Standard Period Life Table Used to Compute the Life Expectancy of Diseased Subpopulations: More Confusing Than Helpful

Life expectancy (LE) based on a period life table (PLT) traditionally serves as a general population summary metric. It is, however, becoming more frequently reported for chronically afflicted subpopulations.

In general populations, there is always an obvious real cohort sharing the hypothetical PLT cohort characteristics, and the LE estimate is intuitively understood as that real cohort mean survival time, assuming constancy of death risks. In diseased subpopulations, the correspondence between the hypothetical cohort and a real cohort is not straightforward. Furthermore, the excess mortality of chronic diseases usually changes according to age at onset and time since onset. The standard PLT method does not allow for proper control of these issues, so the LE estimate can only be deemed valid under specific assumptions.

Without clear statements about the real cohort to whom the estimate is intended and the assumptions allowing disregard of the effect of age at onset and time since onset, LEs of afflicted subpopulations computed with the PLT are only abstract numbers summarizing mortality rates. If called "life expectancy," they can be seriously misleading. The same applies to health-adjusted LE. (*Am J Public Health*. 2017; 107:1615–1620. doi:10.2105/AJPH.2017.303932)

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Life expectancy (LE) estimated through the period life table (PLT) method is widely used in public health to summarize age-specific mortality rates prevailing, at a given moment, in a general population.[1–3] This summary health indicator has many advantages. It builds upon contemporary data, requires only death and population aggregated numbers, gives more importance to death occurring early in life, and is independent of the population age structure. The method can also be extended to compute health-adjusted LEs, reflecting both population mortality and morbidity.[4] Most importantly, this metric is appreciated for its intuitive meaning, making it easy to communicate.

Over the past decade, the PLT method has increasingly been used to summarize mortality rates in subpopulations with various chronic health conditions including mental illnesses,[5–9] diabetes,[10–12] cancer,[12] and some risk factors such as hypertension[12,13] and obesity[14] (Table 1). When a standard PLT is applied to such subpopulations, the resulting LE becomes difficult to interpret and is very likely to be misleading. To our knowledge, this has not yet been described in the scientific literature. We outline how the LE is computed with the PLT in these studies and then discuss the challenges of interpreting the result. We finally present assumptions minimally required for such LE estimates to be valid.

PERIOD LIFE TABLE IN AFFLICTED SUBPOPULATIONS

The PLT is based on the cross-sectional age-specific mortality rates prevailing in a given source population and time period.[15,16] In accordance with this method, a hypothetical cohort progresses from one age stratum to the next until extinction, declining as dictated by the source population's age-specific mortality rates. The quotient of the number of person-years cumulated by the hypothetical cohort to the number of persons the cohort included at the start gives the LE estimate. A cohort of 100 000 women mathematically aged from birth until extinction, by 10-year age stratums, under the Canadian women's 2014 to 2015 mortality rates, could cumulate, for example, 8 000 000 person-years. The resulting LE of 80 years (8 000 000/100 000) represents the mean survival time of this hypothetical cohort aged under Canadian women's 2014 to 2015 death risks.

In the studies discussed here, the PLT method is applied to a subpopulation with a chronic health condition hereafter called "afflicted subpopulation." These studies exhibit minor methodological variations between them but, in essence, they all apply the standard PLT approach[5–14] (Table 1). A data set linking demographic, vital status, and health information is used to divide the source population into healthy and afflicted. The afflicted subpopulation provides the set of age-specific mortality rates for the PLT. Thus, the PLT resulting quotient represents the mean survival time of a hypothetical cohort mathematically aged under the death risks currently prevailing

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TABLE 1—Characteristics of the Studies Selected to Illustrate the Misleading Use of the Period Life Table to Compute the Life Expectancy of Afflicted Subpopulations

