

Living longer with a greater health burden – changes in the burden of disease and injury in the Northern Territory Indigenous population between 1994–1998 and 1999–2003

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In the Northern Territory (NT), and elsewhere in Australia, Indigenous people experience significantly more burden of disease and injury than other Australians.¹ For the period 2005–2007, the estimated life expectancy at birth for Indigenous Australians was 10–12 years shorter than non-Indigenous Australians.² This represented the widest health gap between Indigenous and non-Indigenous populations internationally,³ and Australia was the only country in which the gap was widening. The Australian Government is determined to close the life expectancy gap within a generation, and halve education and employment gaps within a decade.⁴ Accurate measurement of both fatal and non-fatal health outcomes is of paramount importance in providing information for public health intervention and policy making.

The disability adjusted life year (DALY) is a summary measure of fatal and non-fatal conditions used to assess the burden of disease and injury in a population.^{5,6} It is a combined measure of premature death (years of life lost, YLL) and reduced quality of life because of disease or injury (years lost to disability, YLD). The burden of disease methodology was developed by the World Health Organisation to overcome the

limitations of mortality statistics as a measure of population health status, and has been applied in world-wide studies comparing the health of national populations.^{7,8}

Two Australian burden of disease studies have been conducted for the years 1996 and 2003,^{9,10} these national studies included only limited data on the populations of each state and territory. In the NT, a more detailed study, including separate estimates of the burden of disease for the NT Indigenous and non-Indigenous populations, has been conducted for the five-year period 1994–1998.¹¹ Recently a second NT burden of disease study was conducted for the period 1999–2003.¹² Together the studies have the potential for examination of recent trends in burden of disease for both Indigenous and non-Indigenous people, which would greatly benefit health service planning and formulation of health policy, especially in terms of prevention of disease, disability and death.

However, results for the two periods cannot be directly compared because of changes in the availability and quality of data sources and evolutions in the methodology. Greater data availability (more data sources and more data within existing sources) has increased estimates of

Abstract

Objective: To measure changes over time in the burden of disease for Northern Territory (NT) Indigenous and non-Indigenous population.

Methods: The numbers, and crude and age-adjusted rates of disability adjusted life years (DALY) were calculated for periods 1994–1998 and 1999–2003. A measure of information bias was developed to adjust for the tendency of years lost to disability (a component of DALY) to increase over time because of increasing data availability. The jackknife method was used for DALY uncertainty assessment.

Results: The all-cause DALY rate was stable for the non-Indigenous population, but increased for the Indigenous population. For both populations, the burden of premature death decreased while the burden of disability increased. For the Indigenous population, there were substantial increases in DALY rates for type 2 diabetes, depression, nephritis/nephrosis, suicide and sense organ disorders.

Conclusions: The burden of disease for Indigenous people increased over the study periods, with improvement in the burden of fatal outcomes more than offset by substantial increase in the prevalence and severity of non-fatal conditions.

Implications: The paradoxical shift of living longer with a greater health burden has not been previously reported for Indigenous Australians, and highlights the critical importance of prevention for sustaining life expectancy improvement and managing escalation of health costs. This study also demonstrated the usefulness of the DALY to monitor population health.

Key words: Burden of illness, Indigenous health services, life expectancy, premature mortality, morbidity

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the prevalence of disease and disability, so that for more recent years YLD estimates for some conditions may be substantially higher than they would have been, had data availability not changed. The same does not apply to YLL calculations because each deceased person can only be counted once, although the condition to which YLLs are attributed may have changed. One major source of this 'information bias' is in hospital morbidity data, one of the main data sources for DALY calculations. Over time, there has been a considerable increase in the average number of diagnoses recorded for each inpatient episode; this has occurred because of changing coding practices in part related to the introduction of case-mix funding for hospitals¹³ rather than because of deteriorating health. Introduction and improvement of computerised hospital information systems are also partially responsible for information bias. In this study we developed a method to adjust for information bias.

Because of information bias and methodological changes, comparison of DALYs between the two time periods cannot be exact; but while no inference can be drawn from small differences, a large difference in DALY estimates between the two periods indicates that a change occurred, if not its precise magnitude. The objective of this study is therefore to provide an indicative assessment of the changes in the burden of disease and injury experienced by the NT Indigenous and non-Indigenous population between 1994-1998 and 1999-2003.

