INTRODUCTION

Persons aged 85 years or older comprise over 6% of all cancer cases [1, 2] and cancer is the fourth most common cause of death among the very old [3, 4]. As life expectancy lengthens [5], the number of cancer cases and cancer deaths among the elderly and the oldest old, defined as subjects older than 65 and 85, respectively, is projected to increase [6]. The global population of the oldest old is expected to more than triple between 2015 and 2050, growing from 126 to 446 million [7]. In some Asian and Latin American countries, this population is predicted to quadruple [7]. It remains unclear exactly how aging contributes to lifetime cancer risk. While mortality from other non-communicable diseases such as cardiovascular diseases, ischemic heart disease and stroke increases among the oldest old [8], the age-related increase in mortality from cancer appears to decelerate [9–11]. This evidence is paradoxical to the theory of mutation accumulation, which implies that genomic damages accumulate during one’s life course, leading to a steady increase in the risk for cancer [12, 13]. There is also the question of survivor bias, whereby individuals have who have been exposed to fewer risk factors surpass the age of individuals who were more exposed. Risk factor
exposure may vary based on birth cohort, time period, and/or location. For example, exposure to a risk factor at a particular time period may make it difficult to distinguish between whether some of the oldest old in a birth cohort were simply exposed to fewer cancer risk factors or whether the higher survival was due to their age [9]. Observed changes in mortality trends may also be an artifact of variations in diagnostic screening or testing in older age [14]. In particular, trends for less common cancers for which screening efficacy has not yet been well-established, are not yet understood among the oldest old [15].

The aim of this study is thus to determine age-specific trends of cancer mortality from 2000 to 2014 by cancer site across different countries among the oldest old.

RESULTS

General overview of cancer mortality

From 2000 to 2014, cancer mortality increased with each five-year age group following age 65, with the APCs between ages 65-69 and 80-84 being in the range of 25.8% (Poland) to 51.5% (Australia) among men and among women in the range of 25.5% (Poland) to 46.8% (Japan) between ages 65-69 and 85-89 for most countries (Supplementary Tables 2, 3). The overall AAPC of all cancers increased with age following 65 years old up to 95+ years old, ranging from 4.9% (Poland) to 33.6% (Australia) for men and from 11.2% (Poland) and 36.1% (Japan) for women.

Cancer mortality in the selected countries for all cancers, for each major cancer site and both sexes are displayed in Figures 1-6. In Australia, the UK, Germany, and Italy, overall cancer mortality decreased after a peak age of 90 to 94 for both sexes. Trends in Poland started to decline earlier and showed a lower peak cancer mortality for both men (2273.45 per 100,000) and women (1314.07 per 100,000) compared to other countries. Cancer mortality continued to increase in the USA and France, and stabilized in Japan. Mortality rates are displayed in Supplementary Table 1.

Oral cavity and pharyngeal cancers

No strong trends with age were observed among the very old for oral and pharyngeal cancers (Figure 1).

Esophageal cancer

A strong increase with age was not found in most countries. While a small increase was observed for some European countries, the rate change per year was not significant. Overall, the highest esophageal cancer rates among the countries analysed were observed for the UK (peak around 134.2 per 100 000 men aged 85-89 and around 75.2 per 100 000 women aged 90 to 94) (Figure 1).

Stomach and colorectal cancers

Stomach cancer reached a peak at age 90 to 94 and then stabilized or decelerated for both men and women in most countries. Japan had the highest increase of stomach cancer mortality with age (AAPC 31.1% for men and 49.9% for women). Colorectal cancer reached a peak at age 90 to 94 years and stabilized or decelerated in most countries, too, except for the USA, Japan, and France that continued to increase with age (Figure 2).

Liver cancer

Liver cancer mortality rates were similar across most of countries (a peak of 60 per 100 000 or below for men and 25 per 100 000 or below for women at ages 80 to 84 years). Japan had the highest liver cancer mortality rates with a peak of 194.9 per 100 000 for men at age 80-84 and of 99.3 for women (75 per 100 000) at age 85-89 (Figure 2).

Pancreatic cancer

For pancreatic cancer, an increase in mortality rates with age was observed for all countries among both men and women, with stable or declining trends only after 90-94 age for most countries. In the UK, Germany, and Poland, mortality rates peaked earlier at around 85 years of age in both men and women. In Italy and Poland, pancreatic cancer mortality among women overtook the mortality rate among men after age 85-89, in Germany after age 90-94 (Figure 3).

