The burden of cancer in New Zealand:
a comparison of incidence and DALY metrics
and its relevance for ethnic disparities

Abstract

Aim: Cancer burden measured in disability adjusted life years (DALYs) captures survival and disability impacts of incident cancers. In this paper, we estimate the prospective burden of disease arising from 27 cancer sites diagnosed in 2006, by sex and ethnicity; and determine how its distribution differs from that for incidence rates alone.

Methods: Using a prospective approach, Markov and cancer disease models were used to estimate DALYs with inputs of population counts, incidence and excess mortality rates, disability weights, and background mortality. DALYs were discounted at 3.5% per year.

Results: The age standardised Māori:non-Māori incidence rate ratios were 1.00 for males and 1.19 for females, whereas for DALYs they were greater at 1.42 for males and 1.68 for females. The total burden of cancer for 2006 incident cases (i.e. not age standardised) was estimated to be approximately 127,000 DALYs. Breast (27%), lung (14%) and colorectal (13%) cancers for females and lung (16%), colorectal (14%), and prostate (16%) cancers for males were the top contributors. By ethnicity, Māori experienced a substantially higher burden from lung cancer (around 25% for both sexes).

Conclusions: Due to Māori both having higher rates of cancers with a worse survival (e.g. lung cancer), and tending to have worse survival for each cancer site, ethnic disparities in the age-standardised DALY burden were greater than those for incidence (rate ratios of 1.52 and 1.07 respectively, sexes pooled).

Key words: cancer, New Zealand, burden of disease, DALY, YLL, YLD, incidence, Markov models.

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As cardiovascular disease incidence and mortality have steadily declined over the past 30–40 years, the relative burden of disease due to cancer has increased. In 2009, cancer was the leading cause of mortality in New Zealand (NZ) at ICD chapter level, accounting for about 30% of the total number of deaths.[1] The age standardised rate for all cancer sites combined steadily increased post World War II, but is now stable (and possibly decreasing).[2-4] However, there is notable heterogeneity by cancer sites (e.g. stomach cancer rates decreased over time and haemopoietic cancers increased).[2]

Burden of disease studies aim to estimate the burden of each major disease for a given country or region of the world at a given time using a composite measure of mortality and morbidity, the disability adjusted life year (DALY).[5] A burden of disease study has previously been conducted in NZ for 1996, and found that cancers contributed 20% of the total burden of disease, second only to cardiovascular diseases at 24%.[6]

A DALY represents the loss of one year of healthy life, whether it is due to premature death or living in a state of less than full health, or a combination of both. In practice, they are calculated as the sum of years of life lost (YLLs) and years of life lived with disability (YLDs). YLLs capture life lost due to premature death from the disease. YLDs are equivalent to years of life lost as a result of living in health states other than full health, where disability weights (DW) are used to quantify the decremental loss of health.

This paper aims to: estimate the burden of disease in DALYs arising from incident cancer cases diagnosed in 2006 for 27 cancer sites and show how the cancer DALY differences by sex and ethnicity vary from differences in incidence rates of cancer alone.

Methods

We modelled single year age groups (0–100 years), sex (males and females) and ethnicity (Māori and non-Māori) in terms of incidence, survival and background mortality. Due to the good quality of NZ cancer datasets, and the intended migration of this work into cost-effectiveness modelling, a *prospective* method or incidence approach of calculating DALYs was used. That is, rather than estimating the cross-sectional burden for all prevalent cancer cases in 2006, we estimated the future burden arising from cancers diagnosed in 2006.

Following other burden of disease studies,[5,7] we used macro-simulation models, e.g. our unit of analysis was an average-person within a group, and estimated YLLs and YLDs separately for each cancer site (ICD-10 definitions). YLLs were estimated using a Markov time-dependent model with annual cycles and three states: alive with cancer; dead from cancer; and dead from other causes (Figure 1). For each cancer site (i) and age, sex and ethnicity group (j), the model had five main inputs: the incident rate (IR_{ij}); the population counts (N_j); the time dependent probabilities of dying from either the cancer in question (P_{ij}) or from other cause ($Pdoc_j$; from the lifetables); and the disease duration time (or statistical cure time). First, cancer incidence rates were obtained from the Ministry of Health long-term trends and future projections in NZ[2,3] and the Cancer Trends study (a record linkage study of census and cancer records).[4,8] Particularly, the Māori:non-Māori rate ratios from the Cancer Trends study were combined with the overall projected rates (by sex and age) and the distribution of the population by ethnicity to give the necessary incidence rates by age.[9] Second, cancer survival or, more exactly, excess mortality[10,11] by age, sex and ethnicity was estimated using cancer registrations linked to mortality data during 2002-06, and then converted into probabilities of dying from cancer.[9] Third, probabilities of dying from other causes were taken from Statistics NZ age, sex and ethnic-specific life tables. Fourth, duration time or 'statistical' cure time was defined as the number of years post-diagnosis at which any remaining excess mortality due to the cancer in question is negligible. We deviated from previous international practice in the length of time people were considered to have cancer before 'cure' was pronounced (e.g. the Australian study set five years after diagnosis)[12] based on our consideration of statistical cure times apparent in both international[13,14] and NZ[15] cancer survival analyses. Statistical cure times used here ranged from 3 to 20 years (Table 1). Finally, the reference life tables (United Nations Model Life Tables West Level 25 and 26) were sourced from the Global Burden of Disease and Risk Factors Study 2004.[16] As a result, the model provided us with the number of cancer deaths, their timing and survivorship for each combination of age, sex and ethnicity diagnosed in 2006. For instance, a person diagnosed with cancer at age 65 who died from it at age 70 and who would have lived until 88 otherwise (from the model lifetables), would have accrued 11.2 YLLs using a 3.5% discount rate.[9]