Methods

We estimated the burden of disease, measured as DALYs, for the NT population for the five-year periods 1994-1998 and 1999-2003, by indigenous status and gender. The DALY estimates were based on standard methods from the respective Australian burden of disease studies in 1996 and 2003,^{9,10} including classifications, sequelae and disability weights. The DALY has two components: YLL and YLD. YLL was determined by applying the age at death and the standard life expectancy for that specific age. YLD was derived by multiplying the estimated number of new cases of a condition by the average duration (to remission or death) and a disability weight that quantifies the equivalent loss of healthy years of life.

We calculated the number of DALYs, crude and age-adjusted DALY rates for individual disease/injury categories and for all-causes combined. The age distribution of the Australian 2001 estimated resident population was used for age adjustment, for both time periods.¹⁴ The standard life expectancy figures used in the 2003 Australian burden of disease study were used to calculate YLL for both time periods.¹⁰ Standard mapping tables and associated programs were obtained from the Australian burden of disease studies to convert the International Classification of Diseases codes (ninth and tenth revision) to the broad burden of disease and injury categories. The numbers and crude rates of YLD, YLL and DALY, and 95% uncertainty ranges (adjusted for information bias as described below) were used to compare changes in the burden of disease between 1994-1998 and 1999-2003. The age-adjusted DALY rate was used to compare the burden of disease in the NT Indigenous and non-Indigenous populations with the total Australian population within each period. Age-

adjusted rates were not used to compare time changes within the NT population because there was little change in the age distribution of the NT population between the two consecutive periods and because uncertainty ranges could not be calculated for age-adjusted rates that had also been adjusted for information bias. Between 1996 and 2001 (the middle year of each period), the proportion of people aged 65 years and over increased from 2.4% to 2.6% for the Indigenous population and from 3.5% to 4.2% for the non-Indigenous population.

Information bias

We developed a measure of information bias in hospital morbidity data and applied this as a general measure of information bias in the calculation of YLD estimates. YLD estimates for 50 of the 171 conditions used in burden of disease studies are calculated from hospital morbidity data, so this measure of information bias is directly applicable to these conditions. For the other 121 conditions, this measure is a general indicator only; its application relies on the assumption that a similar information bias also exists for other data sources used for assessing morbidity. Using NT public hospital morbidity data between 1976/7 (the first year available) and 2006/7, we examined the average number of diagnoses per inpatient episode within Australian Refined Diagnostic Related Group (DRG, Version 4.1) cost-weight categories. DRG is a classification system for hospital inpatient episodes.¹⁵ Each DRG represents a clinically meaningful group of similar conditions in terms of severity or resource intensity, measured by a relative cost weight with an average given a weight of 1. This information bias adjustment was based on the assumption that, for DRGs with similar severity, the number of diagnoses recorded would be consistent over time if there was no systematic bias in information collection. DRGs were grouped into 28 cost-weight categories from 0.30-0.39 to 3.00-3.09; DRGs with cost-weights less than 0.30 or greater than 3.09 omitted because of insufficient cases. We then calculated the average annual percentage increase in the average number of diagnosis codes recorded per episode. The result was used to recalculate DALY estimates for 1994-1998, adjusted upward by the percentage increase over a five-year period, so that the DALY estimates for the first study period were directly comparable to those for the second study period. The NT to Australian age-adjusted DALY rate ratio for each time period was calculated using unadjusted DALY estimates because there was no need to adjust for time-based information bias when comparing populations within the same time period.

Assessment of uncertainty

There is no established method to calculate standard errors and confidence intervals for DALY estimates using conventional statistical methods because of the complexity of the methodology and the use of multiple data sources.⁹ Bootstrap methods have been used previously to calculate 'uncertainty ranges' for DALY estimates,¹⁶ and in this study we have used the jackknife method (a variant of the bootstrap method which has the advantage over other bootstrap methods of being exactly reproducible) to calculate 95% uncertainty ranges.^{17,18} The jackknife method conducts case deletions to

calculate non-parametric estimates of variance. Without loss of generality, the jackknife standard error of a DALY statistic

$$SE_J = \sqrt{\frac{(n-1) \sum (\theta_{(i)} - \theta_{(-)})^2}{n}}$$

θ can be estimated by

where $\theta_{(i)}$ is the DALY statistic without the observation i ($i=1, \dots, n$) and $\theta_{(-)} = \sum \theta_{(i)} / n$. In this case, θ was a DALY rate and the observation was a population group. Unlike simulation methods,¹⁶ the estimates are not dependent upon the model assumptions.