Author, Country, Year	Affliction	Data Source[a]	Case Definition[b]	Period[c]	LE Computed[d]	Comparison[e]	Note
Chang et al.,[5] United Kingdom, 2011	Mental illness	SLAM[f] database	Patient who contacted SLAM between 2006 and 2009 and received ≥ 1 diagnosis of serious MI[g]	2007–2009	At birth, by sex	General population	From birth to age 15 y, death risk provided by UK general population
Wahlbeck et al.,[6] Sweden, 2011	Mental illness	Nordic hospital discharge registers[h]	Patients with ≥ 1 hospital admission during the 5-y period because of MI[i]	5-y periods from 1987 to 1991, up until 2002–2006	At age 15 y, by country, by sex	General population	
Lawrence et al.,[7] Australia, 2013	Mental illness	WA register of contacts with MHS[j]	Patient with ongoing contact or ≥ 1 contact with MHS within 5 y of reference date because of MI[k]	5-y periods from 1983 to 1987, up until 2003–2007	At birth, by sex	General population	From birth to age 15 y, death risk provided by WA general population; probabilistic matching to link databases
Nordentoft et al.,[8] Denmark, 2013	Mental illness	Nordic hospital discharge registers[h]	All patients with ≥ 1 admission to a psychiatric or somatic department between 2000 and 2006 because of MI[l]	2000–2006	At age 15 y, by country, by sex	General population	Excluded anyone with ≥ 1 admission because of MI in the previous 13 y
Lesage et al.,[9] Canada, 2015	Mental illness	QICDSS database[m]	Any contact with a health service with a diagnosis code of MI[n] in the current y	1999–2012	At age 1 y, by sex	General population	
Manuel and Schultz,[10] Canada, 2004	Diabetes mellitus	Ontario Diabetes database[o]	Patient with ≥ 2 physician claims within a 2-y period or with ≥ 1 hospitalization because of DM	1996–1997	At birth, by sex	Population without DM	Ontario population with and without DM reconstituted by linking the ODD to a population-based survey database; LE extended to compute HALE
Loukine et al.,[11] Canada, 2012	Diabetes mellitus	CCDSS database[p]	Patient with ≥ 2 physician claims within a 2-y period or with ≥ 1 hospitalization because of DM	2004–2006	At birth and age 20, 55, and 80 y; by sex	Population without DM	LE extended to compute HALE
PHAC,[12] Canada, 2012	Diabetes mellitus and high blood pressure	CCDSS database[p]	Patient with ≥ 2 physician claims within a 2-y period or with ≥ 1 hospitalization because of DM and HBP	2004–2006	At birth and age 20 and 55 y, by sex, by condition (DM alone, HBP alone, DM and HBP)	Population without DM, without HBP, without DM and HBP	For HBP from birth to age 20 y, death risk provided by general Canadian population; LE extended to compute HALE
PHAC,[12] Canada, 2012	Cancer	Canadian Cancer Registry[q]	Persons with ≥ 1 primary invasive cancer registered in CCR from 1992 on	2002–2005	At birth and age 20 and 65 y, by sex	Population without cancer	LE extended to compute HALE

Continued

TABLE 1—*Continued*

Author, Country, Year	Affliction	Data Source[a]	Case Definition[b]	Period[c]	LE Computed[d]	Comparison[e]	Note
Loukine et al.,[13] Canada, 2011	High blood pressure	CCDSS database[p]	Patient with ≥ 2 physician claims within a 2-y period or with ≥ 1 hospitalization because of HBP	2004–2006	At age 20–24, 25–29, etc., up to ≥ 85 y, by sex	Population without HBP	LE extended to compute HALE
Steensma et al.,[14] Canada, 2013	Suboptimal weight	NA[r]	Standard BMI categories for underweight, overweight, obese class 1, and obese class 2	2000–2005	At age 20 y, by BMI category, by sex	Population with normal weight	LE extended to compute HALE

Note. BMI = body mass index; CCDSS = Canadian Chronic Disease Surveillance System; CCR = Canadian Cancer Registry; DM = diabetes mellitus; HALE = health-adjusted life expectancy; HBP = high blood pressure; LE = life expectancy; MHS = mental health services; MI = mental illness; NA = not applicable; ODD = Ontario Diabetes Database; PHAC = Public Health Agency of Canada; PLT = period life table; QICDSS = Quebec Integrated Chronic Disease Surveillance System; SLAM = South London and Maudsley NHS Foundation Trust; WA = Western Australia.

[a]Data source allowing the division of the total population into afflicted and not afflicted.