YLDs were estimated using cancer disease models taken from the Australian Burden of Disease Study[12] that specified various disease states: diagnosis and treatment; remission; and (if eventually dying from the cancer) a pre-terminal state; and a terminal state (Figure 2). These disease states were characterised by a disability weight (DW) and a duration time in months (Table 1). We also assumed that the DW in the remission state decreased 20% each year. This assumption allowed for generally improving health with increasing time since cancer, even if one could not be pronounced 'cured'. YLDs were calculated by summing: the YLDs for the deaths at each annual cycle within the Markov model (assumed to all occur mid-cycle), where morbidity from pre-terminal and terminal phases had to be accounted for; and the YLDs for survivors at the cure time (who all have the same disease and hence YLD experience).

Figure 1: Markov model to estimate the Years of Life Lost (YLL) due to cancer.
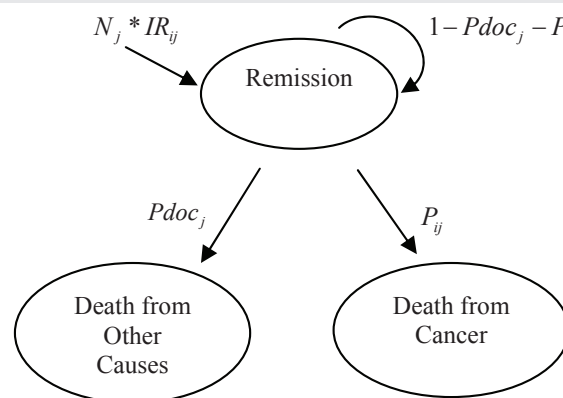
i: Cancer site.
j: Age, sex and ethnicity group.
Nj: Population counts (number of individuals) in the group "j".
IRij: Incidence rate of cancer "i" in the group "j".
Pdocj: Probability of dying of causes other than cancer in the group "j".
Pij: Probability of dying from cancer "i" in the group "j".

Figure 2: General New Zealand cancer disease model for calculating YLDs.
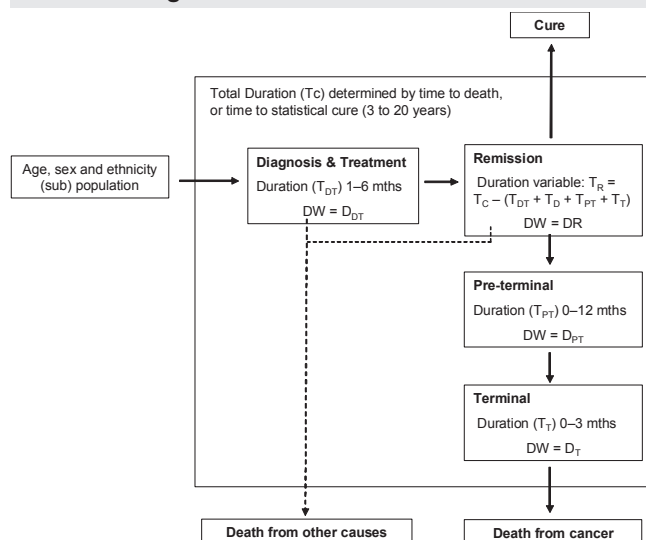
TC = total cancer duration; TDT = time in diagnosis and treatment state; TR = time in remission state; TPT = time in pre-terminal state

Duration in the terminal state took priority over that in the pre-terminal state, which, in turn, took priority over that in diagnosis and treatment. The duration in the remission state was simply the residual of the duration in all other states, subtracted from the total cancer duration time (T_C). For example, survivors of colorectal cancer (cure time eight years) were each assigned 9 months in the diagnosis and treatment stage (with a DW of 0.43; Table 1), and the remaining 7.25 years in the remission state (DW of 0.25 in the first year, and 20% less each subsequent year). People dying from colorectal cancer in the second year were each assigned one month in the terminal state, three months in the pre-terminal state, nine months in the diagnosis and treatment stated, and the remaining five months in the remission state.