Results

Information bias

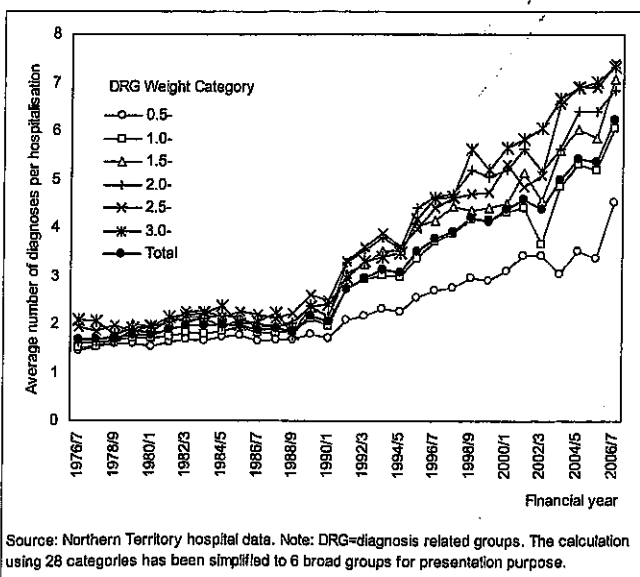
The average number of diagnosis codes recorded per inpatient episode, adjusted for DRG cost-weight category increased by 4.5% per year between 1976/7 and 2006/7 (as illustrated in Figure 1).

All-cause DALYs

For the NT Indigenous population the total all-cause DALYs increased by 35%, between 1994-1998 and 1999-2003, which is much greater than the 11% increase in population between 1996 and 2001, the mid year of each period. As a result there was a 24% increase in the crude DALY rate between the two periods. For the NT non-Indigenous population, the total all-cause DALYs increased by 8%, which was similar to the 7.8% increase in population, and as a result the crude DALY rate was almost unchanged between the two periods (Table 1).

Within the total burden of disease there was a shift over time in the relative contributions of fatal and non-fatal components. For Indigenous and non-Indigenous population, YLL decreased by around 10% and 20% respectively, which was equivalent to improvements in life expectancy at birth by about 1 and 2 years. In contrast to YLL, YLD increased between the two periods by 60% and 10% respectively (Table 2).

Figure 1: Average number of diagnoses by broad cost weight category per hospitalisation, NT public hospitals 1976/77 to 2006/07.



Source: Northern Territory hospital data. Note: DRG=diagnosis related groups. The calculation using 28 categories has been simplified to 6 broad groups for presentation purpose.

In 1999-2003, the age-adjusted DALY rate for the NT Indigenous population was over 3.5 times the all Australian rate for both males and females. The NT non-Indigenous population was 28% higher than the all Australian rate for males and 9% higher for females (Table 3).

Cause-specific DALYs

Although there were differences in rank order, most of the top ten specific causes of lost DALYs (ranked by age-standardised rate) were the same for NT Indigenous and non-Indigenous people: type 2 diabetes, depression, ischaemic heart disease (IHD), chronic obstructive pulmonary disease, road traffic accidents,

Table 1: All-cause DALYs, number and crude rate, by Indigenous status and sex, Northern Territory, 1994-1998 and 1999-2003.

	Number of DALYs		DALYs rate ^a (95% uncertainty range)	
	1994-98 ^b	1999-2003	1994-98 ^b	1999-2003
NT Indigenous				
Male	36,119	49,210	280 (220-340)	347 (275-419)
Female	32,091	43,110	247 (196-299)	306 (250-363)
Persons	68,211	92,319	263 (239-288)	327 (299-355)
NT non-Indigenous				
Male	46,671	51,540	134 (114-153)	138 (114-161)
Female	29,614	30,733	98 (83-114)	94 (82-107)
Persons	76,285	82,273	117 (109-126)	117 (108-127)

Notes:

a) Crude rate per 1,000 population.

b) 1994-1998 DALYs adjusted for information bias.

