics, thus making cancer a more important factor of disability in the Russian population.

In conclusion, a few words on the limitations of this study should be said. When interpreting the model's results, it should be remembered that the Duchêne model used by us is not fully multi-status per se, but rather is approximate or artificial. This model has two features that may result in negative return values of the survival function. Having limited access to data, we were forced to estimate the incidence rate for the entire population rather than for healthy people, i.e. to use not an indicator of the incidence intensity but a so-called second order coefficient. Mortality in the model applies also to the entire population, not just to patients diagnosed with a certain cancer. The results are approximate figures. However, since all indicators are calculated using an identical method, an analysis of their dynamics and a comparison of the two sexes makes sense.

It is also important to note one of the fundamental features of the Duchêne model. Within this model, the synthetic cohort is initially divided into 2 groups: ill with cancer and cancer free. It is assumed that a person may leave the first group not only by contracting the disease under study, but also following an impact made by other causes. The model itself consists of two partial morbidity-mortality models that do not take the possibility of remission into account. These are the double decrement models, in which synthetic cohort members either remain in the healthy group or leave it by contracting the disease, dying from the disease or dying from any other cause. Thus, members of the cohort contracting the disease are susceptible to death from both the cause under study and from any different cause.

Three interrelated states are taken into account: the absence of the disease, its presence, leaving the cohort due to death. The hypothetical cohort mortality from causes other than that under study is set to be equal to that in a healthy population (i.e. in a population not suffering from the disease under study). Such an assumption is undoubtedly a weak side of the model, since it is obvious that the mortality structure of those ill with cancer differs from that of a healthy population, due to the influence of specific risk and behavioral factors. The model includes the possibility of death from a cause other than the one under study, thus a cohort member considered with regard to a particular cancer localization that dies from another, falls into the group "all other malignant neoplasms".

Another problem is the comparability of incidence and mortality data. Incidence and mortality report forms were altered in 2011 (before this, the mortality reporting form was changed in 1999) [Petrova et al. 2015]. Thus, the data published by the P.A. Gerzen Institute before and after 2011 differ in the number of localizations provided. For example, the incidence data published by the institute up to 2011 has no ICD-10 codes corresponding to cancer of the small intestine (C17), as well as to a number of localizations belonging to the class "malignant neoplasms of female genital organs": cancer of the vulva (C51) and cancer of the vagina (C52). This factor should be taken into account when interpreting the model's results. It should also be remembered that, in Russia, data on incidence and mortality are gathered independently by two different entities (the Ministry of Health and Rosstat). This fact can also affect the data's completeness and comparability.

Combination of these two factors, i.e. the lack of incidence and mortality data comparability, as well as the fact that the model is not fully multi-status, explains the problem of negative survival obtained for the diagnostic group "all other malignant neoplasms" in males that arises when calculating the model prior to 2007. It should also be noted that due to these facts the average duration of disease is the least reliable indicator provided, since it represents the difference in indicators calculated based on the data obtained from two independent sources (Form C51 and Form No. 7).

CONCLUSION

It should be emphasized that cancer prevalence analysis is uninformative by itself, since its increase can be both a function of the incidence increase and a consequence of better survival of cancer patients. Obviously, if an increase in prevalence is observed largely due to an increase in incidence, then it should be given a generally negative assessment, but if the same occurs due to better survival of patients already diagnosed with cancer, it is undoubtedly a positive trend. Unfortunately, the analysis of cancer prevalence by itself will not allow for an unambiguous answer to the question posed this way, and therefore it is necessary to analyze it in combination with other population characteristics of cancer.

In this paper, we have applied the J. Duchêne model to assess a number of otherwise inaccessible characteristics of cancer in the Russian population for chosen groups of localizations. We estimated the cancer prevalence, average age at cancer onset and of death from cancer, and the average duration of disease. Based on the results, it can be assumed that, despite the fact that an increase in cancer prevalence in Russia results, among other things, from an increase in incidence, it results also from an increase in the average expected duration of disease, thus indirectly confirming the hypothesis of better survival of cancer patients. The observed shift in the average age at disease onset and at the average age at death from cancer to older ages, with the primacy of the latter, results in an increase in the average duration of disease, calculated as the difference between the average age at death and the average age at cancer onset. This tendency determines the phenomenon of expansion of morbidity that is observed for all groups of cancers considered, with the exception of cancer of the lip, oral cavity and oesophagus (C00-C15) in females, for which a reduction in the average duration of disease or a compression of morbidity is observed. Thus, not only is a confirmed shift of cancer onset and death to older ages occurring in Russia, but also indirect evidence of improved prognosis for cancer survival exists which is reflected in an increase in the prevalence of cancer. Thus, based on the observed dynamics of population processes, it is possible to put forward a hypothesis that in the near future cancer may become an even more important factor of disability in the Russian Federation.

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