Although not shown in Figure 2, sequelae were also modelled as a parallel chain of states for those people who had permanent sequelae (e.g. leg amputated due to bone cancer; see elsewhere for details).[9] Finally, following the guidelines of the Pharmaceutical Management Agency of NZ (PHARMAC),[17] we set a discount rate of 3.5%.

Results

Tables 2 and 3 show the DALY cancer burdens (incidence DALYs, 3.5% discount rate), both as counts (numbers of DALYs and % of total DALY burden) and rates (age-standardised rates per 100,000). Among females, 27.2% of the estimated cancer DALY burden for cancers diagnosed in 2006 was due to breast cancer, followed by lung (14.3%) and colorectal cancers (12.9%). Among males, 16% of the estimated cancer DALY burden for cancers diagnosed in 2006 was due to prostate cancer, followed by lung (15.9%) and colorectal cancers (13.5%). Overall, 19% of the total cancer DALY burden was due to YLDs (i.e. the YLD to DALY ratios in Tables 2 and 3), but was substantially less for Māori (14% for females and 12% for males) due to lower survival increasing YLLs relative to YLDs.

Expressed as a rate ratio comparing Māori to non-Māori, the burden was 1.68 times higher among females and 1.42 times higher among males. By cancer site, these Māori to non-Māori DALY rate ratios were 2.0 or greater for liver, lung and stomach cancer for both males and females. Cancers of the uterus, cervix and larynx also had rate ratios greater than 2.0 among females, and testicular cancer among males. Exceptions to higher DALY rates among Māori were melanoma, colorectal and Hodgkin's cancers across sexes; lip, mouth and pharynx cancer among females; and bladder, prostate and thyroid cancer among males.

Figure 3 compares Māori to non-Māori rate ratios for cancer incidence and DALYs for females and males, respectively. Both measures conveyed a similar picture, in that the Māori /non-Māori rate ratios were higher than 1 for the majority of cancer sites. However, across nearly all cancer sites the ethnic inequalities in DALY rates were greater than for incidence rates. For all cancer sites combined, among females the incidence rate ratio was 1.19 compared to a DALY rate ratio of 1.68. Among males, the incidence rate ratio was 1.00 compared to a DALY ratio of 1.42. That is, the DALY metric, including both incidence and survival, revealed a much greater ethnic inequality than a comparison of incidence rates alone.

Table 1: Age ranges, disability weights (DW) and duration time (T, in years) used in this New Zealand burden of cancer study.[a]

Cancer site	ICD-10 codes	Age range (yrs old)	Statistical cure time (years)	Diagnosis & Treatment		Remission		Pre-terminal (including disseminated cancer)	
				TDT	DW	TR	DW	TPT	DW
Childhood	C00–C96 (< 15)	0-14	5	0.67	0.66	residual	0.20	0.50	0.75
Bladder	C67	25-100	10	0.17	0.27	residual	0.18	0.92	0.64
Bone & connective tissue	C40–41	15-100	10	0.50	0.41	residual	0.30	0.92	0.75
Brain	C71	15-100	5 (< 55 yrs); 10 (≥ 55 yrs)	0.25	0.68	residual	0.18	0.67	0.75
Breast (female)	C50	25-100	20	0.33	0.29	residual	0.26	0.92	0.79
Cervix	C53	25-100	5	0.25	0.43	residual	0.20	0.42	0.75
Colorectal	C18–21	25-100	8	0.75	0.43	residual	0.25	0.25	0.83
Gallbladder	C23–24	25-100	7	0.17	0.43	residual	0.20	0.92	0.73
Hodgkin's	C81	15-100	10	0.33	0.66	residual	0.19	0.42	0.75
Kidney	C64–66, C68	25-100	10	0.17	0.27	residual	0.18	0.92	0.64
Larynx	C32	25-100	10	0.25	0.56	residual	0.37	0.67	0.90
Leukaemia, < 45 yrs	C91–95C91–95	15-44	10	1.17	0.55	residual	0.19	0.25	0.75
Leukaemia, ≥ 45 yrs		45-100	10	0.50	0.55	residual	0.19	0.25	0.75
Lip, mouth, pharynx	C01–14	25-100	10	0.25	0.56	residual	0.37	0.67	0.90
Liver	C22	25-100	7	0.17	0.43	residual	0.20	0.92	0.73
Lung	C33-34	25-100	6	0.42	0.70	residual	0.47	0.42	0.83
Melanoma	C43	15-100	6	0.17	0.22	residual	0.19	0.25	0.81
Myeloma	C90	25-100	20	0.75	0.19	residual	0.19	0.42	0.75
Non-Hodgkin's	C82–85, C96	15-100	20	0.33	0.66	residual	0.19	0.42	0.75
Oesophagus	C15	25-100	6	0.17	0.56	residual	0.37	0.92	0.90
Ovary	C56	15-100	10	0.25	0.43	residual	0.20	0.42	0.75
Pancreas	C25	25-100	5	0.17	0.43	residual	0.20	0.92	0.73
Prostate	C61	25-100	20	0.17	0.27	residual	0.20	1.50	0.64
Stomach	C16	25-100	6	0.50	0.53	residual	0.38	0.92	0.73
Testis	C62	15-100	3	0.25	0.27	residual	0.18	0.75	0.64
Thyroid	C73	15-100	5	0.17	0.27	residual	0.18	0.75	0.64
Uterus	C54–55	25-100	6	0.25	0.43	residual	0.20	0.42	0.75
Adult cancer of other sites[b]	Rest of C00–C96 not listed above (≥15)	15-100	10	0.35	0.44	residual	0.24	0.66	0.75