Lung and laryngeal cancer

Among both men and women, lung cancer mortality in Australia, UK, Germany, and Italy reached a peak at age 80 to 89 (75-79 for Poland) and then decreased. At age 85-89, Japan showed the highest mortality rate of lung cancer, around 707.1 per 100 000 for men, while in women trend continued to increase with age, reaching a rate over 224.6 per 100 000 in over 95. Similar trends were found for laryngeal cancer, with however later peaks (Figure 3).

Breast cancer

The lowest rates were observed in Japan (around 36.5 per 100 000 women aged 80 to 84). Breast cancer mortality increased monotonically with age (including Japan), except for Germany, Italy, and Poland where
Figure 1. Death rate per 100 000 persons for oral cavity and pharynx, esophagus and all cancers in men and women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
Figure 2. Death rate per 100 000 persons for stomach, colorectum and liver cancers in men and women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
Figure 3. Death rate per 100,000 persons for pancreas, larynx and lung cancers in men and women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
Figure 4. Death rate per 100,000 persons for breast, uterus and ovary cancers in women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
Figure 5. Death rate per 100 000 persons for prostate, bladder and kidney cancers in men and women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
Figure 6. Death rate per 100 000 persons for non-Hodgkin lymphoma, multiple myeloma and leukemia in men and women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.
rates stabilized after age 90 to 94 years. The UK had the highest mortality of breast cancer after age 90 years (over 312.5 per 100 000 women). The UK also had the highest increase by quinquennial age, the mortality rate increase from 65 years old to 95+ years was 32.4% (Figure 4).

Uterine cancer

Uterine cancer mortality seemed to decrease or stabilize at oldest old age across all countries. The decreasing trend was stronger among the oldest old in the UK, Germany, Italy and Poland. This latter had the highest mortality rates with a peak of 62.5 per 100 000 women aged 85 to 89 followed by a sharp decrease at a rate of 29.1% per year (Figure 4).

Ovarian cancer

Ovarian cancer peaked in most countries at age 85 to 89 and then decreased. The decrease from age 85 to 89 until 95+ years was highest in Italy (-26.1%), the UK (-22.7%) and Australia (-21.4%) (Figure 4).

Prostate cancer

Among very old men, prostate cancer mortality rates were lowest in Japan and Poland. A large increase in mortality rate was observed between ages 85 to 95+ in the USA, in Japan and France. The increase in all other countries was not significant among these age groups (Figure 5).

Bladder cancer

Bladder cancer rates showed a strong increasing mortality in all countries with age among both men and women. For the UK, Germany, Italy, and Poland were observed decreases after age 90-94 in both sexes. In these countries, the gap in mortality rates among men and women widened after age 85 to 89 years. The exceptions among women were Japan, France, and Poland, with an increase of 29.1%, 36.8%, and 17.6% per quinquennium of age, respectively (Figure 5).

Non-Hodgkin lymphoma, multiple myeloma, and leukemia

Mortality rate trends for non-Hodgkin lymphoma, multiple myeloma, and leukemia were similar among both men and women by age group. For Non-Hodgkin lymphoma and multiple myeloma, an increase was observed for most countries, until a peak at 85 years old, followed by a decrease. Leukemia mortality rates peaked at age 90 years in Australia and the UK; mortality rates increase occurred earlier in Japan, Germany, Italy and Poland, followed by a decrease. In the USA and France, leukemia mortality rates increased for those over 90 years old (Figure 6).

DISCUSSION

Cancers of the esophagus, stomach, colorectum, pancreas, larynx, lung, bladder, uterus, ovary, and kidney, as well as non-Hodgkin lymphoma, multiple myeloma, and leukemia showed a mortality rate acceleration with age followed by a deceleration or levelling off, particularly after 85 years. This pattern was observed for both men and women and in most countries. The acceleration-deceleration trend was especially prominent for nearly all cancers with the exception of prostate and breast cancer, which largely increased and had a later peak age of cancer mortality. Cancers of the esophagus, stomach, liver, and larynx show a weaker relationship with age.

The relationship between age and cancer rate is consistent with cross-sectional studies that also find a rate deceleration or levelling off after a peak at 75 to 85 years old [16–20]. Cancer mortality is likely determined by factors pertaining to lifestyle and risk factor exposure, diagnosis, and treatment, that are site-specific. The mechanisms that may operate in shaping cancer mortality patterns in the elderly include (i) less intense screening, (ii) comorbidities, (iii) reduced likelihood to undergo aggressive treatment, (iv) depletion of the susceptible population, (v) disease misclassification (vi) changes in underlying risk factors (for example, hormones).