Table 2: YLL and YLD age adjusted rate,^a by Indigenous status, Northern Territory 1994-98 and 1999-2003.

	YLL		YLD	
	1994-98 ^b	1999-2003	1994-98 ^b	1999-2003
Indigenous	272	248	138	217
Non-Indigenous	90	73	80	86

Notes:

a) Age-adjusted rate per 1,000 population.

b) 1994-1998 YLD rate adjusted for information bias.

Table 3: All-causes age-adjusted DALY rate and rate ratio (NT to total Australia), by Indigenous status, sex and time period, Northern Territory 1994-1998 and 1999-2003.

	Age-adjusted DALY rate ^a		Rate ratio NT to Australia ^b	
	1994-98	1999-2003	1994-98	1999-2003
NT Indigenous				
Male	440	511	2.57	3.59
Female	381	423	2.80	3.55
Persons	410	465	2.68	3.57
NT non-Indigenous				
Male	190	182	1.08	1.28
Female	146	130	1.04	1.09
Persons	170	159	1.08	1.22

Notes:

a) Age-adjusted rate per 1,000 population.

b) Australian DALY figures were for 1996 and 2003 respectively.

suicide and sense organ disorders (Table 4). However, the DALY rate for each of these causes was much higher for Indigenous than non-Indigenous people. Between the two periods there was considerable increase in the DALY rate for type 2 diabetes, depression and sense organ disorders for both populations. There was also a considerable increase for nephritis/nephrosis and suicide for Indigenous people only.

For the Indigenous population, the age-adjusted DALY rates for type 2 diabetes, depression, nephritis/nephrosis and suicide increased by large amounts in both absolute (Table 4) and relative terms (by 2.3-3.5 times) (Table 5) between 1994-1998 and 1999-2003. The rankings of depression, nephritis/nephrosis and suicide were each elevated 8-12 places in relation to other specific causes with depression becoming the second ranked specific cause of DALYs behind type 2 diabetes. For most specific causes, changes in hospitalisation and death rates are consistent with changes in DALY rates (Table 5).

For the non-Indigenous population, the disease burdens attributable to depression, type 2 diabetes and sense organ disorders increased, while the burdens due to road traffic accident, substance abuse and asthma declined (Table 4). These increases have been confirmed by changes in rank, hospitalisation and death rate ratios, with the exception of a death rate ratio from depression which is not available (Table 5). The decreases were similarly confirmed with two exceptions: against the burden of disease trends, hospitalisation rates for road traffic accident and suicide increased between the study periods.

Table 4: Top 10 causes of DALYs^a by Indigenous status, Northern Territory 1994-98 and 1999-2003.

	Rate ^b (95% uncertainty range)	
	1994-98 ^c	1999-2003
Indigenous		
Type 2 diabetes	16.1 (13.7-18.4)	37.8 (32.2-43.5)
Depression	7.8 (7.0-8.5)	27.1 (25.0-29.3)
Ischaemic heart disease	20.5 (17.1-23.9)	26.0 (21.4-30.6)
Nephritis and nephrosis	5.9 (5.1-6.7)	14.5 (12.1-16.9)
COPD ^d	10.6 (9.0-12.1)	11.3 (9.5-13.1)
Road traffic accidents	12.5 (10.8-14.2)	10.3 (8.9-11.8)
Suicide	4.1 (3.2-4.9)	10.0 (7.7-12.2)
Homicide	7.0 (6.1-7.9)	7.6 (6.5-8.6)
Sense organ disorders	3.9 (3.1-4.7)	7.2 (5.9-8.5)
Scabies-related infection		7.0 (6.7-7.3)
Non-Indigenous		
Depression	8.2 (7.7-8.7)	14.1 (13.2-15.0)
Type 2 diabetes	2.9 (2.5-3.2)	9.5 (7.8-11.3)
Ischaemic heart disease	7.1 (6.0-8.3)	8.3 (6.8-9.7)
Sense organ disorders	2.6 (2.2-3.0)	6.1 (5.0-7.3)
COPD ^d	4.1 (3.6-4.6)	5.1 (4.3-5.9)
Road traffic accidents	6.2 (5.5-6.9)	4.3 (3.7-4.8)
Substance abuse	7.5 (6.7-8.4)	3.9 (3.3-4.5)
Suicide	4.5 (3.8-5.1)	3.7 (3.2-4.2)
Lung cancer	4.0 (3.3-4.8)	3.1 (2.4-3.7)
Asthma	4.6 (4.0-5.1)	2.9 (2.4-3.4)

