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Trends in survival and life expectancy by ethnicity, income and smoking in New Zealand: 1980s to 2000s

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Abstract

Background Survival and life expectancy are commonly used metrics to describe population health. There are two objectives to this paper: (1) to provide an explanation of methods and data used to develop New Zealand life-tables by ethnic, income and smoking groups; and (2) to compare cumulative survival and life expectancy trends in these subpopulations.

Method We generated sex-specific life-tables for seven subpopulations: ethnicity (Māori and non-Māori); income tertiles; smoking (never and current); and two-way combinations (ethnicity by income; ethnicity by smoking; and smoking by income). This was repeated for five census-mortality cohorts (1981–84, 1986–89, 1991–94, 1996–99, and 2001–04).

The method used to create the life-tables brings together three pieces of information: (1) the official Statistics New Zealand (SNZ) life-tables by year and sex; (2) the proportionate distribution of the total population by subpopulation (e.g. smoking prevalence); and (3) estimates of the differences in subpopulation mortality rates (from the New Zealand Census-Mortality Study [NZCMS]).

Results Survival and life expectancy improved in all subpopulations across the five census cohorts. However, improvements were greater in non-Māori compared to Māori and high income compared to low income subpopulations. This led to widening of the gap in life expectancy between 1981 and 2001 between Māori and non-Māori (males), which increased from 5.4 years in 1981 to 9.0 in 2001 and between low income and high income which increased from 4.4 in 1981 to 6.5 in 2001 for males.

The gap in life expectancy between current and never smokers in 1996 was 7.6 in males and 6.7 in females. However, the size of this gap varied by ethnicity: 7.3 and 6.2 for non-Māori males and females, and 4.3 and 3.9 for Māori male and females. Correspondingly, the gap in life expectancy between Māori and non-Māori is greater among never smokers (9.7 and 8.4 for males and females) than among current smokers (4.3 and 6.6 for males and females).

Conclusion Life-tables have been successfully developed for subpopulations in New Zealand, and provide an alternative understanding of health and life in New Zealand over the past 20 years. Ethnic and income gaps in life expectancy have widened, and perhaps surprising results were found for smoking by ethnicity. These life-tables provide an important basis for subpopulation modelling and projections, and are freely available to researchers.

Background

Life expectancy is a commonly used metric to describe population health.[1,2] Life expectancy is calculated from life-tables that give mortality rates by single year of age, up to 100 or more years of age, usually for a 'synthetic' population of 100,000 people to which current mortality rates are applied, i.e. what is called period life expectancy. Whilst an artificial construct that does not actually represent any birth cohort's expectancy of life, they are very useful summary health measures for policymaking, monitoring and communication to the public.

Life-tables are useful for modelling the impact of interventions and calculating other epidemiological measures. For example, relative cancer survival is determined by subtracting expected survival (derived from life-tables) from the observed survival of cancer patients, and to be accurate requires having life-tables for each subpopulation within which one wishes to calculate cancer survival (e.g. by income group, or smoking group).[3-5]

It is this methodological requirement for subpopulation life-tables in order to calculate accurate cancer survival estimates that precipitated the work and outputs presented in this paper. However, subpopulation life-tables and life expectancy are also useful outputs in their own right for describing differences in health status between population groups, and reflecting on societal and other casual mechanisms that have got us to where we are.

In this paper we present life-tables and life expectancies from 1981 to 2001 for various groupings of ethnicity, income and smoking status. An accompanying paper in this issue, uses the ethnic by smoking life-tables to estimate life expectancy in New Zealand in 2040.[6]

Calculating subpopulation life-tables requires reliable data on mortality rates for each subpopulation, which is often not the case when one is relying on routine mortality data that is not linked to census (denominator) data. The existence of linked census-mortality data in New Zealand, especially in light of smoking data being collected on 1981 and 1996 (and more latterly 2006) census data, provides a strong basis for the development of subpopulation life-tables.

Ethnic-specific life-tables are available from Statistics New Zealand (SNZ), but are prone to error prior to 1995-97 due to historic undercounting of Māori deaths (and over counting of non-Māori deaths).[2, 7-9] The Ministry of Health have created life-table estimates by ethnicity and New Zealand Deprivation Index.[10, 11] The existence of linked census-mortality data provides a rich data source for direct calculation of age-specific variations in mortality between ethnic, income and smoking groups that is not usually available to demographers generating life-tables.

Thus, the two objectives to this paper are:

- Explanation of the methods and data used to develop New Zealand life-tables by ethnic, income and smoking groups.
- Comparison of cumulative survival and life expectancy trends in these subpopulations.