a The disability weights and duration time for the Terminal state are the same across all cancer sites (DW=0.93 TT= 0.08) and thus not include in the Table.
b The duration and DWs for 'Adult cancer of other sites' are simply averages of the specified adult cancer sites.

Sensitivity analysis

Given the multiple inputs used to estimate the DALYs, it is important to check the impact of changing these inputs in our burden estimates. In this section, we present and discuss the sensitivity analyses of four key inputs: the discount rate, the statistical cure times, the remission disability weights and the external reference life tables. More detailed results are provided elsewhere.[9]

We began by changing the discount rate and the statistical cure times. Regarding the former, we changed the default one of 3.5% to 0% and 6%. Due to the nature of the incidence approach adopted here, the burden of cancer for sites with earlier average age of onset experienced a greater change. For instance, when setting the discount rate to 0% and 6% the DALYs burden of childhood cancer increased by 150% (as the long stream of future YLLs was not discounted) and decreased by 30%, respectively. On the other hand, setting all cancers to have a statistical cure time of five years, as opposed to the site-specific cure times, reduced the DALY burden for cancers with long durations, which was not surprising. In particular,

the burden caused by prostate, myeloma, non-Hodgkin's and breast cancers was reduced by around 40% to 25%.

Next, we changed our default assumption that the DW in the remission state decreased 20% per year. Without this assumption, the total DALY burden increases by 3.2%. In the case of prostate cancer, it increased by 10.9% reflecting long cure time and relatively low mortality at older ages of this cancer site (i.e. lower YLLs contributing to DALYs, compared to YLDs that had DWs as an input).

Importantly, neither of the above sensitivity analyses changed the main findings: the top burden contributors (breast, lung, colorectal, and prostate cancers) remained the same and the DALY burden showed a much greater ethnic inequality than a comparison of incidence rates alone.

Finally, we used ethnic and sex specific lifetables in our YLLs calculations. As is standard practice with burden of disease studies, our baseline analyses calculated YLLs using an external or 'model' life table that was applied to both Māori and non-Māori. That is, a

Table 2: Disability-adjusted life years (DALYs) due to female cancers diagnosed in 2006, by ethnicity.

