A COHORT ANALYSIS OF MORTALITY IN NEW ZEALAND, 1876–2004

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1. Introduction

New Zealand has long enjoyed a special place in the demographic community for its rich historical data treasure. The country's population and vitals data are arguably among the most complete, systematic and long running series in the world, dating back to the mid-1800s (Kannisto 1994).

New Zealand's significance in the world's demographic history is further underlined by its world-leading position in life expectancy around the turn of the twentieth century. Indeed the historical mortality trends in New Zealand have been the subject of extensive research (for example, see Newman 1882, Pool 1982, Pool and Cheung 2005, Oeppen and Vaupel 2002). The full historical significance, however, has largely been limited to cross-sectional data and techniques employed in those earlier analyses.

This paper presents an empirical analysis of the results of a detailed study of mortality by birth cohorts undertaken by Statistics New Zealand (Dunstan, Howard and Cheung 2006). The study traces the mortality experience of New Zealanders born from 1876 to 2004 by deriving complete cohort life tables for annual birth cohorts. A key objective of that study was to exhaust all available data sources in compiling a single authoritative cohort mortality series.

This paper provides empirical evidence of changes in mortality and survival during New Zealand's history. Trends for New Zealand cohorts are compared with those from other countries where data are available. Special attention is given to the impact of the two World Wars on life expectancy. Later in the paper, differences between cohort and period measures are examined.

2. Data and methodology

A diverse range of methods and approaches for compiling cohort data and constructing cohort life tables have been developed over the years. The use of a combination of methods has become the norm because of the limitations of historical data.

The New Zealand cohort life tables were constructed using the fundamental components of population change. By using data on births, deaths and net migration, the cohort size, exposure-to-risk and mortality history is reconstructed for each birth cohort and traced year by year from birth to death.

This is a most data-intensive approach compared with other methods such as model-based indirect estimations. The approach is afforded by the relatively complete historical data available from multiple sources. Full detail of the methodology has been described elsewhere (Dunstan, Howard and Cheung 2006).

Despite the readily available population component data, significant estimation was necessary because of variations in coverage and completeness over time. Notably, indigenous Mäori births and deaths were highly under-registered before the 1940s; data on war deaths were sourced from non-statistical sources; and interpolation of single-year of age data from grouped age data was necessary.

The demographic data was compiled independent of census data because of the greater irregularity and variable coverage of census data. Overall, the adopted approach provides flexibility for aggregation to grouped birth cohorts or ages.

For cohorts born after the early 1900s which have yet to complete their life span, their remaining cohort mortality experience is projected to enable the calculation of life expectancy and other whole-of-life cohort measures. A modified Brass logit system (Mitra 1997) is used to model the remaining mortality experience based on the observed experience of previous birth cohorts. (See Dunstan, Howard and Cheung 2006 for a full description of the projection methodology.)

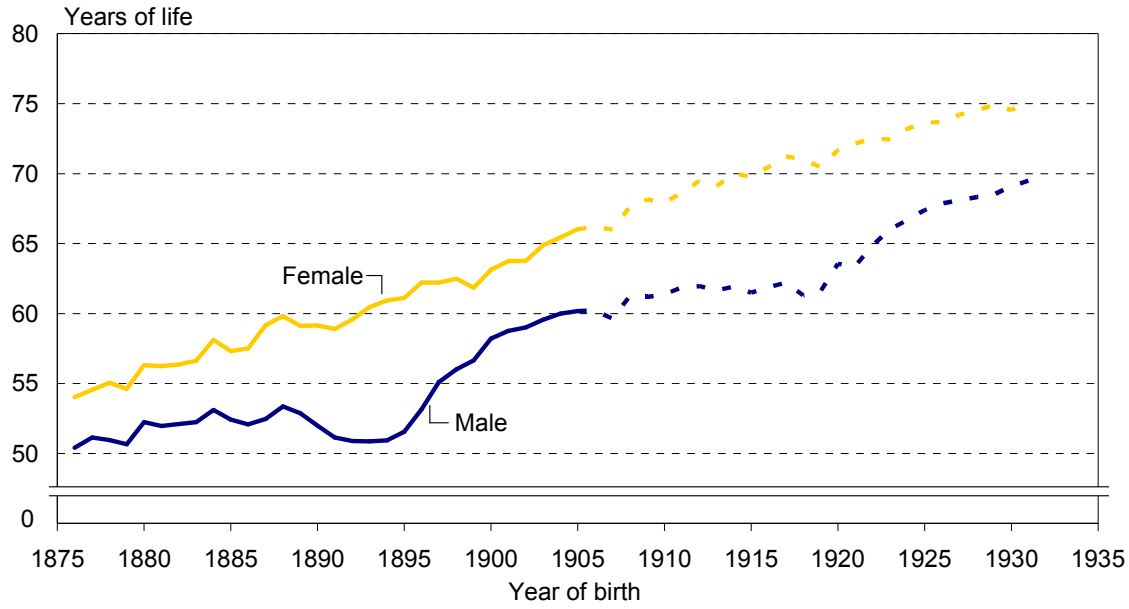
In presenting the results of the cohort life tables, projected life table data are distinguished from the observed historical data by the use of dashed lines in the figures and italics in the table in this paper.

3. Results

In New Zealand, mortality decline and the accompanying increases in life expectancy have been steady for successive birth cohorts. Life expectancy at birth for males born in 1876 was 50.4 years. In the space of just over half a century, life expectancy at birth for males born in 1931 (the most recent cohort for whom life expectancy has been calculated) increased by nearly 20 years, to 69.5 years. Even greater increases occurred among females, from 54.0 years for the 1876 cohort to 75.2 years for the 1931 cohort.