Methods

Overview—We generated life-tables for seven subpopulations, each for males and females separately, namely: two ethnic groups (Māori and non-Māori); three income groups (tertiles of household income: low, medium, high); and two smoking groups (never and current). Then we generated life-tables for two-way combinations of these subgroups (for males and females): six ethnic by income groups; four ethnic by smoking groups; and six smoking by income groups. That is, another 16 life-tables for each sex. Finally, this was repeated for each of the five census-mortality cohorts (1981–84, 1986–89, 1991–94, 1996-99, and 2001-04), a total of 158 life-tables (110 for various ethnic and income combinations but only 48 for life-tables involving smoking as it was only elicited at the 1981 and 1996 censuses).

Before giving more detail, it is useful to first understand that our method brings together three pieces of information:

- The official SNZ life-tables by year and sex (i.e. all ethnic, income and smoking groups combined).
- The proportionate distribution of the total New Zealand population by subpopulation (e.g. smoking prevalence) (sourced from census data).
- Estimates of the differences in subpopulation mortality rates (sourced from the New Zealand Census-Mortality Study [NZCMS]).

These three inputs were combined to produce mortality rates by single year of age for each subpopulation, and thence complete life-tables for each subpopulation. Put another way, we used NZCMS information on subpopulation differences in mortality applied to official life-tables.

A brief overview of life-table terminology is provided in Appendix 1 at the end of this article.

Data

The SNZ m_x (mortality rate in each single year age group on official life-table)

Complete period life-tables, by sex and year of age, are available from SNZ for the three years surrounding each census, 1980-1982, 1985-1987, 1990-1992, 1995-1997, and 2000-2002.[2, 12] In the SNZ life-tables the construction of each complete life-table involved two stages. First, central death rates (m_x) were calculated for each age (x), except the first year of life, and were then smoothed to eliminate any apparent irregularities. Second, the smoothed rates were used to calculate a set of age-specific probabilities of death (q_x), which were then used to derive other life-table functions.[2, 12]

The proportion of the population in each social group of interest within each single year age group

We used census data to determine the proportion of the population within each one year age group in each census year (i.e. 1981, 1986, 1991, 1996, 2001) in each subpopulation of interest (including combinations of, say, ethnicity by income). If the census count by single year of age in the subpopulation was less than 5 (i.e. as often occurred at older ages), age was aggregated up to 5 year age bands, and the subsequently calculated proportion was assumed to apply uniformly to all subsumed single-year ages.

The estimated mortality rate (ratios) between social groups from NZCMS data

Much previous work using NZCMS data has documented social inequalities in mortality [8], and we used this prior information to specify analyses for generating life-tables. Briefly, we pooled all NZCMS data (i.e. 1981-84, 1986-89, 1991-94, 1996-99 and 2001-04), and ran pre-specified Poisson regression models by sex based on prior information to specify interactions (SAS code is available at www.uow.otago.ac.nz/nzcms-info.html).

We conducted the modelling of NZCMS data on observations with complete data for each analysis (nearly all observations for smoking, 20% missing for household income). To 'smooth' estimates across multiple small categories (e.g. single year age group; calendar year, small social groups), we used continuous variable specifications of age (centred at 60 years of age and linear splines with knots at ages 15, 24, 45 and 60) and calendar year (linear and quadratic terms). NZCMS data includes deaths up to age 77 (except for 2001-04 which includes all ages).

To allow for variations in mortality between subpopulations of interest, main effect and interaction coefficients were specified. For example, an interaction term was specified for each subpopulation with the spline function of age (as mortality rate ratios by ethnicity, smoking and income vary by age, often in a non-linear way[8]).

Due to missing deaths above age 77, the rate ratio (RR) between the groups of interest (e.g. Māori compared to non-Māori) was specified to decrease linearly to 1.0 at age 100 from that predicted at age 80. For example, if the estimated RR was 1.40 at age 80, then we set it at 1.38 at age 81, 1.36 at age 82, and so on. For two-way life-tables (e.g. ethnic by smoking groups) rate ratios for cross-classified subpopulations compared to the overall referent group (e.g. non-Māori never smokers) reduced linearly to the null.

Calendar year (census), and calendar year squared, were included as continuous variables in the regression models to allow for secular trends in mortality over time, and interactions with social group variables. Tertile groups of household income were calculated, separately for each five-year age group, for all census years pooled after CPI adjustment (see CancerTrends technical report for details[13]). Ethnicity was coded as Māori and non-Māori. We did not include Pacific ethnicity in the calculation of life-tables due to small numbers and the imprecision around the mortality estimates over time.

Previous research has shown no interaction of ethnicity and income for mortality on the relative scale on average across time[8]; therefore no interaction between income and ethnicity was included in the regression models.