| Site	Māori				Non-Māori				Māori: Non-Māori Rate ratio	Total			
	YLD / DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]	YLD / DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]		YLD/ DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]
Bladder	0.12	85	1.0%	57	0.22	919	1.6%	41	1.37	0.21	1,005	1.5%	49
Bone and connective tissue	0.12	80	0.9%	39	0.21	437	0.8%	26	1.47	0.20	516	0.8%	33
Brain	0.07	160	1.8%	91	0.08	1,177	2.1%	68	1.33	0.08	1,337	2.0%	79
Breast	0.22	2,432	27.9%	1,270	0.28	15,408	27.2%	860	1.48	0.27	17,840	27.2%	1,065
Cervix	0.20	240	2.7%	121	0.25	776	1.4%	48	2.52	0.24	1,016	1.6%	84
Colorectal	0.14	474	5.4%	289	0.21	7,957	14.0%	376	0.77	0.21	8,431	12.9%	333
Gallbladder	0.07	54	0.6%	35	0.10	486	0.9%	23	1.53	0.10	540	0.8%	29
Hodgkin's	0.29	16	0.2%	8	0.24	153	0.3%	10	0.76	0.25	169	0.3%	9
Kidney	0.10	137	1.6%	78	0.15	1,154	2.0%	60	1.30	0.14	1,291	2.0%	69
Larynx	0.19	18	0.2%	11	0.22	87	0.2%	4	2.45	0.22	105	0.2%	8
Leukaemia	0.12	222	2.5%	130	0.16	1,946	3.4%	96	1.35	0.15	2,168	3.3%	113
Lip, mouth and pharynx	0.19	66	0.8%	37	0.23	749	1.3%	38	0.97	0.22	815	1.2%	38
Liver	0.06	128	1.5%	74	0.08	605	1.1%	30	2.48	0.08	733	1.1%	52
Lung	0.08	2,150	24.6%	1,336	0.10	7,184	12.7%	361	3.70	0.10	9,334	14.3%	849
Melanoma	0.19	89	1.0%	46	0.38	1,565	2.8%	86	0.54	0.37	1,653	2.5%	66
Myeloma	0.09	140	1.6%	86	0.11	1,126	2.0%	54	1.58	0.11	1,265	1.9%	70
Non-Hodgkin's	0.10	302	3.5%	181	0.15	2,612	4.6%	135	1.34	0.15	2,914	4.5%	158
Oesophagus	0.10	67	0.8%	44	0.13	796	1.4%	35	1.24	0.13	864	1.3%	39
Ovary	0.13	376	4.3%	201	0.13	2,787	4.9%	150	1.34	0.13	3,163	4.8%	176
Pancreas	0.06	207	2.4%	136	0.08	1,618	2.9%	75	1.81	0.08	1,825	2.8%	106
Stomach	0.10	369	4.2%	218	0.12	1,159	2.0%	56	3.90	0.12	1,528	2.3%	137
Uterus	0.57	240	2.7%	136	0.64	1,219	2.1%	62	2.19	0.63	1,458	2.2%	99
Thyroid	0.09	53	0.6%	27	0.11	277	0.5%	16	1.64	0.10	330	0.5%	22
Childhood	0.15	114	1.3%	104	0.18	323	0.6%	100	1.03	0.18	437	0.7%	102
Adult cancer of other sites	0.09	514	5.9%	305	0.13	4,224	7.4%	198	1.54	0.12	4,737	7.2%	251
Total	0.14	8,732	100%	5,058	0.19	56,742	100%	3,012	1.68	0.19	65,475	100%	4,035

1. YLD to DALY ratio (YLD contribution to total DALY).
2. Total DALY numbers.
3. Percentage of the total DALYs contributed to by each cancer, within columns.
4. Rates are per 100,000 people, age standardised to the WHO standard population of 15+ (except Childhood 0–14).