Notes:

- Ranked by 1999-2003 DALY rate.
- Crude rate per 1,000 population and 95% uncertainty range.
- Adjusted for information bias.
- Chronic obstructive pulmonary disease.

Discussion

The DALY is an established measure for gauging population health outcomes and informing health care priorities.¹⁹ This study demonstrates the comparability of DALY results over-time and its additional potential for monitoring changes in population health, after appropriate adjustment for information bias and estimation of uncertainty.

The DALY is also a health gap measure. It has been demonstrated that the NT Indigenous population experienced much worse health outcomes than the general Australian population. In terms of the all-cause DALY, the total disease burden for the NT Indigenous population worsened between 1994-1998 and 1999-2003, but remained static for the non-Indigenous population.

Changes in data sources and methods prevent precise comparison between DALY estimates for the two study periods, but the large increases for the Indigenous population in all-cause DALY rate and in DALY rates for several specific conditions (depression, diabetes, nephritis/nephrosis and suicide) indicate real increases in the burden of disease because: we have adjusted, if only approximately, for information bias; uncertainty ranges do not overlap indicating that the differences are greater than would be expected from random variation; the size of the increases for specific conditions is large relative to changes for most other conditions; the DALY calculations are consistent with changes in both hospitalisation and death data, indicating that the changes are not an artefact of the assumptions and not due to information bias; and the all-cause DALY rate for the non-Indigenous population, which was calculated mostly from the same data sources, changed very little over the same period, indicating that the changes for the Indigenous population are not due to bias in data sources.

Significantly the relative contribution of fatal and non-fatal outcomes to the total burden of disease shifted from early death to disability, as seen in the decrease in YLL but increase in YLD for both Indigenous and non-Indigenous populations. This significant and paradoxical shift of living longer with a greater health burden has not been previously reported within the Australian Indigenous population as a consolidated analysis but there has been evidence for specific conditions. In this study the burden of type 2 diabetes increased considerably between the two study periods in both the Indigenous and non-Indigenous population. This is consistent with the national projections,²⁰ which estimate that treatment costs for type 2 diabetes will approximately double every 10 years. In the NT, the increase is apparently higher than for Australia overall, but is consistent with recent prevalence estimates for the Indigenous population.^{21,22} The increase in depression is also shared by the NT Indigenous and non-Indigenous populations. This increase is likely due in part to underestimation of depression burden for the first period and improvement in the YLD methodology nationally for mental disorders.¹⁰ The magnitude of the increase in the burden of depression in the NT may also be substantially higher than for Australia generally, especially for the Indigenous population especially for the Indigenous population.²⁰ For IHD, the impact among the NT Indigenous people is also rising, contrary to the falling national rate.²³ This finding is consistent with the recent report for this population of rising incidence and improved survival after acute myocardial infarction.²⁴ There is also wider

evidence that the burden of nephritis and nephrosis continues to increase in the Australian Indigenous population.^{25,26} Sense organ disorders include glaucoma, cataract, macular degeneration, hearing loss, refractive errors and other vision loss. Increase in the burden of sense organ disorders could be explained partly by improved diagnosis and recording, and partly by high prevalence of chronic diseases in Indigenous population.²² The underlying causes of the emerging epidemic of chronic diseases among Indigenous population are unclear. Socioeconomic disadvantage, unhealthy lifestyle and poor nutrition are likely to be major contributors.^{27,28}

To curb the increase in burden of disease and injury for the NT Indigenous population, the action must go beyond the traditional approach of health care to focus on the root causes of poor Indigenous health. The results of this study highlight the importance of addressing the underlying causes of disease, including socio-economic determinants (low income, poor education, high unemployment and poor living conditions) and related risk factors of disease and injury (physical inactivity, smoking and alcohol abuse), through emphasis on public health and primary prevention in parallel to continuing commitment to secondary prevention and high quality tertiary care.^{29,30}