Figure 1. Plot of rate ratio of mortality for Māori low income versus non-Māori high income for males, derived from regression modelling of NZCMS data

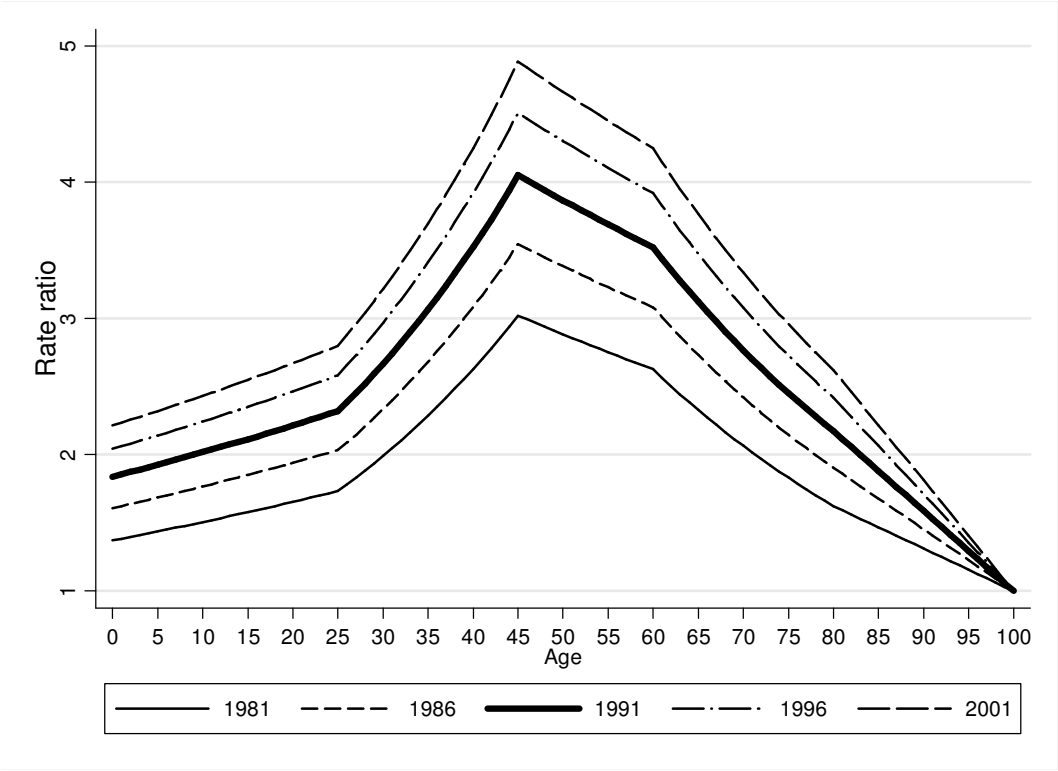


Figure 1 shows the estimated rate ratios across ages for the five census years for the ethnicity by income model (rate ratio of Māori low-income v non-Māori high-income). Figure 1 highlights the effect of the age knots and age spline in the rate ratios. The 1991 census is highlighted as the model was centred on this year. The figure also highlights the large inequalities for simultaneous ethnic by income stratification, with a predicted rate ratio of all-cause mortality between low-income Māori and high-income non-Māori of nearly five at 45 years of age in the 2001 Census.

For the smoking models the 1981 and 1996 Census data (pooled) were included, for people aged 0-74 on census night. Those with missing smoking data were excluded. Note that only those aged 15 and up were

included in the models of smokers. For smoking life-tables, mortality rates up to age 14 were assumed to be those of the sex by ethnic group (i.e. not stratified by smoking status).

Generation of subgroup specific life-tables—Having estimated the rate ratios by age, year and subpopulation group of interest using the NZCMS regression estimates, the m_x in the reference group was calculated using simple algebra. The three pieces of information, SNZ mortality rate ($m_{x,SNZ}$), proportion of the population (P_M), and mortality rate ratio (RR) described above (further index by M and nM for Māori and non-Māori, respectively) were brought together to estimate m_x.

For example, m_x non-Māori (reference):

$$m_{x,nM} = \frac{m_{x,SNZ}}{\left(P_{nM} * RR_{nM}(1) + P_M * RR_M\right)}$$

Therefore, estimating m_x in Māori is:

$$m_{x,M} = RR_m * m_{x,nM}$$

Finally, with estimated mx's for each subpopulation group and single year of age (x = 0 to 100), the whole life-table could be generated. The subsequent qx (probability of dying in the year) and px (probability of surviving another year) were back calculated using the above formulae. The cumulative survival (to age x) and life expectancy (from age zero) were then calculated as follows:

Cumulative survival = $\prod_{0}^{x} p_x$

Life Expectancy at birth = $e_0 = \frac{\sum_{i=0}^{100} L_i}{l_x}$, where l_x at age 0 is estimated to be 100,000.

Validation—The estimated ethnic-specific life-tables were compared to the official SNZ Māori and non-Māori life-tables for more recent years where numerator denominator bias is not problematic, and found to closely agree.

Comparison of ethnic-specific life expectancy to SNZ official life expectancy was also made. Our estimated life expectancy at age 0 for non-Māori was very similar to the SNZ estimates of life expectancy. However, the SNZ ethnic-specific life-tables do not take into account the undercounting of mortality in Māori and therefore SNZ Māori life expectancy in 1981 to 1996 censuses was overestimated.