Figure 3: Māori to non-Māori incidence and DALYs rate ratio for cancers diagnosed in 2006.
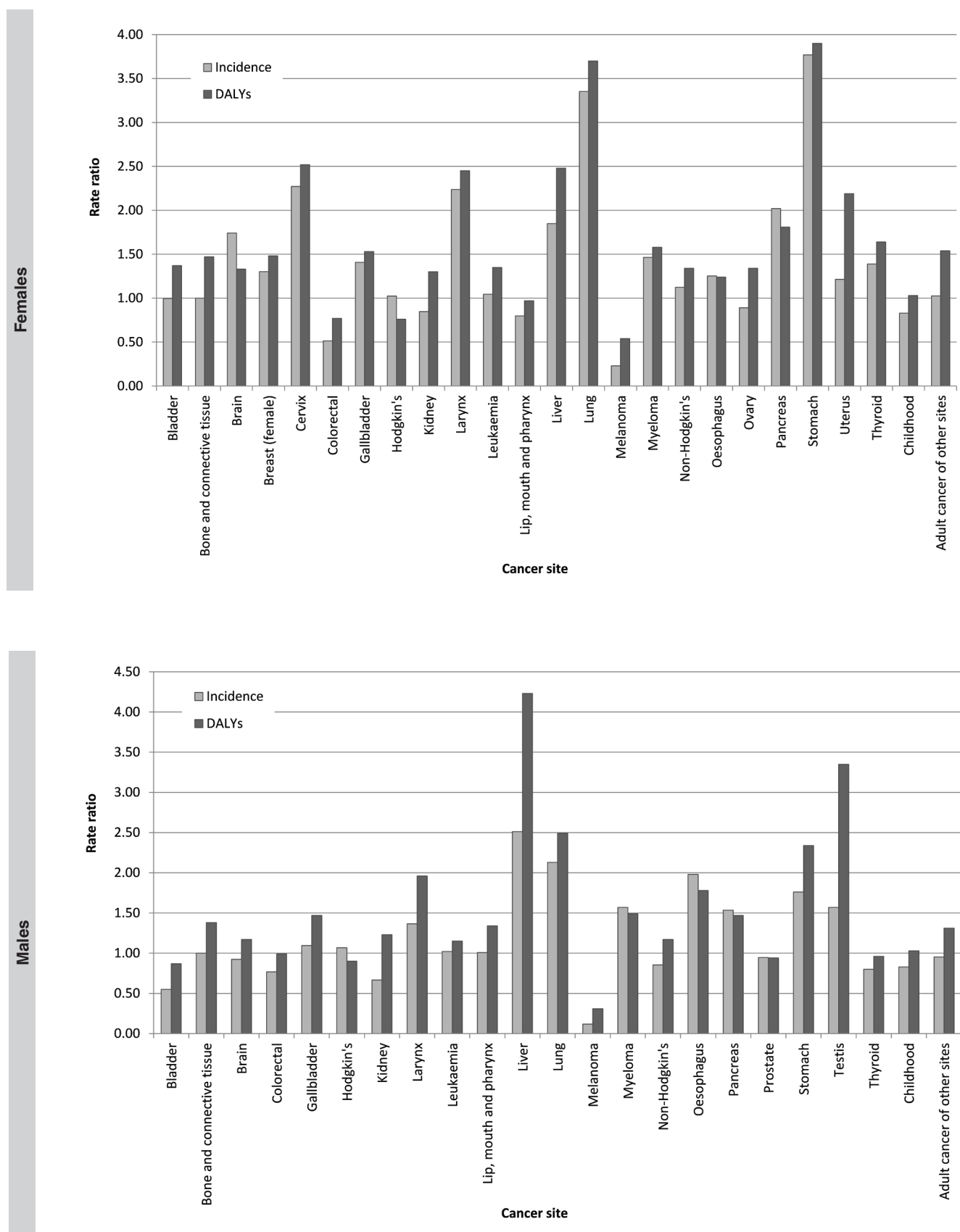
death at a given age for either Māori or non-Māori was assumed to result in the same number of years of life lost. This is sometimes termed a gap analysis of disease burden with an external yardstick set of remaining years of life at any age, applied commonly to any country, social group, time, etc. However, mortality rates in NZ are considerably higher for Māori than non-Māori. Thus, an alternative and arguably more realistic estimate of actual YLLs arising from a cancer could be obtained by using the current period Māori and non-Māori lifetables – not the external model life tables. When using ethnic and sex specific lifetables to estimate YLLs, the total DALY burden decreased by 10.8% and the ratio of Māori to non-Māori DALY rates from cancer decreased to 1.33. This rate ratio was lower than the one using the external lifetables (1.52) but still considerably higher than the ratio of Māori to non-Māori cancer incidence rates (1.07). Therefore, changing the reference life tables from 'model' to ethnic-specific did not change the fact that the cancer burden for Māori was still higher when measured in DALYs than incidence rates.

Discussion

By quantifying the health loss attributable to cancer, a burden of disease approach helps to unveil the additional contribution of morbidity (nonfatal outcomes) to the total burden of cancer. While the cancer burden was dominated by fatal outcomes, we found that cancers that did not have a high case fatality rate, but instead had a long clinical duration – such as prostate and breast cancer – ranked highly in their contribution to the total cancer burden regardless of ethnicity. More specifically, the top three contributions (in percentages) to cancer burden by sex and ethnicity were:

- Māori females: breast (28%), lung (25%) and colorectal cancer (5%)
- Non-Māori females: breast (27%), lung (14%) and colorectal cancer (13%)
- Māori males: lung (24%), colorectal (9%) and prostate (8%)
- Non-Māori males: prostate (17%), lung (15%) and colorectal (14%).

Haemopoietic cancers – lymphomas and leukaemias (combined) – also ranked highly across sex and ethnic groups in their contribution

Table 3: Disability-adjusted life years (DALYs) due to male cancers diagnosed in 2006, by ethnicity.