[b]Characteristics used to identify the afflicted subpopulation.

[c]Period for which the LE by PLT was computed.

[d]Age at which and subgroups for which the LE was computed by PLT.

[e]Group to which the afflicted subpopulation LE by PLT was compared.

[f]Provider of secondary mental health care.

[g]Schizophrenia, schizoaffective disorders, bipolar affective disorder, substance use disorder, depressive episode, and recurrent depressive disorder.

[h]Registers of the Danish psychiatric central, Finnish hospital discharge, and Swedish hospital discharge.

[i]Any *International Classification of Diseases (ICD)-10* codes F00–F69.

[j]Includes inpatient, outpatient, and community-based mental health services.

[k]Alcohol or drug disorders, schizophrenia, affective psychoses, other psychoses, neurotic disorders, stress or adjustment reaction, depressive disorders, and other mental disorders.

[l]Substance abuse, schizophrenia spectrum, affective disorders, and personality disorders.

[m]Database linking Quebec physician billing agency and Quebec Ministry of Health and social services databases.

[n]Any *ICD-9* codes 290–319 or *ICD-10* equivalent, that were further divided into mood and anxiety disorders, and schizophrenic disorders.

[o]Population-based registry linking Ontario Health Insurance Registry Database, physician claims database, and hospital discharges database; started in 1996.

[p]Collaborative network of Canadian provincial and territorial chronic disease surveillance system linking province or territory health insurance registry database, physician billing database, hospital discharges, and vital status registry; started in 1999.

[q]Cancer registry that contains information on incident cancer diagnosed in Canada from 1992 onward.

[r]Instead of direct subdivision of the total population into afflicted and none afflicted subpopulations, authors decomposed, by age stratum, the total Canadian death rate into death rates by BMI categories. This decomposition was based on BMI categories' prevalence and BMI categories' hazard ratio of death, relative to normal weight. The prevalence and hazard ratios were obtained from, respectively, a cross-sectional population-based survey and the analysis of a longitudinal population-based survey.

in a given afflicted source subpopulation.

THE LIFE EXPECTANCY OF WHOM?

In any PLT, the hypothetical cohort is characterized by the age at which the life table starts, and the time, place, and person characteristics of the source population providing the mortality rates. If a PLT starts at age 20 years and is supplied with the Canadian 2014 to 2015 women's mortality rates, the hypothetical cohort's characteristics are being aged 20 years in 2014 to 2015, residing in Canada, and being female. When LE is computed for such a population, delineated by time, place, and basic personal characteristics acquired at birth, it is easy to identify a real cohort sharing the PLT cohort's characteristics. There was a meaningful group of women aged 20 years in 2014 to 2015 in the Canadian population. The only thing differentiating this real cohort from the PLT cohort is that, over time, the former will experience actual death risks, whereas the latter is artificially aged under the 2014 to 2015 death risks. This makes the LE according to the PLT readily understood as the average time this real cohort of women would live, assuming the 2014 to 2015 death risks be frozen until their extinction.

When the LE of an afflicted subpopulation is computed with the PLT, the hypothetical cohort is not defined only by time, place, and personal characteristics acquired at birth, but also by some affliction features. Here the source population providing the mortality rates must meet criteria of ongoing care use (active prevalent case) or

recent diagnosis (incident case) or of some suboptimal state (e.g., being obese). Therefore, the PLT hypothetical cohort implicitly meets the same case definition at each subsequent age of its hypothetical life. In some cases (e.g., exposure to a lifestyle risk factor), it might be relatively straightforward to identify a meaningful group of real individuals that meets a given invariable case definition at each subsequent age throughout their life, after a given age. But for conditions defined by an event, such as a recent episode of care or a recent diagnosis, there will be no clinically meaningful group with such characteristics. No real cohort will have had a recent episode of diabetes care at each subsequent age of its life since, for example, age 20 years. Likewise, no real cohort will have had a recent hospitalization for mental illness or a recent cancer diagnosis at each subsequent age of its life. In these cases, the real cohort closest to the hypothetical cohort might be the one sharing its characteristics precisely at the first age stratum of the PLT; in our examples, respectively, the one with a recent episode of diabetes or a recent hospitalization for mental illness or a recent cancer, precisely, at the age of 20 years.