The trajectory of cohort life expectancy increase is remarkably linear, especially for females (Figure 1). The annual rate of increase in life expectancy at birth between 1876 and 1931 was 0.35 years for male cohorts and 0.38 years for females (R^2 = 0.93 and 0.99, respectively). Spells of short-term fluctuations interrupted the long-term historical trend for both males and females. The impacts of war deaths on male cohort life expectancies are profound, as evident by the plunge for the early 1890s and the late 1910 cohorts; a point that we return to later in this paper.

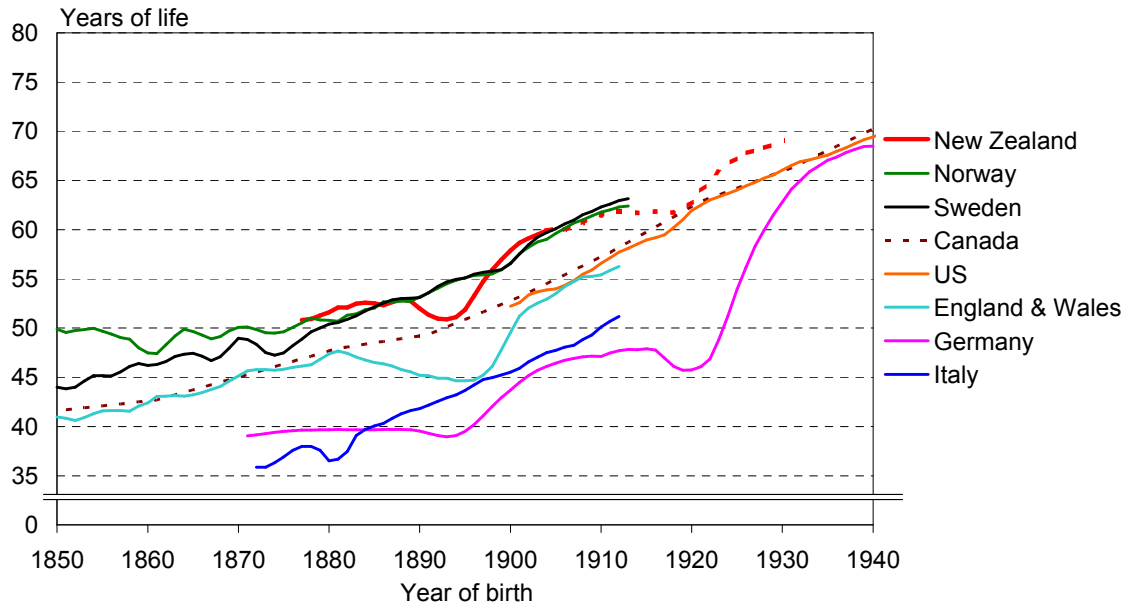
Figure 1. Life expectancy at birth



3.1 International comparison

Historically, New Zealand period life expectancies are amongst the highest in the world, and this pattern is reinforced by the cohort measures. Figures 2 and 3 compare New Zealand cohort life expectancy at birth with those from other countries comparable in terms of their timings of mortality and demographic transitions and where data are available.

Figure 2. Male cohort life expectancy at birth (three-term moving average), New Zealand and selected countries

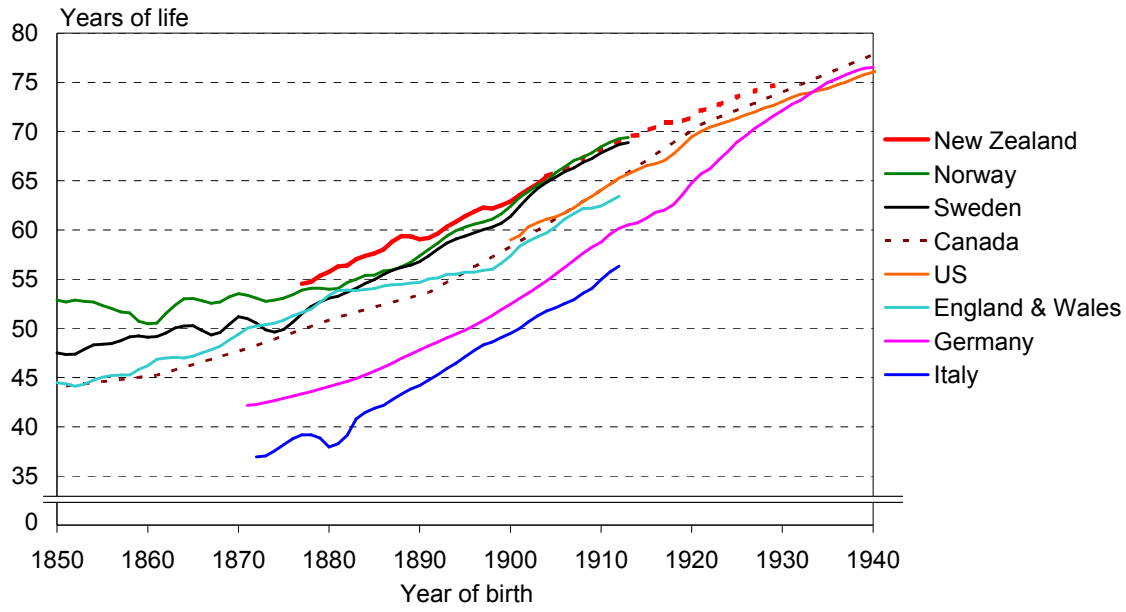


Note: Methodological differences between countries in data compilation and life table construction would suggest caution in making detailed comparisons.