Site	Māori				Non-Māori				Māori: Non-Māori Rate ratio	Total			
	YLD / DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]	YLD / DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]		YLD/ DALY[1]	DALY Count[2]	%Total DALY[3]	DALY Rate[4]
Bladder	0.15	128	2.0%	96	0.26	2,136	3.9%	111	0.87	0.25	2,264	3.7%	103
Bone and connective tissue	0.11	122	1.9%	66	0.19	739	1.3%	48	1.38	0.18	861	1.4%	57
Brain	0.07	244	3.9%	135	0.08	1,861	3.4%	116	1.17	0.08	2,105	3.4%	125
Colorectal	0.16	570	9.0%	412	0.22	7,746	14.0%	417	0.99	0.22	8,316	13.5%	414
Gallbladder	0.07	44	0.7%	29	0.10	370	0.7%	20	1.47	0.10	414	0.7%	25
Hodgkin's	0.31	16	0.3%	9	0.26	148	0.3%	10	0.90	0.26	164	0.3%	9
Kidney	0.10	200	3.2%	125	0.16	1,819	3.3%	101	1.23	0.16	2,020	3.3%	113
Larynx	0.19	65	1.0%	45	0.23	417	0.8%	23	1.96	0.23	482	0.8%	34
Leukaemia	0.14	230	3.6%	161	0.18	2,482	4.5%	140	1.15	0.18	2,712	4.4%	150
Lip, mouth and pharynx	0.18	164	2.6%	103	0.22	1,334	2.4%	77	1.34	0.21	1,498	2.4%	90
Liver	0.06	469	7.4%	281	0.08	1,169	2.1%	66	4.23	0.07	1,637	2.7%	174
Lung	0.09	1,526	24.1%	1,106	0.11	8,281	15.0%	444	2.49	0.11	9,806	15.9%	775
Melanoma	0.13	77	1.2%	45	0.29	2,494	4.5%	143	0.31	0.28	2,571	4.2%	94
Myeloma	0.10	169	2.7%	119	0.12	1,463	2.6%	80	1.49	0.12	1,632	2.6%	100
Non-Hodgkin's	0.10	330	5.2%	202	0.16	2,988	5.4%	173	1.17	0.15	3,318	5.4%	187
Oesophagus	0.10	207	3.3%	155	0.13	1,603	2.9%	87	1.78	0.12	1,810	2.9%	121
Pancreas	0.06	190	3.0%	137	0.08	1,696	3.1%	93	1.47	0.08	1,886	3.1%	115
Prostate	0.32	480	7.6%	435	0.38	9,410	17.0%	464	0.94	0.38	9,890	16.0%	449
Stomach	0.10	412	6.5%	266	0.13	2,084	3.8%	114	2.34	0.12	2,496	4.0%	190
Testis	0.28	95	1.5%	45	0.58	170	0.3%	13	3.35	0.47	264	0.4%	29
Thyroid	0.22	15	0.2%	9	0.25	155	0.3%	9	0.96	0.25	171	0.3%	9
Childhood	0.16	128	2.0%	110	0.20	358	0.6%	106	1.03	0.19	486	0.8%	108
Adult cancer of other sites	0.09	454	7.2%	313	0.13	4,428	8.0%	238	1.31	0.13	4,882	7.9%	276
Total	0.12	6,336	100%	4,403	0.20	55,350	100%	3,092	1.42	0.19	61,686	100%	3,748

1. YLD to DALY ratio (YLD contribution to total DALY).
2. Total DALY numbers.
3. Percentage of the total DALYs contributed to by each cancer, within columns.
4. Rates are per 100,000 people, age standardised to the WHO standard population of 15+ (except Childhood 0–14).

to total disease burden, a function of both their increasing incidence over time relative to other cancers[3,18] and their often chronic nature having an impact on years lived with disability. Stomach cancer was also notable for its relatively high contribution among Māori (4.2% and 6.5% for females and males respectively). Ovarian cancer was fourth ranked among both Māori (4.3%) and non-Māori females (4.9%).

The ratio of Māori to non-Māori cancer incidence varied enormously across cancer sites, often (but not always) for etiological reasons that are reasonably well understood.[4] However, across all cancers combined, and sexes pooled, we found that for cancers incident in 2006 the age standardised incidence rate was 7% higher among Māori. The main aim of this paper was to additionally determine the difference in cancer burden between Māori and non-Māori. We found that the age standardised DALY rate for Māori is 52% greater than for non-Māori. Even if we allowed the use of non-Māori and Māori lifetables to determine the years of life lost due to cancer in each group (rather than a common external 'model' lifetable), Māori had a 33% higher DALY rate from cancers compared to non-Māori.

Why was the ratio of cancer disease burden for Māori compared to non-Māori so much higher than for cancer incidence? First, Māori were more likely to develop cancers with poor survival (e.g. lung cancer as opposed to melanoma). Second, even within each cancer, Māori generally had worse survival than non-Māori,[9,19,20] which fed into our modelling as higher annual transition probabilities to death from cancer for Māori. These two factors combined and worked through greater years of life lost for Māori compared to non-Māori to confer a much greater per capita disease burden upon Māori.

Notably, this finding – higher cancer burden than that suggested by incidence alone – was unaffected by altering the discount rates, statistical cure times, remission disability weights and the external reference life tables. The alternative scenarios changed the absolute contributions of each cancer site but not their relative contribution to the total burden, e.g. rank ordering of magnitude of cancer burden by cancer site was largely unchanged and the top cancer sites remained the same.

