The Productivity Burden of Diabetes at a Population Level

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OBJECTIVE

Recent studies suggest that diabetes may impact work productivity. In the current study, we sought to estimate the lifetime and population impact of diabetes on productivity using the novel measure of "productivity-adjusted life years" (PALYs).

RESEARCH DESIGN AND METHODS

Using age-specific mortality rates and a productivity index attributable to diabetes (akin to the quality of life index, but which adjusts for reduction in productivity) and life table modeling, we estimated years of life and PALYs lost to diabetes among Australians with diabetes currently aged 20–65 years, with follow-up until 69 years. Life tables were first constructed for the cohort with diabetes and then repeated for the same cohort but with the assumption that they no longer had diabetes. The "nondiabetic" cohort had lower mortality rates and improved productivity. The differences in total years of life lived and PALYs lived between the two cohorts reflected the impact of diabetes.

RESULTS

Overall, diabetes reduced total years of life lived by the cohort by 190,219 years or almost 3%. Diabetes reduced PALYs by 11.6% and 10.5% among men and women, respectively. For both sexes, the impact of diabetes on productivity was lowest in those aged 65–69 years and highest in those 20–24 years. Among the latter, PALYs were reduced by 12.2% and 11.0% for men and women, respectively.

CONCLUSIONS

Elimination of diabetes can prolong life years lived by the whole population and increase the amount of productive years lived. Employers and government should be aware that having diabetes affects work force productivity and implement prevention programs to reduce the impact of diabetes on the workforce.

While the prevalence of diabetes is highest among people of middle and older age, the absolute burden of disease is potentially much greater among younger populations owing to their larger numbers and longer lifespans. Also compelling is the fact that the prevalence of diabetes is expected to continue to rise among younger people as overweight and obesity become more common (1). In Australia in 2015, the prevalence of diagnosed diabetes among those 40–60 years had reached 5%, which means that the true prevalence, including undiagnosed diabetes, would be expected to be on the order of 10% (2).

That diabetes (or indeed any chronic condition) affects people of working age is of added concern because of the impact on their work productivity. Productivity loss occurs because of absenteeism (absence from work due to illness) as well as presenteeism (reduced efficiency while at work) (3). A high diabetes prevalence in a working-age population, coupled with high rates of diabetes complications and subsequent disability, can result in significant loss of productivity. This imposes a significant

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economic cost to a country in terms of lost income earnings, tax revenue, and diminished gross domestic product (GDP)—all in addition to the burden on the health care system.

Data describing the impact of diabetes on work productivity are scarce. A recent study from the U.S. showed that work efficiency is significantly impaired by diabetes (4) and correlated with diabetes duration and the burden of comorbidities such as depression. In the U.S., it is estimated that as much as 58 billion USD annually is lost to diabetes, resulting from a combination of loss of earnings owing to unemployment, reduced work efficiency, permanent disability, and death (4). This impact is expected to be proportionally larger in low-income countries, as premature deaths are more common, including among those of productive age (5).

In Australia, similar studies have not been performed, but available data suggest that people with diabetes receive 88% less income than those without owing to unemployment (6). They also pay less tax and receive more subsidies. No research has been undertaken to describe the impact of diabetes on work productivity at a population level.

Our study sought to estimate the future burden of diabetes in terms of years of life lost as well as "productivity-adjusted life years" (PALYs) lost. PALYs are a novel measure that we have developed that adjusts years of life lived for productivity loss attributable to disease or a condition, in the same way that quality-adjusted life years (QALYs) are adjusted for a reduction in quality of life (Fig. 1).

RESEARCH DESIGN AND METHODS

Life Table Modeling Approach

Dual-state ("alive" and "dead") life tables were constructed using age-specific rates of mortality for persons with and without diabetes. These were used to simulate the progress of separate sex and age (in 5-year age bands) cohorts of Australians aged 20–65 years until death or age 69 years.

The number and demographic profile of individuals with diabetes in Australia were based on 2011 data from the National Diabetes Services Scheme (NDSS) (2), a national registry that captures $>$90% of Australians with diabetes (7). The NDSS was established in 1987 by the Australian government and provides patients access to subsidized blood glucose testing equipment as well as educational material about diabetes. Registration into the NDSS is free and is completed by a medical practitioner or credentialed diabetes educator after a diagnosis has been made by a physician. Mortality rates, stratified by sex and 5-year age bands, were estimated via linkage of the NDSS data set to the Australian National Death Index. Diabetes included type 1 and type 2 diabetes.