Data sources: New Zealand – Statistics New Zealand (2006), www.stats.govt.nz/datasets/population/
Canada – Statistics Canada, www.statcan.ca/cgi-bin/downpub/

Germany – Federal Statistical Office, Germany, www.destatis.de/
Denmark, England and Wales, Italy, Norway, Sweden – The Human Mortality Database, www.mortality.org/

Figure 3. Female cohort life expectancy at birth (three-term moving average), New Zealand and selected countries



See Figure 2 for methodological note and data sources.

The significance of Figures 2 and 3 is New Zealand's position relative to other countries collectively. For those born between the late 1870s and 1910, cohort life expectancy at birth in New Zealand surpassed other countries under comparison. The advantage of New Zealand female cohorts is most noticeable. Comparison of the male cohorts is complicated by the differential impacts of the war deaths across countries, as well as the differential treatment of war deaths in different studies.

Trends in life expectancy at birth mask important age differentials in mortality. In sharp contrast to the leading position at birth, New Zealand cohort life expectancy at ages 15 and above was below many countries under comparison (data not shown here). In other words, the advantage in cohort childhood survivorship that New Zealand enjoyed over other countries did not extend to adult ages. An in-depth discussion of this pattern is presented elsewhere (Cheung and Didham 2007).

3.2 Age differentials

Cohort life expectancy trends at selected ages are shown in Figures 4 and 5. Among cohorts born in the late 1870s, life expectancy at birth (age 0) was at a similar level to that at age 15. That is, upon surviving the first 15 years of life, longevity outlook was still the same as at birth. This highlights the prevalence of childhood mortality at the time.

Figure 4. Male life expectancy at selected ages

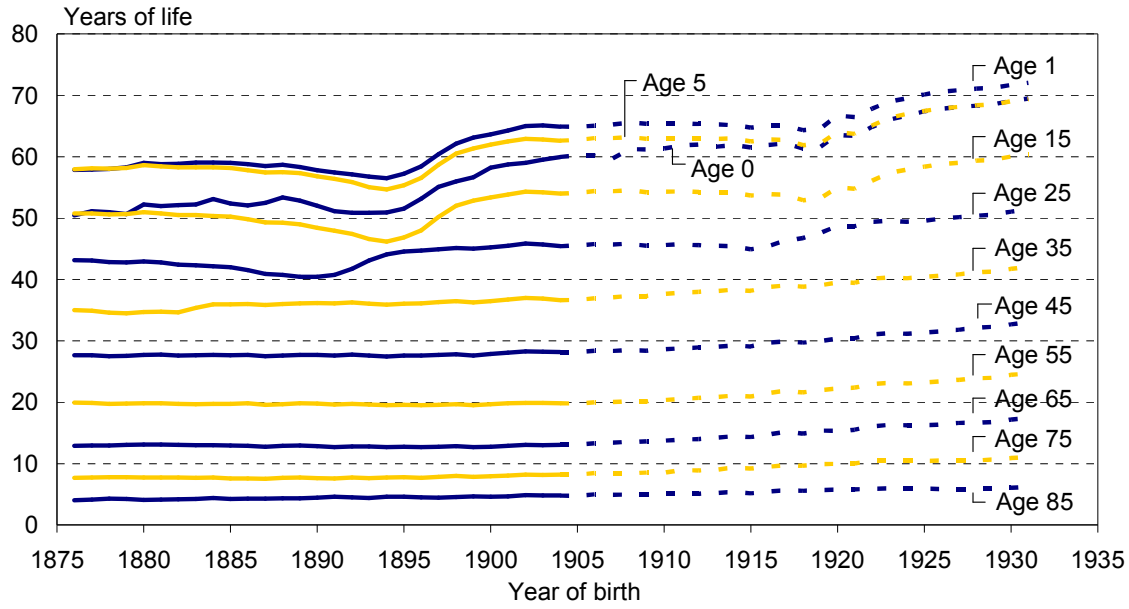
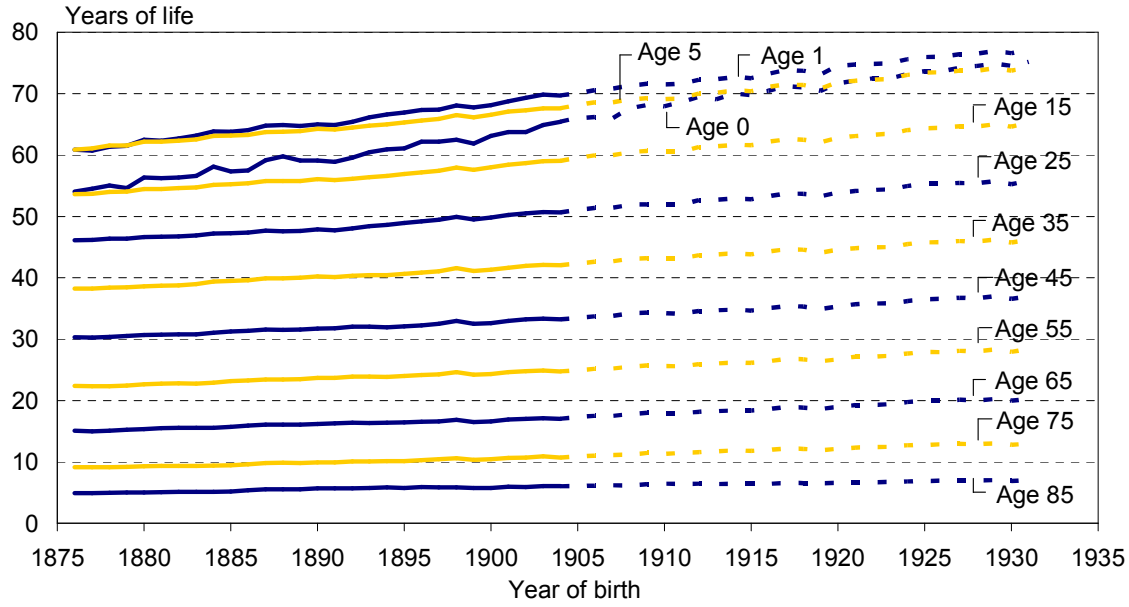


Figure 5. Female life expectancy at selected ages



The difference between life expectancy at birth and at age five was about seven years for those born in the late 1870s. The crossover in life expectancy at birth and at age five occurred only towards the end of the comparison period: among females born in the early 1920s and males born in the early 1930s.