Individuals over 85 years have been mostly studied in aggregate when it comes to public health outcomes, leading to some uncertainty in rate estimations for each specific age year after 85 over shorter time periods. When pooling data by age over the course of a longer time period, however, it becomes difficult to separate period from cohort effects in the interpretation of cancer rates. The question of cancer rates among the oldest old still remains. A 2015 study using Surveillance, Epidemiology, and End Results (SEER) data which analyzed the age-period-cohort effects in individuals over 85 years in Utah [21] found that the decreasing trend in total cancer rate among the oldest old was still present, even after accounting for period and cohort effects [21]. The period effects accounted for events affecting all age groups because they occurred at one time point. For example, changes in cancer screening protocol and technology can affect all age groups to have higher or lower mortality rates, although the overall age-trend remains similar. A study of cancer trends from 1970 to 2015 [22], found an increase in prostate cancer mortality in males over age 65 years old.
for western countries to peak in the early 1990s, although overall, older men still had a higher mortality from prostate cancer than younger men [23, 24]. In addition to less intense screening, the effect of improved cancer treatment of aggressive prostate cancer subtypes is likely to have played a large role in decreasing mortality among the oldest old over time, although mortality rates still show an acceleration pattern and remain substantially higher than among younger men [22, 25].

Cohort effects include the unique experiences or exposures of a certain group, such as behavioral or environmental factors. Considering the variation in female bladder cancer rates among different countries, countries such as the UK and France with historically higher smoking rates in the 1950s [26] have a higher rate of bladder cancer mortality at the oldest age groups than countries with historically lower female smoking rates (for example, Italy with a 10% female smokers prevalence in the 1950s). The pattern of lung cancer mortality rates follows a similar trend with regards to tobacco smoking. The increasing lung cancer mortality among females over 85 years old in the US, for example, is preceded by increasing lung cancer rates 10 to 20 years before [27]. High mortality rates were found among men born in the 1920s [27], and who would have been in their 70s or 80s in 2000-2014, the time of this study). These cohort effects are reflected in the changes observed in mortality in particular age groups and may partly explain variations in mortality rates between countries.

Studies on the benefits of breast cancer screening often exclude women older than the age of 75 years, because screening is not recommended beyond that age [28–31]. While it has been proposed that older women may present with more aggressive or higher-risk disease [32, 33], other studies have documented that elderly women have less aggressive disease and a more favorable tumor marker profile (ER+ and/or PR+, HER2/neu, and decreased levels of cell proliferation markers) [34, 35]. Although the exact cause is not clear, the acceleration with age for breast cancer is less steep than non-epithelial cancers [36, 37].

Existing comorbidities and whether or not a patient is able to tolerate cancer therapy can also influence cancer mortality. Patients over 85 years with colorectal cancer have more comorbidities and are treated less aggressively than their younger counterparts [38], although colorectal cancer presents more frequently among the elderly and at more advanced disease stages [39]. Advanced colorectal cancer often requires major surgery as part of treatment, and the comorbidities heavily influence surgical eligibility and potential benefit from other treatment options [40, 41]. Because patients over 85 years old are at a greater risk of non-cancer-related mortality, they frequently receive adjuvant chemotherapy and more often discontinue treatment before completion [42–45]. The combination of comorbid conditions that may cause a competing risk of death before cancer death and the avoidance of higher risk therapies that may not be beneficial, may partly explain a mortality deceleration for this age group after a peak at middle age.

There is evidence for a biological component for longer survival. Genome-wide association (GWA) studies comparing the oldest old to younger control individuals, have found multiple genes to be associated with survival and longevity [46–48]. There is also evidence for a hereditary component of age at mortality from cancer. Inherited genetic factors are estimated to play a role in about 5 to 10 percent of all cancers [49], although penetrance among families is not completely understood.

Among twins, the effect of heritable factors ranged from 27 percent to 42 percent for colorectal, breast, and prostate cancer and single-gene mutations are expected to account for a fraction of these [50]. By age 70, the median cumulative risk for BRCA1 mutation carriers is about 50% to 80% for breast cancer and 24% to 40% for ovarian cancer [51]. Above age 70 to 75 years, the cumulative risk of breast cancer and ovarian cancer among BRCA1 and BRCA2 mutation carriers stabilizes [52]. Differences in breast cancer survival among BRCA2 mutation carriers are observed among patients carrying different genotype distributions. These differences may at least partly account for differences in survival among individuals with mutations of high-risk susceptibility genes. However, the frequency of mutations in known high-risk susceptibility genes as well as DNA mismatch-repair genes in hereditary nonpolyposis colorectal cancer, and the candidate gene HPC1 in prostate cancer [50] is too low to fully explain the majority of cancer mortality cases.