Comparing life expectancy at birth for the 2001 census cohorts, the results for females were similar for Māori and non-Māori but for Māori males our calculated life expectancy was underestimated by about 0.8 years. This may be an artefact of the assumptions made in the modelling of mortality, i.e. the quadratic for calendar year may not have 'been enough' to fit the notable fall in Maori mortality between the 1996-99 and 2001-04 cohorts. We also compared our estimated life expectancy to adjusted ethnic-specific national life-tables,[14] and the overall results were similar.

Results

Figure 2a compares cumulative survival across year of age in the 1981 and 2001 censuses by ethnicity, for males and females. The further to the right the curve, the greater the life expectancy, which in turn is given by the area under the curve. Of note, the survival curve for non-Māori in 1981 is to the right of the survival curve for Māori in 2001, consistent with Māori life expectancy in 2001 not having caught up with where non-Māori life expectancy was in 1981. All survival curves in females are shifted further right towards older ages compared to males. Survival improved the most in non-Māori males over these two decades.

Figure 2a. Cumulative survival probability by ethnicity and sex, 1981 and 2001

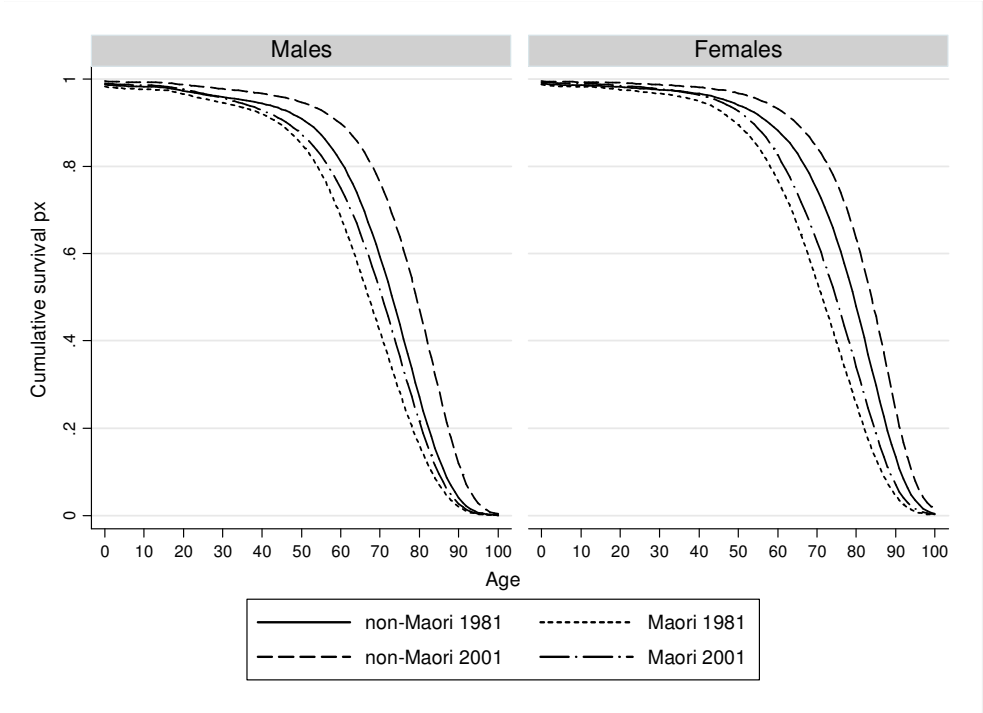


Figure 2b. Cumulative survival probability by income and sex, 1981 and 2001

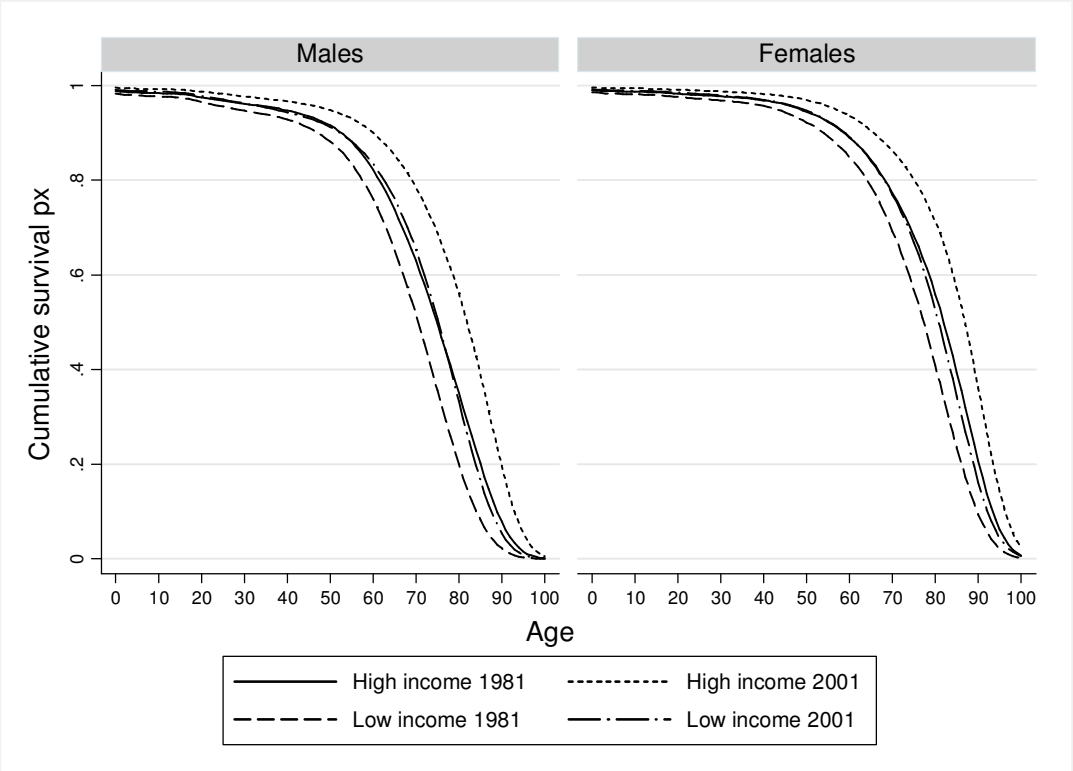