No crossover in life expectancy occurred between birth and age one. The gap reduced progressively but persisted. This is not surprising given that the crossover between life expectancy at birth and at age one in period life tables only occurred in the mid-1970s for females and early 1980s for males.

Interestingly, trends for male life expectancy at middle and old ages stayed virtually unchanged for cohorts born from late 1870s to early 1910s, before

showing an appreciable upswing among more recent birth cohorts. The male trajectory contrasts with the almost linear trends for females (see also Table 1).

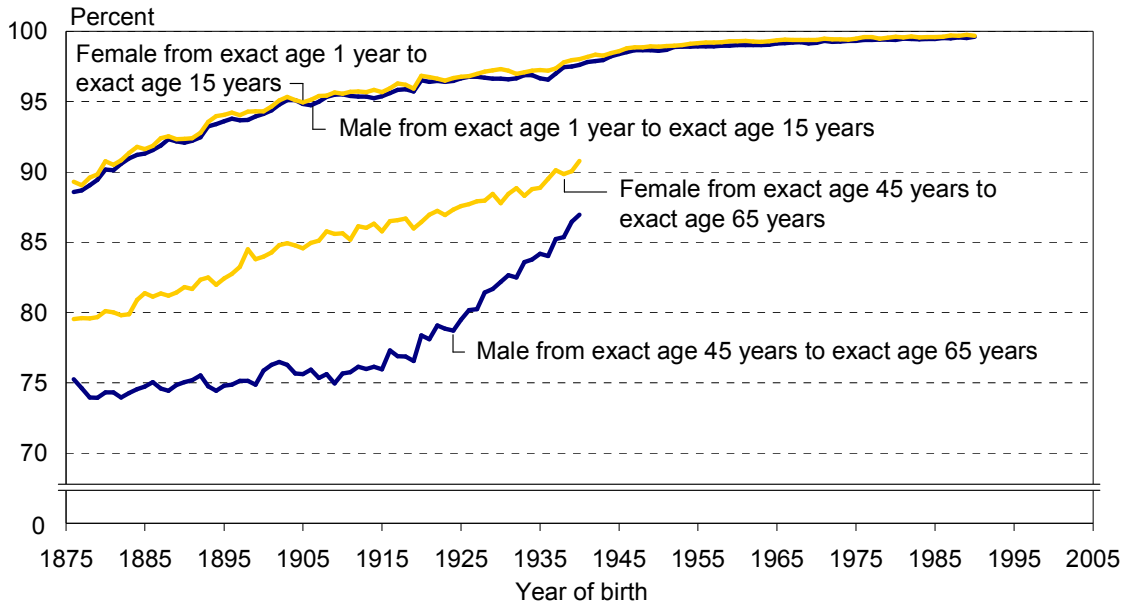
Table 1. Proportion surviving between selected ages 0 to 85 years by sex and selected birth cohorts 1876–2001

Year of birth	Male proportion surviving from exact age to exact age (years)					Female proportion surviving from exact age to exact age (years)				
	0 to 1	1 to 15	15 to 45	45 to 65	65 to 85	0 to 1	1 to 15	15 to 45	45 to 65	65 to 85
	Percent									
1876	85.6	88.6	83.1	75.3	31.2	87.3	89.3	85.2	79.5	41.1
1881	86.8	90.1	83.0	74.3	31.2	88.7	90.5	86.1	80.0	42.2
1886	87.0	91.6	81.1	75.1	30.3	88.3	91.8	87.0	81.1	43.6
1891	87.4	92.2	78.3	75.2	29.2	89.3	92.4	87.3	81.7	45.6
1896	89.4	93.8	79.5	74.9	30.6	91.0	94.2	89.3	82.7	48.5
1901	89.9	94.4	90.0	76.3	33.7	91.3	94.7	90.5	84.3	50.7
1906	91.1	94.7	90.6	75.9	36.4	92.4	95.1	92.2	84.9	52.6
1911	93.1	95.4	89.8	75.8	40.5	94.5	95.7	92.8	85.2	55.4
1916	93.6	95.6	87.5	77.3	43.3	94.9	96.0	94.2	86.5	59.9
1921	93.9	96.4	88.4	78.1	*46.4*	95.2	96.7	94.8	87.0	*61.6*
1926	94.7	96.8	93.9	80.2	*49.1*	95.6	96.8	95.7	87.7	*64.3*
1931	95.1	96.6	94.4	82.6	*53.0*	96.3	97.2	96.2	88.4	*65.0*
1936	95.1	96.6	94.6	84.0	..	95.9	97.2	96.9	89.5	..
1941	95.4	97.8	95.3	..	..	96.3	98.2	97.4	..	..
1946	96.3	98.5	95.7	..	..	97.0	98.8	97.5	..	..
1951	96.8	98.7	95.5	..	..	97.5	98.9	97.6	..	..
1956	97.5	98.9	95.3	..	..	97.9	99.2	97.7	..	..
1961	97.4	99.0	..	..	..	98.0	99.3	..	..	..
1966	97.9	99.2	..	..	..	98.5	99.4	..	..	..
1971	98.2	99.3	..	..	..	98.5	99.5	..	..	..
1976	98.4	99.4	..	..	..	98.8	99.6	..	..	..
1981	98.7	99.5	..	..	..	99.0	99.6	..	..	..
1986	98.8	99.5	..	..	..	99.0	99.6	..	..	..
1991	99.1	..	..	..	..	99.3	..	..	..	..
1996	99.2	..	..	..	..	99.4	..	..	..	..
2001	99.4	..	..	..	..	99.5	..	..	..	..