An additional contribution of our work was to provide comprehensive and consistent burden estimates across cancer sites using a prospective approach. We calculated DALYs for the majority of cancer sites at the age, sex and ethnicity level in NZ, so the figures presented here constitute a rich baseline that could be used to assess the effectiveness of different cancer interventions and provide key information to cancer policy makers.

Caveats and extensions

Developing a consistent framework to estimate the mortality and morbidity burden across a comprehensive number of cancer sites unavoidably required using simplified disease progression models, quantifying the impact on the health loss of cancer patients, and using multiple data sources, amongst other simplifying assumptions. Our analysis hence has a number of potential limitations.

First, we simplified the cancer disease progression to a few states (Figures 1 and 2) and provided no explicit quantification of uncertainty about these structural assumptions. Regarding the former, given our aim to estimate the disease burden for a comprehensive number of cancer sites these simplifications were necessary and in accordance with standard practice in burden of disease studies.[5,12,21] More complex models, e.g. natural history models estimated using Bayesian approaches,[22,23] would have made this separation unnecessary but also would have required detailed longitudinal data not yet available for all cancer sites at the ethnicity level in NZ. With regard to the latter, we opted to focus on the point estimates and assess their robustness through sensitivity analysis only. Interestingly, our findings were coherent with previous NZ evidence on cancer incidence and mortality. For example, Robson et al. reported that for the period 1996-2001 Māori had a 1.18 times higher incidence rate of cancer, but a 1.93 times higher mortality rate.[20] Therefore, we believe that the choice of "width" over "depth" in our modelling strategy was adequate.

In order to quantify the cancer impact on nonfatal health outcomes, we used an adaptation of the cancer disease models specified in the Australian burden of disease study[12,24] and Dutch disability weights,[25] that decreased by 20% per year in the remission state. Given our aim to model a comprehensive number of cancer sites and its progression these adaptations were necessary and were based on consultation with clinicians and other experts. These included, for example, the aggregation of stages for some cancer sites (see pages 7-17 of reference nine for details). On the other hand, sensitivity analyses showed that the paper's main findings remain the same without the decreasing remission DW's assumption.

Third, most of our inputs came from (by international standards) high-quality NZ data, including by ethnicity, with the exceptions of the cure times and the cancer survival rates. Sensitivity analyses about the cure times showed that they affect the overall DALY burden, but do not substantially change the relative rank of the main burden contributors (breast and prostate cancers). On the other hand, we also assumed by default that cancer survival estimates from 2002–06 could be applied into the future. This will not be the case for many cancer sites (they will improve), but given that the years of life lost were mainly a function of survival in the first few years post diagnosis this bias is likely to be small.

Lastly, we estimated YLLs and YLDs with different cycle lengths (yearly and monthly, respectively) and assumed that other than the cancer in question people had no other diseases that were affecting their health. These simplifications are reasonable up to late middle-age, but by the age of about 80 years both the probability of dying from other causes starts to get closer to the probability of dying from cancer, and the expected average disability weight across the population from other diseases starts to increase, from around 0.2 to 0.3.[12] These omissions could have caused an upwards bias in our burden estimates, since we would have attributed deaths from competing causes and disability caused by co-morbidities to cancer. However, the relative magnitude of this overestimation is likely to be small as it would have only affected cancer patients from the oldest age-groups.

Further extensions to the work presented could include development of a cancer disease model that estimates YLLs and YLDs simultaneously and quantifies their uncertainty. Also, given that the worse cancer survival among Māori was partly due to later stage at diagnosis,[19,26] another relevant task is to incorporate stage at diagnosis in the survival analysis and the cancer disease models. The Burden of Disease Epidemiology, Equity and Cost-Effectiveness (BODE3) Programme is currently working on these improvements.[27,28]

Conclusion

This study fully described for the first time the cancer burden in NZ using a 'prospective' lens (which will differ from the corresponding burden measured cross sectionally using 'prevalence' DALYs – as is currently being done as part of the New Zealand Burden of Disease, Injury and Risk Factors Study).[29] We showed that the Māori cancer burden was considerably higher than non-Māori cancer burden, more so than inequality in incidence rates alone would have suggested. This elevated Māori burden was due to Māori being more likely to develop cancers with a higher case fatality, as well as a general pattern across all cancers for Māori survival to be worse than non-Māori.[9,19,20] Other notable ethnic variations in cancer burden included a greater percentage contribution of stomach and liver cancer among Māori, compared to a greater contribution of haemopoietic and melanoma cancers among non-Māori. Finally, in addition to research findings in their own right, the methods described in this paper lay the foundation for future modelling of cancer control interventions and estimation of cost effectiveness and equity impacts.

Acknowledgements

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