Figure 2b compares cumulative survival across year of age in the 1981 and 2001 censuses by low and high income tertiles (medium income not presented here), for males and females. There is a trend of better survival with increasing level of income in 1981 and 2001 and for males and females. Although survival at younger ages has improved in 2001, there seems to be a steeper decline in survival at older ages (> 75 years) in males in 2001. The survival of low income females in 2001 is less than survival of high income females in 1981, so it seems that female improvements in survival over time and within income groups were not as great as those for males.

Figure 3 presents cumulative survival for the ethnicity and income combinations in the 2001 census, for males and females. There are strong disparities in the survival curves between Māori and non-Māori for both males and females. The disparities between Māori and non-Māori within income groups appear to be greater in females compared to males. For males at older ages (85+ years) the survival of non-Māori low income is similar to that of the Māori high income group. When looking at survival across the income groups within ethnicity, the distance between low and high income survival curves is greater in Māori compared to non-Māori.

Figure 3. Cumulative survival probability for ethnicity by income and by sex, 2001.

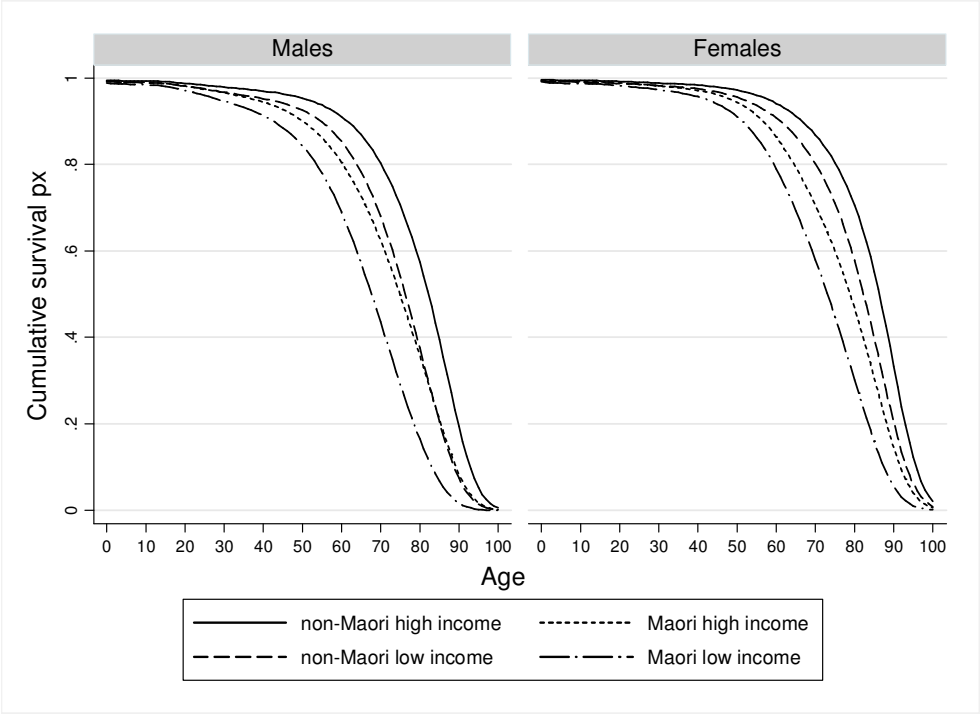


Table 1. Life expectancy at birth (age 0) by subpopulations for males and females by cohort