Symbol: .. figures not available

Figure 6 highlights interesting gender and age differentials. Males and females benefited almost equally in childhood survivorship improvements, but experienced contrasting fortunes in terms of middle (and old) age survivorship. Among older working age females there were steady improvements throughout the period. In relative terms, improvements of female older working age survivorship were only slightly less than those at infancy, childhood and reproductive ages.

Figure 6. Proportion surviving childhood and older working ages



Among older working age males, survivorship deteriorations and fluctuations among the earlier cohorts were accompanied by very rapid improvements among the post-World War I cohorts. These trends and the male-female differences are likely to be explained by patterns of smoking and coronary heart disease. The rapid survivorship increases in male older working ages helped close the sex gap in life expectancy. This is a trend also indicated by period life tables since the mid-1970s (Dunstan, Smeith and Thomson 2004).

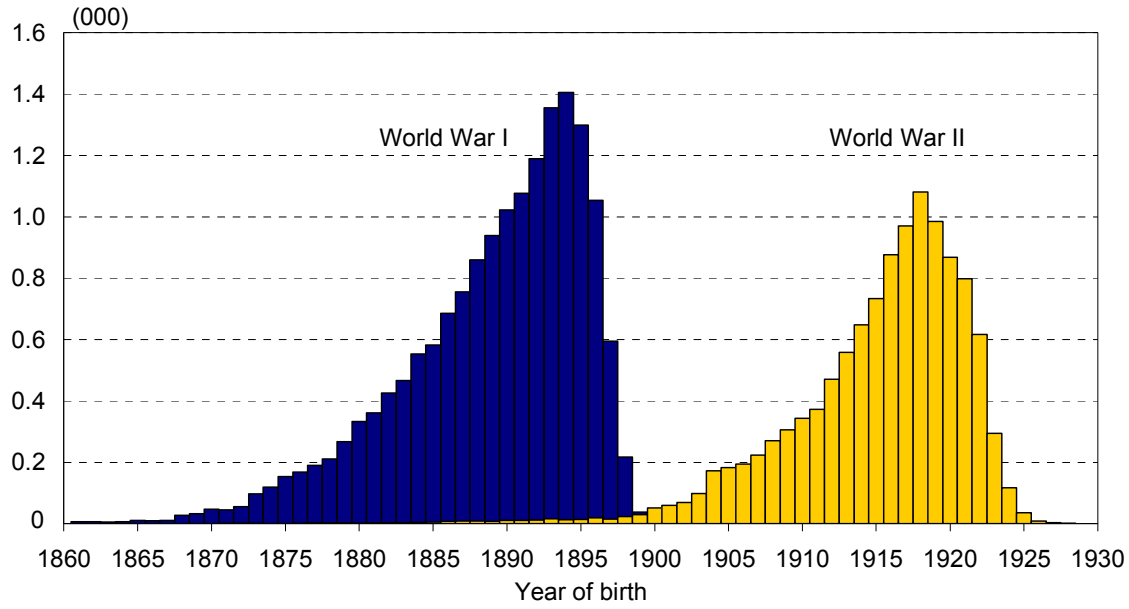
3.3 War deaths

As noted earlier in this paper, male cohort life expectancy was significantly affected by war deaths, principally from the two World Wars. As would be expected, the impacts were strongly age selective, materially affecting age differentials in cohort survival.

War deaths are an integral part of the history of many New Zealand birth cohorts and indeed of the history of New Zealand, even though all deaths occurred outside of New Zealand. The significance of the war deaths is heightened by their relative impact on a fledgling nation with a small population.

In World War I, 110,000 New Zealand men served overseas in the armed forces, or about 20 percent of New Zealand's male population and 40 percent of males aged 20–44 years. Almost 17,000 were killed, half of whom were born in 1890–1896 (Figure 7). In addition, there were over 41,000 wounded. In World War II, 140,000 New Zealand men served overseas in the armed forces, which accounted for about 15 percent of the male population. Almost 12,000 were killed, half of whom were born in 1916–1921. In addition, there were 17,000 New Zealanders wounded.