So, contrary to a PLT computed in a general population, identifying the real cohort to whom the LE estimate belongs is not straightforward. In the scientific literature reporting LE according to PLT as summary mortality metric for afflicted subpopulations, readers are often convened to restrict their interpretation to some descriptive meaning. But never are they guided to which group of individuals the average survival time estimate should be attributed, assuming constancy of death rates. Lay people, patients, health care providers, planners, and decision-makers will interpret such LE result as the average survival time of some real group of people. They are likely to attribute the result to an ill-defined group who met the PLT case definition at some point in their life course, which corresponds neither to the group who met the case definition precisely at the start of the life table nor to the even more restricted group who met it at every subsequent age of its life. Even when the intention is to describe current cross-sectional death rates, it is mandatory to specify to what real cohort the LE estimate is intended. Otherwise, the LE estimated by the PLT is just an abstract number summarizing current death rates that cannot be intuitively understood as the mean remaining time to live of any real group. Calling such measure an LE is definitely confusing and misleading.

WHEN IS SUCH LIFE EXPECTANCY ESTIMATE VALID?

Once one understands to which real cohort the LE calculated by the PLT might belong, the question is whether the estimate is valid. Does this number of years reflect properly what that specific real cohort could expect to live, assuming the current death risks be frozen until its complete extinction?

First, the PLT does not take into account patterns of remission and recurrence of time-dependent conditions, such as mental illnesses, that can come and go over the life course. With such conditions, the PLT can only estimate the mean duration of life for a fraction of the entire afflicted subpopulation. Because the case definition will usually identify the prevalent active cases, this fraction will usually be composed of the individuals from the afflicted subpopulation that never comes into remission.

Second, for most chronic health conditions, whether time-dependent or time-independent, the magnitude of excess mortality changes over time. Generally, it will rise slowly over time, but it can also drop sharply, as with cancer. Moreover, sometimes the age at onset discriminates between disease variants with different outcomes. In diabetes, age at onset discriminates between type 1 and 2 diabetes featuring different evolution patterns.[17] Because the standard PLT does not allow proper control of these issues, LE estimate of an afflicted subpopulation will only be valid when time elapsed since onset of the condition and age at onset can be disregarded.

This happens when in the source population, after a given age, the disease status of individuals becomes highly correlated over time. Chetty et al. computed the LE with the PLT of US men and women aged 40 years, in 2001 to 2014, conditional on household income percentile at age 40 years.[18] The validity of their approach relies on the fact that earnings after age 40 years are highly correlated over time, an assumption clearly stated and demonstrated by the authors. Indeed, when the onset of an afflicted state occurs pretty much at the same age for everyone and is mostly irreversible, then the PLT automatically controls for age at onset and time since onset. This pattern of occurrence appears more likely for states of exposure to health determinants or risk factors, as in the Chetty et al. study, rather than for states of mental or physical illness.

Another instance in which an afflicted subpopulation's LE according to the PLT could be deemed valid is when computed for a condition whose excess mortality remains stable over time. Survivorship beyond the immediate posttraumatic phase of a spinal cord injury has been considered such a nonprogressive condition.[19] This means that, beyond the acute phase, the age-specific mortality experience of spinal cord–injured people would be increased, in comparison with general population, by a constant factor throughout their remaining life. Because of the nonprogressiveness of such a condition, the LE according to the PTL could not be impaired by time elapsed since onset. If ever age at onset affects the excess mortality associated with such a nonprogressive condition, life tables could be computed separately for different ages at onset. Debating the accuracy of the nonprogressiveness assumption for whatever chronic condition is beyond our scope, but it could mainly apply to states of physical or mental disability.