Variables		Male					Female				
		1981	1986	1991	1996	2001	1981	1986	1991	1996	2001
Ethnicity	Māori	65.4	64.5	65.1	66.4	68.2	69.7	69.4	70.4	71.4	73.0
	non-Māori	70.8	71.7	73.6	75.4	77.2	76.9	77.7	79.4	80.5	81.8
Income	Low	68.1	68.2	69.6	71.0	72.7	74.9	75.2	76.6	77.4	78.8
	Medium	70.5	71.0	72.6	74.2	76.1	76.7	77.2	78.7	79.6	81.0
	High	72.5	73.5	75.4	77.2	79.2	78.2	78.9	80.7	81.8	83.5
Smoking	Current	68.1			69.7		73.8			74.9	
	Never	73.2			77.3		77.8			81.6	
Income*Ethnicity											
Low	Māori	63.3	62.2	62.8	64.0	65.6	68.2	67.6	68.6	69.6	71.3
	non-Māori	68.8	69.1	70.7	72.3	74.0	75.6	76.0	77.5	78.5	79.8
Medium	Māori	65.9	65.2	66.1	67.5	69.5	70.3	70.0	71.1	72.1	73.9
	non-Māori	70.8	71.5	73.2	74.9	76.8	77.1	77.7	79.3	80.2	81.6
High	Māori	67.8	67.4	68.6	70.3	72.5	71.7	71.5	72.9	74.4	76.6
	non-Māori	72.8	73.8	75.8	77.7	79.7	78.6	79.3	81.0	82.3	83.9
Smoking*Ethnicity											
Current	Māori	63.9			63.8		68.8			69.5	
	non-Māori	68.6			70.9		74.3			76.0	
Never	Māori	65.6			68.1		69.7			73.4	
	non-Māori	73.8			78.3		78.2			82.2	
Smoking*Income											
Current	Low	65.8			66.5		72.2			72.6	
	Medium	68.1			69.7		73.8			74.9	
	High	70.3			72.7		75.4			77.3	
Never	Low	71.0			74.2		76.5			79.7	
	Medium	73.5			77.3		78.1			81.6	
	High	75.3			79.8		79.3			83.5	

Table 1 presents life expectancy at birth (age 0) for all main effect and interaction subpopulations of interest. There are improvements in life expectancy at age 0 for all subpopulations across the cohorts, from 1981 to 2001. When looking at trends over time the largest improvements in life expectancy were seen in non-Māori males and more generally for non-Māori compared to Māori (absolute increase 1981-2001 6.5 years male non-Māori, 2.8 years male Māori; 5.0 years female non-Māori, 3.3 years female Māori) and for the high income population compared to the low income population (absolute increase 6.7 years male high income, 4.6 years male low income; 5.3 years female high income, 3.9 years female low income). This led to the greatest improvements in survival in non-Māori high income males and females over time. The smallest improvement in life expectancy by ethnicity and income was in the Māori low income population (particularly males).

The estimated gap in life expectancy between Māori and non-Māori widened over the 20 years, with the absolute difference between ethnic groups in males increasing from 5.4 years in 1981 to 9.0 years in 2001.

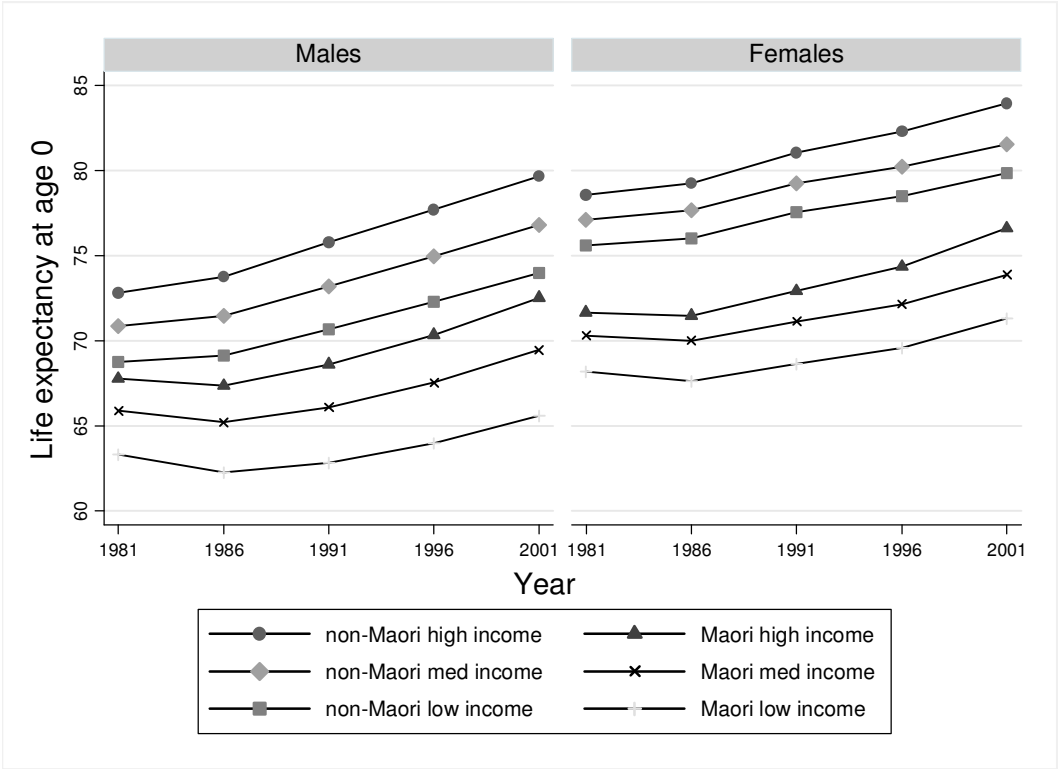
The widening of the gap occurred mainly between 1981 and 1996 and stabilising in the following years. In females the gap was relatively stable over time. There were also differential increases in life expectancy across income groups leading to widening of the gap in life expectancy between then low and high income groups (absolute difference between high and low income was 4.4 years for males in 1981, and 6.5 in 2001; and 3.3 years for females in 1981, compared to 4.7 years in 2001). When looking at the differences in life expectancy by ethnicity and income the size of the gap between Māori and non-Māori is similar within each income group, but increasing over time.