Figure 7. New Zealand male deaths in World War I and II

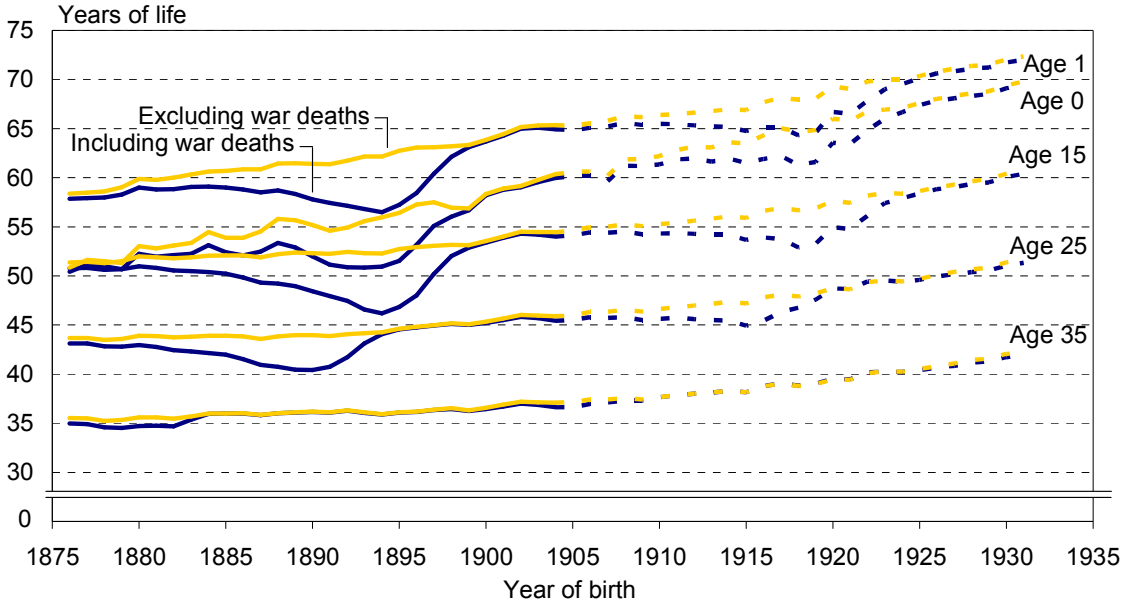


To quantify the impact of war deaths on male cohort life expectancies, a scenario-based approach was adopted to model the two extremes: including or excluding war deaths from the cohort life table calculations. The scenario of excluding war deaths effectively treats those deaths as external migration rather than mortality.

It should be noted that the impact of war deaths cannot be completely isolated and removed. For example, returning war veterans may have been affected by injuries and illnesses incurred during the war that compromised their lifetime survival. Conversely, the selection effects among survivors could also have positive statistical ramifications on survival. The number of war deaths is one of the many consequences of war, and, as a corollary, excluding war deaths is not the same as entirely removing the effect of wars on cohort survival.

The exclusion of war deaths produces a male cohort life expectancy time series that parallels that of females, although male life expectancy is still lower than that of females for each corresponding birth cohort. The results suggest that without the direct effect of war deaths, life expectancy at birth would have been 2–5 years higher for the 1887–1897 cohorts and 2–3 years higher for the 1915–1921 cohorts (Figure 8). As would be expected given a median age of the war deaths of 26, the impact persists through the young ages, and starts to diminish from the mid 20s to become insignificant by age 40.

Figure 8. Male life expectancy at selected ages, including and excluding war deaths



For males born in the early 1890s, one-third had died before the age of 32. If the war deaths are removed, one-third would have died instead by age 53. For comparison, among females born in the early 1890s, one-third had died by age 57.

3.4 Differences between cohort and period measures

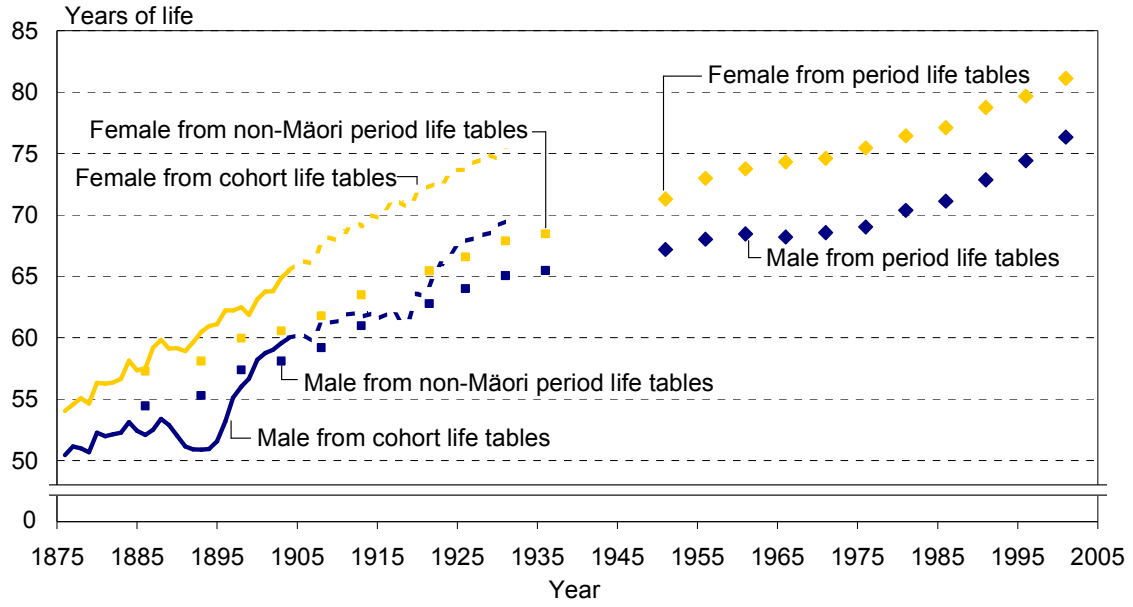
In an environment of systematic mortality decline, period life tables tend to underestimate the true extent of survivorship improvement and the level of life expectancy. This limitation of period life tables is generally well understood by demographers, although the same is not always true among the policy and analytical communities. An understanding of this underestimate is hindered by a scarcity of empirical evidence, reflecting the substantial undertaking that is required to derive cohort life tables.

The earliest official period life tables relating to the New Zealand population were for the non-Māori (predominately of European origin) mortality experience. That is, they did not include the mortality experience of the indigenous Māori population. Complete period life tables for the total New Zealand population began with the 1950–1952 period and have been published at five-year intervals (Dunstan, Smeith and Thomson 2004).