For estimation of mortality rates among people without diabetes, the numbers of deaths among people without diabetes were first calculated by subtracting deaths among NDSS subjects from total national deaths in each sex group and age-group. Then, populations at risk (denominators) were estimated by subtracting the numbers of NDSS participants from total populations in each sex group and age-group. Mortality rates by sex can be found in the Supplementary Data.

Mortality rates were obtained for 5-year age bands and extrapolated using exponential functions to provide rates for age in single years, assuming that the rate for a 5-year age-group applied to people in the midpoint of that age band.

For estimation of the impact of diabetes on total years of life lost to diabetes (among people with diabetes), progress of the NDSS cohort was resimulated assuming the mortality rates of people without diabetes. That is, the NDSS cohort was hypothetically assumed not to have diabetes. The differences in life table outputs between the NDSS cohort and the hypothetical NDSS cohort without diabetes reflected the impact of diabetes in terms of years of life lost.

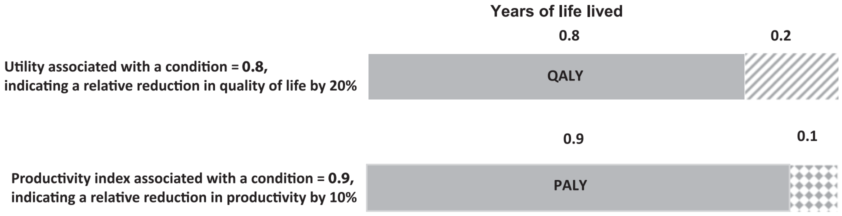

Figure 1—A schematic diagram describing the concept of a PALY. A PALY is similar in concept to a QALY, but instead of multiplying years of life lived by a utility (to derive QALYs), years of life lived are multiplied by a productivity index to derive PALYs.

Estimation of PALYs

For estimation of PALYs lived by the diabetes cohort, each year of life lived by the cohort was multiplied by "productivity indices." As illustrated in Fig. 1, a productivity index is the proportion by which a year of life lived is multiplied to derive a PALY. It is akin to a "utility," the value by which a year of life lived is multiplied to derive a QALY.

In the models, productivity indices were based on estimates by the American Diabetes Association (ADA) (4). In their report entitled "Economic Costs of Diabetes in the U.S. in 2012," the ADA estimated that in terms of absenteeism, workers with diabetes worked 3 days less per year compared with workers without diabetes. In Australia, workers are entitled to 4 weeks' annual leave, and therefore work 240 days per year (48 weeks). A 3-day reduction to 240 days represents a 1.3% proportional reduction. In terms of presenteeism, the ADA estimated the reduction to be 6.6%. Hence, the total reduction in work productivity was assumed to be 7.9%, and the productivity index was assumed to be 0.921 ($1 - 0.079$). We assumed that the productivity index had a negative linear relationship with age starting at 0.92 in 20 year olds and finishing at 0.93 in 69 year olds.

All analyses were undertaken using Microsoft Excel 2011. This study was approved by Monash University Human Research Ethics Committee (project no. CF16/917-2016000480).

RESULTS

The population of individuals with diabetes used in the modeling is shown in Table 1.

The annual mortality rates among men and women with and without diabetes are described in Supplementary Table 1. The projected deaths in each 5-year age-group by sex from the life table modeling are shown in Table 2. It was estimated that until each cohort reached 69 years of age, diabetes caused 13,185 and 6,536 extra deaths in men and women, respectively.

Table 3 summarizes the estimated number of years to be lived by the cohort of Australians with diabetes from age 20–69 years and the number of years

Table 1—Model population at baseline from the NDSS diabetes population in 2011

	Men			Women		
Age-group (years)	Population	People with diabetes	Diabetes prevalence	Population	People with diabetes	Diabetes prevalence
20–24	823,470	3,665	0.0045	788,193	3,484	0.0044
25–29	841,084	4,480	0.0053	817,086	4,554	0.0056
30–34	769,211	6,285	0.0082	766,950	6,487	0.0085
35–39	782,204	9,995	0.0128	791,706	10,580	0.0134
40–44	786,748	17,201	0.0219	800,496	18,915	0.0236
45–49	764,147	26,352	0.0345	777,690	26,538	0.0341
50–54	739,627	40,196	0.0543	754,436	35,721	0.0473
55–59	662,069	53,970	0.0815	673,924	42,872	0.0636
60–64	611,198	68,667	0.1123	614,802	51,146	0.0832
65–69	474,253	78,092	0.1647	480,007	56,098	0.1169