The difference in life expectancy between non-Māori and Māori are greatest in the low income group for both males and females. The ethnic gap within income groups increases over time in males but appears to peak in 1991 for females. Disparities in life expectancy between the low and high income groups in Māori are at least 1 year greater than in non-Māori.

Figure 4 shows a plot of trends in life expectancy at age 0, for the ethnicity and income cross-classified subpopulations, across the five cohorts, for males and females. This shows the widening of the gap in life expectancy among the income groups for Māori and non-Māori over time. The estimated gap between low and high income groups, within ethnic groups was greatest in the 2001 census.

The gap in life expectancy in 1996 (the most recent smoking cohort) between current smokers and never smokers (ex-smoker data not presented here) is 7.6 years in males and 6.7 years in females. This is less than the gap in life expectancy between Māori and non-Māori. However, the difference in life expectancy in 1996 between current and never smokers is greater within non-Māori (7.4 years males, 6.2 years females) compared to within Māori (4.3 years males, 3.9 years females). Also the gap in life expectancy between Māori and non-Māori is greater within never smokers (10.2 years males, 8.8 years females) than within current smokers (7.2 years males, 6.5 years females). There have been minimal improvements in life expectancy between 1981 and 1996 in current smokers (less than 2 years).

Figure 4. Life expectancy at birth for Māori and non-Māori by high, medium and low income groups and by sex, 1981-2001.



Discussion

The results from these life-tables are an important contribution for the understanding of "life" in New Zealand over the past 20 years, as well as to estimation of the future life expectancy of New Zealanders across important subpopulation groups. This study is unique in that it utilises mortality data linked to the New Zealand census, to enable examinations of life expectancy between important subpopulation groups by ethnicity, income and smoking status. This study adds to unique data created by the Ministry of Health and Statistics New Zealand breaking down life expectancy by ethnicity and area deprivation and rurality.[10, 11] We have identified widening of gaps in life expectancy between Māori and non-Māori, particularly in low income populations, and up to the turn of the century.

The development of these subpopulation life-tables provides an alternative set of data for policymakers and the public to monitor summary health measures. The production of subpopulation group life-tables also makes a significant contribution to the methods for estimating population-based cancer survival rates by subpopulation group over time.

Of particular note, and the motivating reason for us doing this work, cancer relative survival calculations that do not draw expected mortality from subpopulation life-

tables will give spurious estimates—especially in a society such as New Zealand where there are large ethnic inequalities in mortality. Further, the existence of smoking on New Zealand census data allows the estimation of smoking life-tables, and provides a significant methodological step forward for calculation of smoking-related cancer survival.

These life-tables, however, have their limitations. Caution is required in their use for year by year monitoring of health status. Indeed, some of the strengths of our data and methods (e.g. smoothing across the multiple censuses) can manifest as weaknesses for ethnic-specific life expectancy in a particular year when trends over time in mortality rates may not have been 'smooth' (be that smooth in linear and quadratic terms as included in our underlying regression analyses on NZCMS data). Also NZCMS data does not include deaths beyond the age of 77 prior to 2001, causing us to assume that mortality rate ratios tended to 1.0 above the age of 80. Thus, we recommend using 'official' SNZ ethnicity life-tables and life expectancy since 1996 if one specifically wants to monitor and report on recent ethnic life expectancy trends.

We do, however, provide life expectancy estimates combing ethnicity, income and smoking status that were hitherto unavailable in New Zealand. These show, perhaps, surprising results with greater gaps in life expectancy between current smokers compared to never smokers in non-Māori compared to Māori. The reason for the lesser life expectancy impact of smoking within Māori, compared to non-Māori, is twofold.[15-17]

First, the rate ratio of mortality comparing current to never smokers is less among Māori, due to the much higher background mortality of Māori never smokers compared to non-Māori never smokers (due to other causes of ethnic disparities in mortality). Second, and related, the survival curve is generally shifted to the left for Māori, to an age profile that is beneath that for a maximal impact of smoking on life expectancy. But, this will not necessarily be the case in the future; an accompanying paper estimates Māori and non-Māori life expectancy out to 2040, and suggests that the smoking impact on life expectancy will be more comparable between ethnic groups by 2040.