The comparison confirms that period life tables generally underestimate the life expectancy of cohorts born in each period (Figure 9), as represented by the vertical distances between period and cohort figures in a given year, or what is known as the “gap” (Goldstein and Wachter 2006). While this is consistent with expectations, it is interesting that the underestimate of life expectancy has been less for males than females. The consequences of war experience on male cohort mortality meant that period life tables of the late 1800s actually

overestimated life expectancy, albeit the period measures relate to non-Māori only.

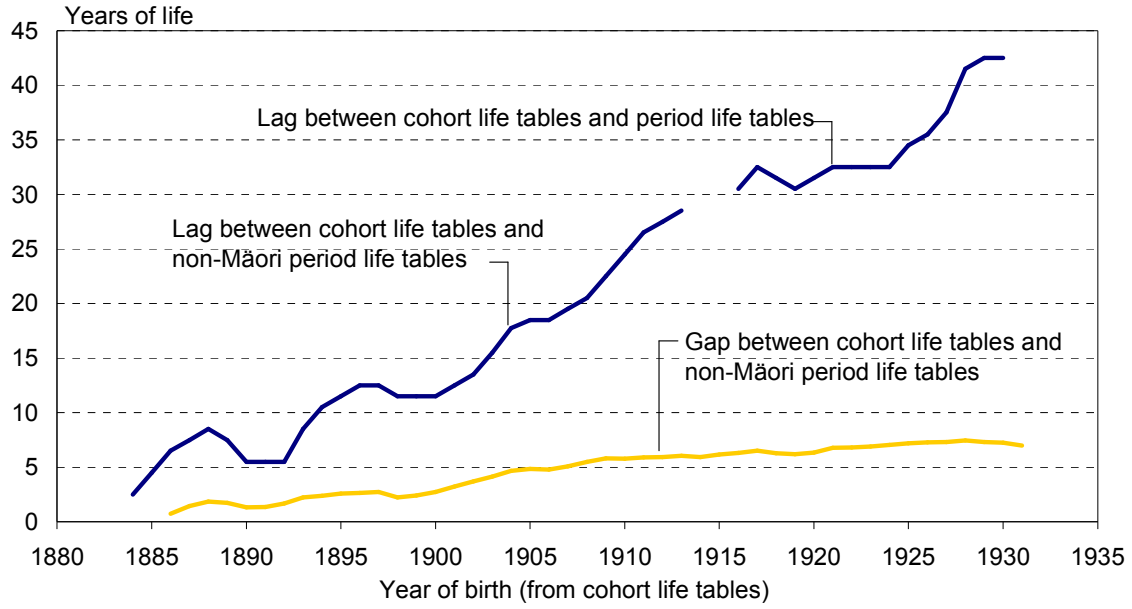
Figure 9. Life expectancy at birth from cohort and period life tables



Note: Data from cohort life tables refers to year of birth. Data from period life tables refers to year of death.

In comparison with the cohort life tables, the 1931 non-Māori period life tables underestimated life expectancy at birth by 7.3 years for females and 4.4 years for males. It was not until the mid-1970s that the period life tables indicated life expectancies at birth similar to the 1931 cohort life tables; a measure of the "lag" (Goldstein and Wachter 2006). Figure 10 illustrates the gap and lag for New Zealand females. (Males are not presented here because period life tables did not incorporate war deaths).

Figure 10. Gap and lag between female life expectancy at birth from cohort life tables (three-term moving average) and period life tables

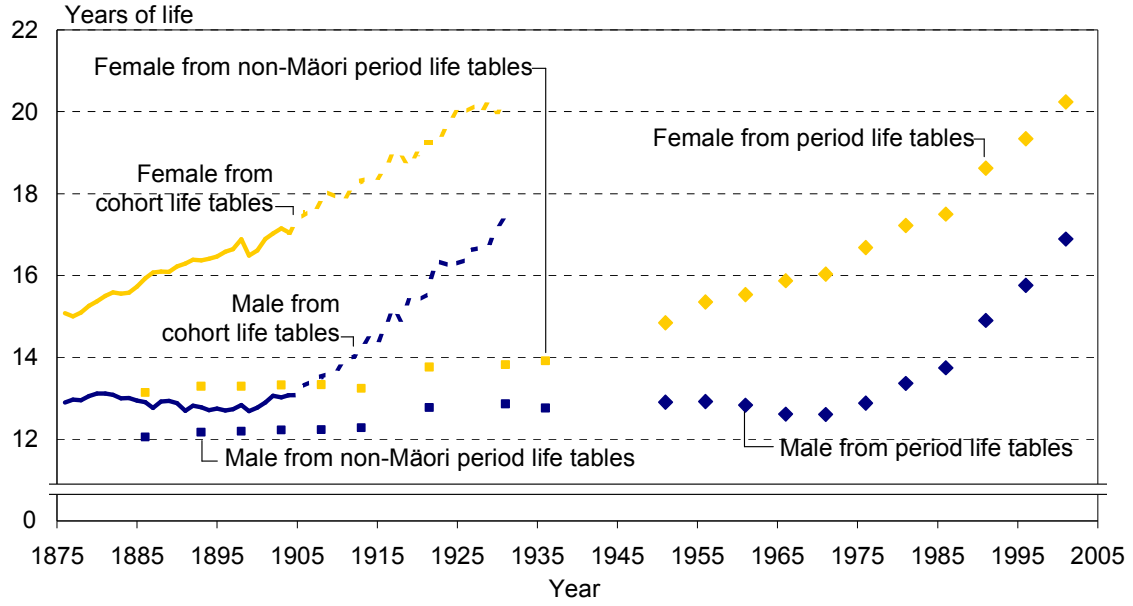


Note: Period life table data has been interpolated to provide the annual estimates of gaps and lags.