Data are *n* unless otherwise indicated.

that would have been lived had diabetes not been present. The loss of life from diabetes declines as age increases and is significantly higher in men compared with women. Overall, diabetes was estimated to reduce years of life lived by the current cohort of Australians by 190,219 or 2.5%. This equates to 0.34 years of life lost per person (0.39 in men and 0.27 in women).

Table 4 summarizes the estimated number of PALYs to be lived by the cohort of Australians with diabetes from age 20–69 years and the number of PALYs that would have been lived had diabetes hypothetically not been present. More PALYs would be lost from diabetes among younger compared with older people and among men compared with women. Overall, diabetes was estimated to reduce PALYs lived by the current cohort of Australians by 791,428 (or 11.1%). This equated to 1.4 PALYs lost per person (1.41 in men and 1.39 in women).

Simple extrapolations highlight the significant financial implications of diabetes in Australia. The current Australian GDP per capita is 63,000 AUD (8). Assuming, conservatively, that the GDP per Australian of working age (20–65 years) is 100,000 AUD, then this would be the economic value of each PALY. Assuming, again conservatively, that the economic value of each PALY in Australia stays constant at 100,000 AUD into the future, then multiplying this amount by the nearly 800,000 PALYs lost by the cohort until age 69 years would equate to 80 billion AUD in GDP being lost to diabetes.

This means that up to 80 billion AUD could have been spent on the current cohort of Australians aged 20–65 years with diabetes to prevent their diabetes until they reached 69 years and the program would still be cost saving to the broader Australian society. Alternatively, from a microeconomic perspective, because each person with diabetes lost 1.4 PALYs to diabetes, up to 140,000 AUD could have been spent on preventing diabetes in each individual.

Of course, although there are many effective diabetes prevention strategies (9) that are cost effective, diabetes is not 100% preventable, and, hence, the "break even" amount to invest needs to be adjusted according to preventive efficacy. For example, up to 14,000 AUD could be spent on individual prevention if the intervention prevented diabetes in 10% of the target population and up to 70,000 AUD could be spent if the intervention prevented diabetes in 50%.

Table 2—Number of deaths in those with diabetes and in those without, simulated from life table modeling

Age-group (years) by sex	Population with diabetes	Population assuming no diabetes	Total population	Percent change of death in people with diabetes compared with people without diabetes
Men				
20–24	938	615	1,552	34.5
25–29	1,125	742	1,868	34.0
30–34	1,539	1,023	2,563	33.5
35–39	2,362	1,585	3,947	32.9
40–44	3,864	2,622	6,486	32.2
45–49	5,498	3,779	9,276	31.3
50–54	7,496	5,231	12,727	30.2
55–59	9,466	6,649	16,115	29.8
60–64	7,708	5,583	13,291	27.6
65–69	3,916	2,900	6,816	25.9
Total (men)	43,913	30,728	74,641	30.0
Women				
20–24	606	399	1,005	34.2
25–29	776	516	1,292	33.5
30–34	1,073	724	1,797	32.6
35–39	1,682	1,152	2,226	31.5
40–44	2,842	1,985	4,827	30.1
45–49	3,676	2,629	6,305	28.5
50–54	4,383	3,223	7,605	26.5
55–59	4,340	3,298	7,638	24.0
60–64	3,679	2,904	6,584	21.1
65–69	1,769	1,459	3,228	17.5
Total (women)	24,825	18,289	43,115	26.3
Total	68,739	49,017	117,756	28.7

Data are *n* unless otherwise indicated.