The Canadian Public Health Agency reported a LE of 22.4 years at age 20 years, in 2002 to 2005, for men with cancer, compared with 62.1 years for men without cancer.[12] They build the PLT by using 1992 to 2005 Canadian Cancer Registry data. Is 22.4 years a valid estimate of the actual mean survival time any real Canadian cancer group can expect to live, assuming constancy of the Canadian 2002 to 2005 death risks? Here, the PLT hypothetical cohort meets a definition of recent cancer history at each subsequent age of its life after age 20 years. This has no correspondence in the real world. The closest real cohort

could be the Canadian men aged 20 years in 2002 to 2005, with a cancer diagnosed between 1992 and 2005 (between age 10 and 20 years). Can this group of individuals expect to live on average 22.4 years, assuming constancy of 2002 to 2005 death risks? Most likely they will live, on average, much longer. For this health condition, one cannot disregard age at onset and time since onset. Thus, the 22.4-year figure is just an abstract number summarizing 2002 to 2005 mortality rates among Canadian men aged 20 years and older with a recent cancer diagnosis. It is the LE of no one else than a hypothetical cohort, with no correspondence in the real world. Capocaccia et al. published more realistic LE estimates for male cancer patients.[20] These estimates were 21.2 years, at age 47 years, for colorectal cancer and 45.2 years, at age 30 years, for testicular cancer.

In most instances in which the LE estimated with the PLT metric is used to summarize current age-specific death rates of an afflicted subpopulation, there is confusion around the real cohort to whom readers should attribute the LE estimate. Once that is solved, there is still questioning around the validity of the estimate, even assuming constancy of current death risks. Moreover, afflicted subpopulations' LE according to the PLT will include some "immortal time" if the life table starts before the age at which the subpopulation forms. Over and above the interpretation problems already discussed, comparison of LE according to the PLT including different immortal time intervals will be biased.[21]

Such measures are therefore very likely to be misunderstood and to mislead whatever audience to which they are communicated. Unless under the specific circumstances described previously, health professionals should rely on established epidemiological frequency measures such as standardized, adjusted, or stratified mortality rates to summarize current age-specific mortality rates of diseased subpopulations. Although not as intuitive, they are unlikely to be misinterpreted.

PERIOD LIFE TABLE IN DISEASED SUBPOPULATIONS

Reporting LE computed with the PLT of chronically afflicted subpopulations might be done for purposes other than summarizing current death rates. Authors may want to assess the contribution of a given condition to the global health of a population. Such contribution can be assessed by using a summary health gap metric, such as the disability adjusted life year, or using a counterfactual approach, including the "cause-deleted LE" metric, but not using a positive summary health measure like LE.[22] Authors may also want to predict the survival time of some individuals. This is questionable because death risks in modern times are volatile, making the constancy of current death risks assumption hardly justifiable. This issue is even more crucial with diseased subpopulations, as the death risks in such groups may be highly sensitive to access, quality, and efficacy of health care. Such forecasting of injured, disabled, or diseased individuals' survival time is usually achieved through alternatives to the PLT approach such as the cohort approach.[23,24] Finally, authors may want to measure how a particular condition affects the future prospect of patients at different times in their life course. This has been done for cancer by using a data set with long retrospective follow-up and a PLT adapted to account simultaneously for age at diagnosis and time since diagnosis.[20]

Moreover, there exists an important body of research on the relationship between the PLT approach and the cohort approach to estimation of LE.[25] We did not address this issue, but rather intentionally restricted our comment on the standard PLT because we felt there was an urgent need for clarification over its increasing use with diseased subpopulations.

CONCLUSION

The growing availability of health databases makes it now feasible to compute LE, based on the standard PLT method, for subpopulations with various chronic conditions such as exposure to lifestyle risk factors, health determinants, mental illnesses, chronic diseases, or cancers. When this metric and its derived health-adjusted LE metric are computed for such subpopulations with a personal characteristic acquired after birth, the result is complex to interpret and very likely to mislead those to whom it is communicated. Even after one assumes constancy of the current death risks, without clear statements about the real cohort to whom the LE estimated with the PLT is intended and about reasons why age at onset and time since onset can be disregarded, the LE according to the PLT of afflicted subpopulations are only abstract numbers. In most cases, they only express the mean survival time of a hypothetical cohort that has no correspondence in the real world. AJPH

CONTRIBUTORS

L. Perron and M. Simard designed this commentary. All of the authors were directly engaged in discussion surrounding the production of this article, written by L. Perron. All authors revised the first draft of the article and approved the final version.

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Because no human participants were directly involved for this methodological commentary, no institutional review board approval was needed.

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