Finally, we have developed methods for life expectancy estimation that, to our knowledge, are novel—albeit driven and permitted by the particular strengths of New Zealand data. We encourage others, nationally and internationally, to critique our methods and results. The life-tables can be found at www.uow.otago.ac.nz/nzcms-info.html We encourage colleagues to use these life-tables for modelling and projections.

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References:

1. Siegel JS, Swanson DA, eds. The Methods and Materials of Demography. 2nd ed. California: Elsevier Academic Press; 2004.
2. Statistics New Zealand. New Zealand Life-tables: 2005-07. Wellington: Statistics New Zealand; 2009.
3. Dickman PW, Adami HO. Interpreting trends in cancer patient survival. . Journal of Internal Medicine. 2006;260:103-117.
4. Dickman PW, Coviello E, Hills M. Estimating and modelling relative survival. The Stata Journal. 2009;in press.
5. Sarfati D, Blakely T, Pearce N. Measuring cancer survival in populations: relative survival versus cancer-specific survival. Int J Epidemiol. 2010; 39(3):766-768.
6. Blakely T, Carter K, Wilson N, et al. If nobody smoked tobacco in New Zealand from 2020 onwards, what effect would this have on ethnic inequalities in life expectancy? N Z Med J. 2010;123(1320). http://www.nzma.org.nz/journal/123-1320/4264
7. Ajwani S, Blakely T, Robson B, et al. Unlocking the numerator-denominator bias III: adjustment ratios by ethnicity for 1981-1999 mortality data. The New Zealand Census-Mortality Study. NZ Med J. 2004;116(6).
8. Blakely T, Tobias M, Atkinson J, et al. Tracking disparity: trends in ethnic and socioeconomic inequalities in mortality, 1981-2004. Wellington: Ministry of Health; 2007.
9. Blakely TA, Robson B, Atkinson J,et al. Unlocking the numerator-denominator bias. I: Adjustments ratios by ethnicity for 1991-94 mortality data. The New Zealand Census-Mortality Study. NZ Med J. 2002;115(1147):39-43.
10. Ministry of Health. Life Expectancy and Small Area Deprivation in New Zealand. Wellington: Ministry of Health; 2001.
11. Tobias M, Yeh L-C. Life Expectancy in New Zealand 2005-07. Technical Note. Wellington: Ministry of Health; 2009.
12. Statistics New Zealand. New Zealand Life-tables: 2000-02. Wellington: Statistics New Zealand; 2004.
13. Atkinson J, Shaw C, Blakely T, et al. Linkage of Census and Cancer Registrations, 1981-2004: CancerTrends Technical Report No. 1. Wellington: Department of Public Health, University of Otago, Wellington; 2010.
14. Blakely TA, Tobias M, Robson B, et al. Widening ethnic mortality disparities in New Zealand, 1981-99. Soc Sci Med. 2005;61(10):2233-2251.
15. Blakely T, Fawcett J, Hunt D, Wilson N. What is the contribution of smoking and socioeconomic position to ethnic inequalities in mortality in New Zealand. Lancet. 2006;368(9529):44-52.
16. Hunt D, Blakely T, Woodward A, Wilson N. The smoking-mortality association varies over time and by ethnicity in New Zealand. Int. J. Epidemiol. 2005;34(5):1020-1028.
17. Wilson N, Blakely T, Tobias M. What potential has tobacco control for reducing health inequalities? The New Zealand situation. International Journal for Equity in Health. 2006;5:14-11.

Appendix 1: Life-table terminology

x	Exact age (e.g. exact age 5 corresponds to 5 years and 0 days).
L_x	Average number of persons alive in the age interval x to $x + 1$.
l_x	Number of persons alive at exact age x.
d_x	Number of deaths in the age interval x to $x + 1$.
q_x	Probability that a person at exact age x dies within a year.
p_x	Probability that a person at exact age x lives another year.
m_x	Central death rate for population in the age group x to $x + 1$.
e_x	Expected number of years of life remaining at age x.

The mortality rate (m_x) is calculated as the number of deaths in each age interval divided by the person time lived within the interval:

$$m_x = d_x/L_x$$

These rates can be converted into probabilities using the linear model.[1] The probability of dying within the next year at age x is:

$$q_x = m_x/(1+0.5m_x) = 2m_x/(2+m_x)$$

This formula is based on the assumption that deaths between ages x and $x+1$ occur, on average, at age x+0.5. Deaths at age x in a given year are uniformly distributed by age and time interval.[1] The probability of surviving another year is:

$$p_x = 1\text{-}q_x$$