Table 3—Years of life lived, simulated from life table modeling

Age-group (years) by sex	Population with diabetes	Population without diabetes	Percent reduction of years of life lost: no diabetes versus diabetes
Men			
20–24	162,043	168,192	3.8
25–29	176,840	183,658	3.9
30–34	218,613	227,066	3.9
35–39	301,333	312,816	3.8
40–44	439,831	455,949	3.7
45–49	554,578	573,447	3.4
50–54	665,677	685,619	3.0
55–59	797,299	819,514	2.8
60–64	520,321	528,874	1.6
65–69	228,514	230,046	0.7
Total (men)	4,065,050	4,185,182	3.0
Women			
20–24	158,213	162,501	2.7
25–29	184,895	189,908	2.7
30–34	232,389	238,589	2.7
35–39	328,859	337,303	2.6
40–44	498,948	510,906	2.4
45–49	576,043	588,377	2.1
50–54	609,292	620,210	1.8
55–59	532,056	539,230	1.3
60–64	395,366	398,645	0.8
65–69	165,695	166,174	0.3
Total (women)	3,681,756	3,751,842	1.9
Total	7,746,805	7,937,024	2.5

Data are *n* unless otherwise indicated.

CONCLUSIONS

Our study predicted that among a cohort of Australians currently aged 20–65 years with diabetes followed up until age 69 years, the presence of diabetes would lead to a significant reduction in years of life lived as well as productive years of life lived.

Regarding years of life lost to diabetes, despite the fact that the prevalence of diabetes was lower among younger people, the relative impact was generally greater among younger people. This is consistent with several reports in the literature showing that diabetes in young people exerts a greater impact compared with diabetes in older people (10,11). We also show that the relative impact of diabetes on years of life lost was slightly greater among men. This was because the prevalence of diabetes was generally higher among men, and they did not live as long as women (12). In a burden of disease study, Begg et al. (13). also found that number of years of life lost to diabetes was higher in men (9%) than women (7%). We also show that from the age of 45 years, someone with diabetes will live 3 years less than someone without diabetes up until age 69 years. This is consistent with other reports in the literature (12,14,15).

In terms of impact on productivity, the results from our modeling suggest that if diabetes did not exist, the total number of PALYs lived from age 20–69 years by Australians with diabetes would increase by ~11%, and GDP would improve by 80 billion AUD as a conservative measure. This is not insignificant and is supported by other evidence. Adepoju et al. (16) found that diabetes affects both absenteeism and presenteeism, causing total productivity losses of 4% and 44%, respectively. As with years of life lost to diabetes, in proportional terms, greater productivity loss would be borne by younger people and by men. This again reflects that prevalence of diabetes is higher in men and that they do not live as long as women. Other studies have also found that men tend to be more affected by diabetes than women in terms of workforce participation (17,18).

Traditional health economic analyses evaluate the cost-effectiveness of health interventions in terms of net costs per year of life saved or QALY saved (19,20). For example, using data from the Diabetes Prevention Program Outcomes Study (DPPOS), the Diabetes Prevention Program Research Group (9) estimated that lifestyle intervention was associated with an incremental cost-effectiveness ratio (ICER) of 10,037 USD per QALY saved over a 10-year time period. QALYs adjust for reduced quality of life due to ill health, but they have no intrinsic financial value, and, hence, arbitrary ICER thresholds need to be set to determine which health interventions are cost-effective. ICERs $<$50,000 USD per QALY saved are generally considered cost-effective for high-income countries (20). PALYs are conceptually similar to QALYs but adjust for loss of productivity (rather than loss of quality of life) due to ill health and therefore can be ascribed a financial value. Because of this, estimating the impact of health interventions on PALYs obviates the need for ICERs; net costs are inherently calculated. We are suggesting not that PALYs replace QALYs in health economic evaluations but, rather, that PALYs represent another useful measure of the potential benefits of health interventions, focused primarily on their economic value to the broader society.

The results of our study highlight that the prevention of diabetes and diabetes complications is vitally important from an economic perspective, just as it is from a health perspective. The problem with high health care expenditure is that it is perceived as just that: an expenditure. Rather, devoting funds to health care and money spent on prevention strategies should be perceived as an investment. Our work identifies the age-groups and sex group that would benefit most from prevention strategies, namely, younger people and males. For highly prevalent and highly consequential diseases like diabetes, such investments are crucial and will be of paramount importance for developing countries where diabetes prevalence is rising in the working age-groups at a much more rapid rate than in developed countries (21).