Importantly this study throws light on how to verify temporal changes in burden of disease and injury, but there are a number of methodological weaknesses in this study. The true magnitude of

the changes remains unquantifiable. Our measure of information bias was directly applicable to the 50 specific conditions for which DALY estimates are calculated from hospital separation data. Generalisation of this adjustment to other conditions has not been tested and further development is required in this aspect of the burden of disease methodology to enable more precise comparisons of changes in burden of disease over time. On the other hand, if the DALY measure cannot be compared over time then burden of disease estimates will remain limited to cross-sectional comparison, which become rapidly outdated. This must be a high priority for methodological development of burden of disease studies.

This study suggests that the number of diagnosis codes recorded for the DRGs with similar severity is a potentially useful indicator for information bias assessment in application of routinely collected administrative datasets (eg. hospital morbidity) for epidemiologic purpose, in the wake of introduction of computerised hospital information system and output based hospital funding. More research is needed to further explore the usefulness of administrative datasets in disease monitoring. In this study we used a non-parametric jackknife method, in which we re-sampled the data by deleting one subgroup of records at a time and recalculated the DALY measures. To the best of our knowledge, this is the first time that the jackknife method has

Table 5: Top 10 specific causes of DALYs in 1999-2003 compared to 1994-98: DALY rate and rank, hospitalisation and death rates, Northern Territory.

	DALY rate ratio ^a	Change in rank ^b	Hospitalisation rate ratio ^c	Death rate ratio ^d
Indigenous				
Type 2 diabetes	2.3	1	2.2	1.1
Depression	3.5	8	2.4	na
Ischaemic heart disease	1.3	-2	2.1	1.2
Nephritis and nephrosis	2.5	10	2.5	1.8
COPD ^e	1.1	2	1.3	0.9
Road traffic accidents	0.8	-3	2.3	0.9
Suicide	2.4	12	2.2	2.8
Homicide	1.1	1	1.4	1.4
Sense organ disorders	1.8	12	1.3	0.0
Scabies related infection	na	na	na	na
Total	1.2		2.3	1.1
Non-Indigenous				
Depression	2.1	0	1.8	na
Type 2 diabetes	3.3	9	2.4	1.0
Ischaemic heart disease	1.2	-1	1.7	1.2
Sense organ disorders	2.9	9	1.5	na
COPD ^e	1.4	5	0.9	1.0
Road traffic accidents	0.7	-2	1.8	0.7
Substance abuse	0.6	-4	0.7	0.6
Suicide	0.8	-2	1.9	0.9
Lung cancer	0.8	-1	0.9	0.8
Asthma	0.8	-1	0.7	0.2
Total	1.0		1.3	1.0

Notes:

- Ratio of age-adjusted cause-specific DALY rates, 1999-2003 compared to 1994-1998.
 - Change in rank order of age-adjusted DALY rate, 1999-2003 compared to 1994-1998.
 - Ratio of age-adjusted cause-specific (by principal diagnosis) hospital admission rates, 1999-2003 compared to 1994-1998.
 - Ratio of age-adjusted cause-specific (underlying cause of death) death rates, 1999-2003 compared to 1994-1998.
 - Chronic obstructive pulmonary disease.
- na Not applicable.

been used to calculate uncertainty ranges for DALY estimates. In comparison with the Monte Carlo simulations used for the world health reports,³¹ this approach is simpler and requires fewer assumptions. Although we believe that our use of the jackknife method is plausible and satisfactory for our purpose, further research is needed to confirm its wider application in DALY uncertainty estimates.

Conclusion

Despite the imprecise nature of our comparison, the large increases in DALY rates indicate that considerable change has occurred in the burden of disease for the NT Indigenous population between 1994-1998 and 1999-2003, in contrast to Australians generally and to the NT non-Indigenous population. The very large increases for conditions such as type 2 diabetes and kidney disease demonstrate the critical importance of chronic diseases among Indigenous Australians. Importantly the results provide a collective and systematic summary of the substantial increase in the burden of non-fatal conditions which has implications for long term planning for both a sustainable improvement in life expectancy and for the management of escalating health care costs.

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