In terms of the trend in life expectancy at birth, the cohort life tables indicate a more rapid rate of change than the period life tables. This is also a feature noted by Wilmoth (2005).

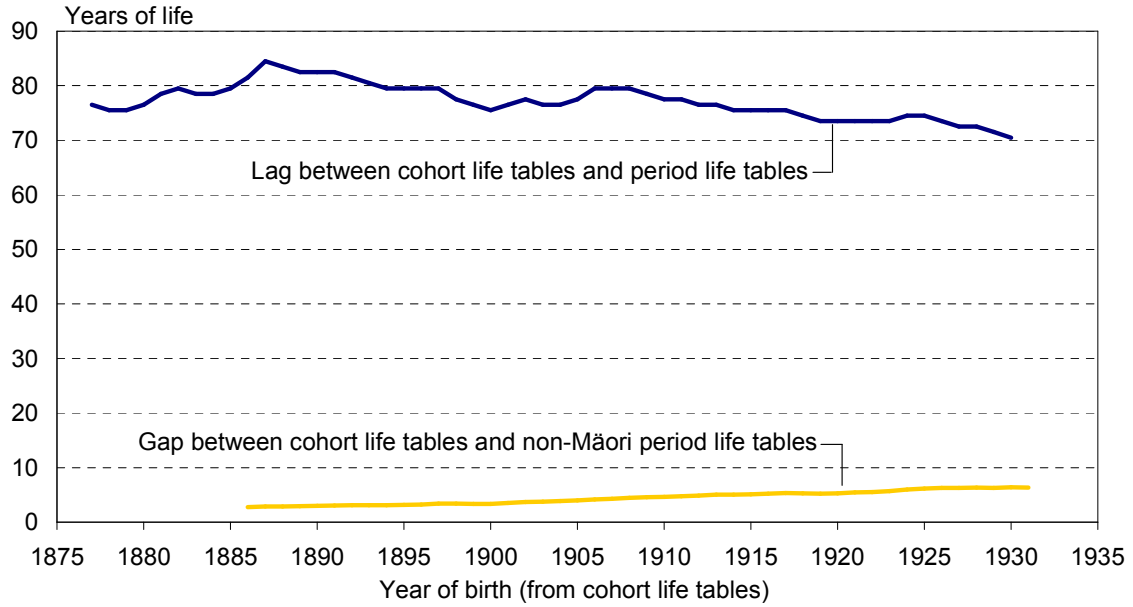
Compared with the cohort life tables, the period life tables significantly underestimate life expectancy at age 65 (Figure 11). In comparison with the cohort life tables, the 1931 non-Māori period life tables underestimated life expectancy at age 65 by 6.5 years for females and 4.5 years for males. It was not until the mid-2000s that the period life tables indicated life expectancies at age 65 similar to the 1931 cohort life tables. So although the cohort and period life tables exhibit a similar pattern of change in life expectancy at age 65, the period life table results lag behind those of the cohort life tables by about three-quarters of a century (Figure 12).

Figure 11. Life expectancy at age 65 from cohort and period life tables



Note: Data from cohort life tables refers to year of birth. Data from period life tables refers to year of death.

Figure 12. Gap and lag between female life expectancy at age 65 from cohort life tables (three-term moving average) and period life tables



Note: Period life table data has been interpolated to provide the annual estimates of gaps and lags.

4. Conclusion

The empirical analysis afforded by the cohort life tables reveals some important insights. Increases in life expectancy at birth between the 1876 and 1931 birth cohorts were almost linear, by 0.38 years of life per female birth cohort, and by 0.35 years of life per male birth cohort (excluding war deaths).

The analysis shows that life expectancy of people in New Zealand has been much higher than previously indicated by period measures. For example, life expectancy at birth for the 1931 cohort was at a level comparable to that from the 1975–1977 period life tables. (Similarly, in comparison with the cohort life tables, the 1931 non-Mäori period life tables under-estimated life expectancy at birth by 7.3 years for females and 4.4 years for males). Furthermore, the rate of change in life expectancy at younger ages has been more rapid than indicated by period life tables.

For the first time in any New Zealand population study, the deaths of New Zealanders in overseas wars have been included, quantifying the direct impact of war on the life expectancy of males. The impact of war deaths was hugely significant, such that life expectancy at birth would have been as much as five years higher for males born in the mid-1890s if the war deaths are excluded. Under that scenario, female death rates were slightly higher than male in the main reproductive ages (20–34 years) among cohorts of the late 19th century.

Also for the first time, the study covers the entire New Zealand population by combining Mäori and non-Mäori data. Previous cohort studies have been limited to Mäori or non-Mäori trends before World War II. While the integration of Mäori and non-Mäori data provides complete coverage of the nation, the data cannot be readily disaggregated to provide separate Mäori and non-Mäori cohort measures. Cohort measures are more affected by the evolving concept and measurement of ethnicity in New Zealand, as well as changes in individual ethnic identity and identification over time. Period measures, however, continue to provide evidence of persistent ethnic mortality differentials (Dunstan, Smeith and Thomson 2004).

A useful by-product from the effort by Statistics New Zealand is that it produces a single and authoritative source of comprehensive historical birth, death and migration data, which was painstakingly compiled from all available sources on a consistent basis. In the process, the major events in New Zealand's history which impacted on health and population were systematically documented, thereby increasing the understanding of New Zealand's history. The resultant dataset is a statistical treasure to the research community.

In summary, this paper presents the actual and changing life expectancy of New Zealanders born at different points in history. In doing so the analysis greatly complements the earlier cross-sectional analyses by providing an ongoing longitudinal perspective. The compilation and analysis of cohort mortality provides a new and valuable analytical resource to research endeavours in the areas of mortality, human longevity and various transition theories.

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