Strengths and limitations of our study should be addressed. The major strength was the use of contemporary national Australian mortality rates and representative diabetes prevalence data from the NDSS, which is considered the best available national data source for estimating overall prevalence of diagnosed diabetes in Australia (7). While there are no published data on the completeness of the NDSS, data from the Fremantle Diabetes Study, a cohort study of people with

Table 4—PALYs lived, simulated from life table modeling

Age-group (years) by sex	Population with diabetes	Population assumed not to have diabetes	Percent reduction in PALYS: no diabetes versus diabetes
Men			
20–24	149,907	168,192	12.2
25–29	163,504	183,658	12.3
30–34	202,012	227,066	12.4
35–39	278,292	312,816	12.4
40–44	405,969	455,949	12.3
45–49	511,591	573,447	12.1
50–54	613,728	685,619	11.7
55–59	734,910	819,514	11.5
60–64	479,172	528,874	10.4
65–69	210,325	230,046	9.4
Total (men)	3,749,408	4,185,182	11.6
Women			
20–24	146,353	162,501	11.0
25–29	170,940	189,908	11.1
30–34	214,729	238,589	11.1
35–39	303,697	337,303	11.1
40–44	460,515	510,906	10.9
45–49	531,374	588,377	10.7
50–54	561,729	620,210	10.4
55–59	490,248	539,230	10.0
60–64	364,097	398,645	9.5
65–69	152,506	166,174	9.0
Total (women)	3,396,188	3,751,843	10.5
Total	7,145,596	7,937,024	11.1

Data are *n* unless otherwise indicated.

diabetes, showed that 88% and 87% of persons with type 1 and type 2 diabetes, respectively, were registered in the NDSS, including 81% of diet-treated individuals (W. Davis, personal communication). These data confirm very high capture rates in all groups.

Another potential issue is that there is a large proportion of people with diabetes who are unaware of its presence (22), but diabetes could still exert an impact, and thus these results may be considered an underestimation of the effect of diabetes on work productivity. Further, the life table model simulated the progress of the current cohort of Australians with (known) diabetes but did not account for the future onset of diabetes among people who currently do not have diabetes. This would have underestimated future prevalence of diabetes and therefore loss. Overall, the above limitations would have led to an underestimation of the impact of diabetes on health and productivity.

While life table modeling is a recognized epidemiological and demographic tool, modeling analyses of any type are subject to uncertainty, and three major sources of uncertainty warrant mention. We acknowledge that the productivity indices used in the model were potentially crude, without stratification by age, sex, or the type of work that people undertake (for example, diabetes may be more likely to affect people who work in manual jobs). Despite this, more precise estimates of the impact of diabetes on the productivity of specific subgroups of the population would not have changed the overall conclusion of our study that diabetes exerts a significant burden on the Australian population.

We also have assumed that "work" related to paid employment and we did not capture loss of productivity in unpaid work, and we assumed that the population worked full-time and made no attempt to account for part-time employment. As with other key assumptions, these latter assumptions would have led to an underestimation of the impact of diabetes on health and productivity; hence, again, our conclusion is unchanged.

Another source of uncertainty pertained to future projections of mortality rates. As is common in life table modeling, the current study used age-specific cross-sectional mortality data to simulate prospective follow-up of a cohort of individuals, but the underlying assumption was that there were no temporal trends into the future. Lastly, we did not present any uncertainty intervals around any estimates.

The current study is novel because it predicts the indirect cost of diabetes in terms of labor force participation and highlights that devotion of funds to prevent and control diabetes should be viewed as a worthwhile investment as opposed to an expenditure. While disease may indirectly generate GDP by creating the need for health services, money lost through reduced productivity is never generated in the first place.

The findings of the current study are highlighted by the rising prevalence of diabetes, especially among people of working age including those in developing countries across the world. Through the development of the PALY, this study has provided novel insight into the magnitude of the burden imposed by diabetes at a population level. Future studies should investigate the impact of diabetes and diabetes-related complications specifically on absenteeism and presenteeism, as well as mechanisms by which these occur. Such studies will further inform targeting of relevant interventions. For example, interventions based on lifestyle or medications such as metformin have been proven to increase labor engagement among people with diabetes (23). The assigning of accurate costs to productivity loss will also be highly informative. Additionally, comparison of the above results across countries with varying levels of economic development would provide a clearer picture of the regional and global impact of diabetes.

Diabetes imposes a very large burden on the Australian population, not only in terms of health and well-being but also in terms of productivity. This burden is set to increase into the future as the prevalence of diabetes increases. This underscores the importance of prevention and adequate control of diabetes. Devotion of funds to this cause should be viewed as a (worthwhile) investment rather than, traditionally, as an expenditure.

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