This study uses estimates that reflect the quality of national mortality data based on WHO principals [55]. There is a paucity of epidemiological data regarding cancer mortality trends in the very old, and persons over 85 years are commonly excluded from clinical trials or combined in a single age group in population-based analyses [5, 53, 54]. By stratifying by country and, at the same time, pooling data by a span of 15 years, we were able to compare mortality trends among the oldest old and younger age groups. We were also able to provide an overview of trends for cancer mortality in total and cancer mortality by site, including less common non-epithelial cancers. As this study was limited to countries with a high standard of data quality, it is not an exhaustive view on mortality in all adults.
aged 85+ years worldwide. In particular, caution must be taken not to extrapolate the interpretation of these findings to low- to middle- income countries with varying access to diagnostic and treatment resources. There is an under-ascertainment of cancer mortality at older age groups in epidemiology. Worldwide the Global Burden of Diseases have observed increases in the incidence of breast, colorectal and prostate cancer, especially in countries in transition [54]. Preventive strategies, including minimizing risk factors and optimizing screening, are likely to be critical to provide the necessary cancer care to reduce the burden of cancer in an ageing population.

MATERIALS AND METHODS

Official death certification data from 2000 through 2014 were extracted from the World Health Organization (WHO) Statistical Information System (WHOSIS) [15] for all cancers and 17 cancer sites: oral cavity and pharynx, including lip (C00-C14), esophagus (C15), stomach (C16), colorectum (C18-C21), liver (C22), pancreas (C25), larynx (C32), lung (C33-C34), breast (C50), uterus (cervix and corpus) (C53 and C54), ovary (C56), prostate (C61), bladder (C67), kidney (C64-C65), non-Hodgkin lymphoma (C81-C90, C96), multiple myeloma (C90), leukemia (C91-C95) and total cancers (malignant and benign) excluding non-melanoma skin (C00-C96, excluding C44). We retrieved mortality figures for 8 major countries with over 20 million inhabitants and over 95% population death certification coverage [55]. This included the USA, Japan, Australia, the UK, Germany, France, Italy and Poland. Cancers were coded in the WHOSIS database, based on the 10th Revision of the International Classification of Diseases (ICD) [56]. For the period 2000-2002 in Italy, the 9th Revision of the ICD was used [57]. Because coding differences between various revisions were, in general minor, we recoded all data for Italy according to the 10th Revision.

Statistical analysis

Age-specific mortality rates (2000-2014) were calculated for each 5-year age group from 65 and 84, and compared to 85 to 95+ age groups. We used joinpoint regression models [58], allowing for up to two trend segments, to identify age groups for which there were significant trend changes in the age-specific mortality for the 8 countries and the 17 cancer sites under study. We computed the estimated age percent change (APC) (defined as the percent change from one 5-year age group to the next) and the average quinquennial age percent change (AAPC) over all age groups considered [59, 60].

AUTHOR CONTRIBUTIONS

DH developed the study, wrote the manuscript, and interpreted the results. GC analyzed the data. SW provided expertise and contributed to the interpretation of the results. MM and PB extracted the data and supervised the analysis. EN, CL and PB supervised the study and edited the manuscript.

CONFLICTS OF INTEREST

All authors report no conflicts of interest.

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REFERENCES


2. GLOBOCAN and World Health Organization, Department of Information, Evidence and Research, mortality database.


4. United Nations, Department of Economic and Social Affairs, Population division. World Population Prospects, the 2015 revision.


24. The UK NSC recommendation on Prostate cancer screening/PSA testing in men over the age of 50. https://legacyscreening.phe.org.uk/prostatecancer


33. Statistics and Cancer Control Division, Research Center for Cancer Prevention and Screening, National Cancer Center: about Evidence Based Cancer Screening Promotion Home Page (in Japanese). http://canscreen.ncc.go.jp/.


SUPPLEMENTARY MATERIALS

Supplementary Tables

Please browse Full Text version to see the data of Supplementary Tables 1 to 3.

Supplementary Table 1. Age-specific cancer mortality rates per 100,000 from selected cancer sites at ages 69-69, 70-74, 75-79, 80-84, 85-89, 90-94 and 95+ in selected countries worldwide over the period 2000-2014.

Supplementary Table 2. Joinpoint analysis for oral cavity and pharynx, esophagus, stomach, colorectum, liver, pancreas, larynx, lung, prostate, bladder, kidney, non-Hodgkin lymphoma, multiple myeloma, leukemia and all cancers in men at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.

Supplementary Table 3. Joinpoint analysis for oral cavity and pharynx, esophagus, stomach, colorectum, liver, pancreas, larynx, lung, breast, uterus, ovary, bladder, kidney, non-Hodgkin lymphoma, multiple myeloma, leukemia and all cancers in women at age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95+ years, in selected worldwide countries.