Incremental healthcare expenditure attributable to diabetes mellitus: a cost of illness study in Tasmania, Australia.

Short title: Incremental healthcare expenditure attributable to diabetes

Authors

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Conflict of interest

MJ is a member of the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA) Executive Committee

What is already known? Diabetes is a chronic disease that places a huge burden on the Tasmanian healthcare system. However, until now, no data have been published on the economic burden of diabetes in Tasmania.

What this study has found? On average, the incremental costs in people with diabetes were almost double those for people without diabetes, and the cost differences have increased over time. Furthermore, the impact of diabetes on costs was different by sex, age group and socioeconomic status.

What are the implications of the study? Our findings will motivate and support policymakers in future planning for diabetes and enable targeted interventions for those sub-groups with higher long-term costs.

Data availability statement

Due to ethical concerns, the data that support the findings of this study cannot be made available openly.

1   **Abstract**

2   **Aims.** To quantify the incremental direct medical costs in people with diabetes from the
3   healthcare system perspective; and to identify trends in the incremental costs.

4   **Methods.** This was a matched retrospective cohort study based on a linked dataset developed
5   for investigating chronic kidney disease in Tasmania, Australia. Using propensity score
6   matching, 51,324 people with diabetes were matched on age, sex, and residential area with
7   102,648 people without diabetes. Direct medical costs (Australian dollars 2020-2021) due to
8   hospitalisation, Emergency Department visits and pathology tests were included. The
9   incremental costs and cost ratios between mean annual costs of people with diabetes and
10   their controls were calculated.

11   **Results.** On average, people with diabetes had healthcare costs that were almost double their
12   controls ($2,427 (95% CI 2,322-2,543); ratio 1.87 (95% CI 1.85-1.91); pooled from 2007-2017).
13   While in the first year of follow-up, the costs of a person with diabetes were $1,643 (95% CI
14   1,489-1,806); ratio 1.83 (95% CI 1.76-1.92) more than their control, this increased to $2,480
15   (95% CI 2,265-2,680); ratio 1.69 (95% CI 1.62-1.77) in the final year. Although the incremental
16   costs were higher in older age groups (e.g., ≥70: $2,498 (95% CI 2,265-2,754); 40-49: $2,117
17   (95% CI 1,887-2,384)), the cost ratios were higher in younger age groups (≥70: 1.52 (95% CI
18   1.48-1.56); 40-49: 2.37 (95% CI 2.25-2.61)).

19   **Conclusions.** Given the increasing burden that diabetes imposes, our findings will support
20   policymakers in future planning for diabetes and enable targeting sub-groups with higher
21   long-term costs for possible cost savings for the Tasmanian healthcare system.

22   **Key words.** Diabetes, cost of illness, data linkage, record linkage, Tasmania, Australia

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Introduction

Diabetes mellitus imposes a large burden on the health and social care systems because of its chronic nature and increasing prevalence, in combination with damaging complications.[1] In Australia, 2.7 billion (2.3% total healthcare expenditure) was spent on diabetes care in 2015-2016.[2] Tasmania is an Australian state with high prevalence of chronic diseases, including diabetes. According to the Tasmanian Health Survey, diabetes prevalence in Tasmania reached 8.3% in 2019.[3] In this context, accurate information about the direct costs of diabetes care over the recent years can provide some insight on the increasing burden that diabetes imposes on the Tasmanian health system and support policymakers to take practical actions to reduce the economic burden of diabetes.

In cost of illness studies, there were two approaches that have been specifically developed to estimate different types of costs: the total cost approach and the incremental cost approach. Previous studies found that the incremental cost approach may more accurately estimate the costs incurred, compared to the total cost approach.[4,5] The incremental cost approach uses either matching algorithms or regression method to calculate the incremental costs reflecting the difference in healthcare costs between people with and without the disease.[1,6].

In Australia, there are several published papers that have estimated the incremental costs in people with diabetes. However, most of them used relatively small,[7-9] clinic-based samples[7,10] and quantified the costs incurred in either a single year[7] or short-term periods.[8-10] More importantly, until now, no data have been published on the economic burden of diabetes in Tasmania. As a result, there is an urgent need for up-to-date information related to the economic burden of diabetes in Australia in general and Tasmania in particular. To address this glaring evidence gap, we conducted this study using a matched control method to quantify the incremental direct costs (including hospital, emergency visit and pathology costs) of people with diabetes, compared to people without diabetes in Tasmania. Because diabetes is a chronic disease having long-term effects on the healthcare system, we also aimed to identify trends in the incremental costs over the 11-year period.

Methods

2.1. Data sources

This was a matched retrospective cohort study using a subset of a linked administrative dataset in Tasmania, an Australian state with the total area of 68,401 km^2 and a population of approximately 541,500 people. Ethics approval (with waiver of consent) for the study was obtained from the Tasmanian Health and Medical Human Research Ethics Committee (reference number H0018548).

The study population was identified from two pathology datasets: Royal Hobart Hospital Pathology (RHHPATH) and Hobart Pathology (Diagnostic Services Pty Ltd [DSPL]). Because the dataset was first developed to investigate chronic kidney disease, the study population included any individual who had a serum creatinine test between 1/1/2004 to 31/12/2017 from RHHPATH or DSPL.[11] This data was then linked to Tasmanian Public Hospital Admitted Patient Episodes (AP), Tasmanian Public Hospital Emergency Department Presentations (ED),

78 Tasmanian Death Register and Tasmanian Coded Cause of Death (DEATH) data, the Tasmanian
79 Cancer Registry (TCR), and the Australia and New Zealand Dialysis and Transplant Registry
80 (ANZDATA).

81   RHHPATH and DSPL provided information about participants' glycaemic control (HbA1c,
82 fasting plasma glucose (FPG), random plasma glucose (RPG)) and other pathology tests
83 (Appendix 1); admitted patient data included information about hospital episodes
84 (International Statistical Classification of Diseases and Related Health problems 10th Revision
85 Australian Modification (ICD-10-AM) codes, Australian Refined Diagnosis Related Groups (AR-
86 DRGs), number of admissions and length of hospital stay); ED data included information about
87 ED presentations (primary diagnosis codes, urgency related groups (URGs), number of
88 presentations and length of ED stay); DEATH provided information about cause of death and
89 date at death; while TCR and ANZDATA provided information about comorbidities.

90   The dataset was linked by the Tasmanian Data Linkage Unit, Menzies Institute for Medical
91 Research, The University of Tasmania. Details about the linkage process were published
92 elsewhere.[11] The dataset included approximately 87% (355,622) of the adult population in
93 Tasmania (409,729) during 2013-2017.[11]

94 *2.2. Participant selection*

95   From the initial dataset that comprised any individual that had a serum creatinine test,
96 people with diabetes were defined as those people who satisfied at least one of the following
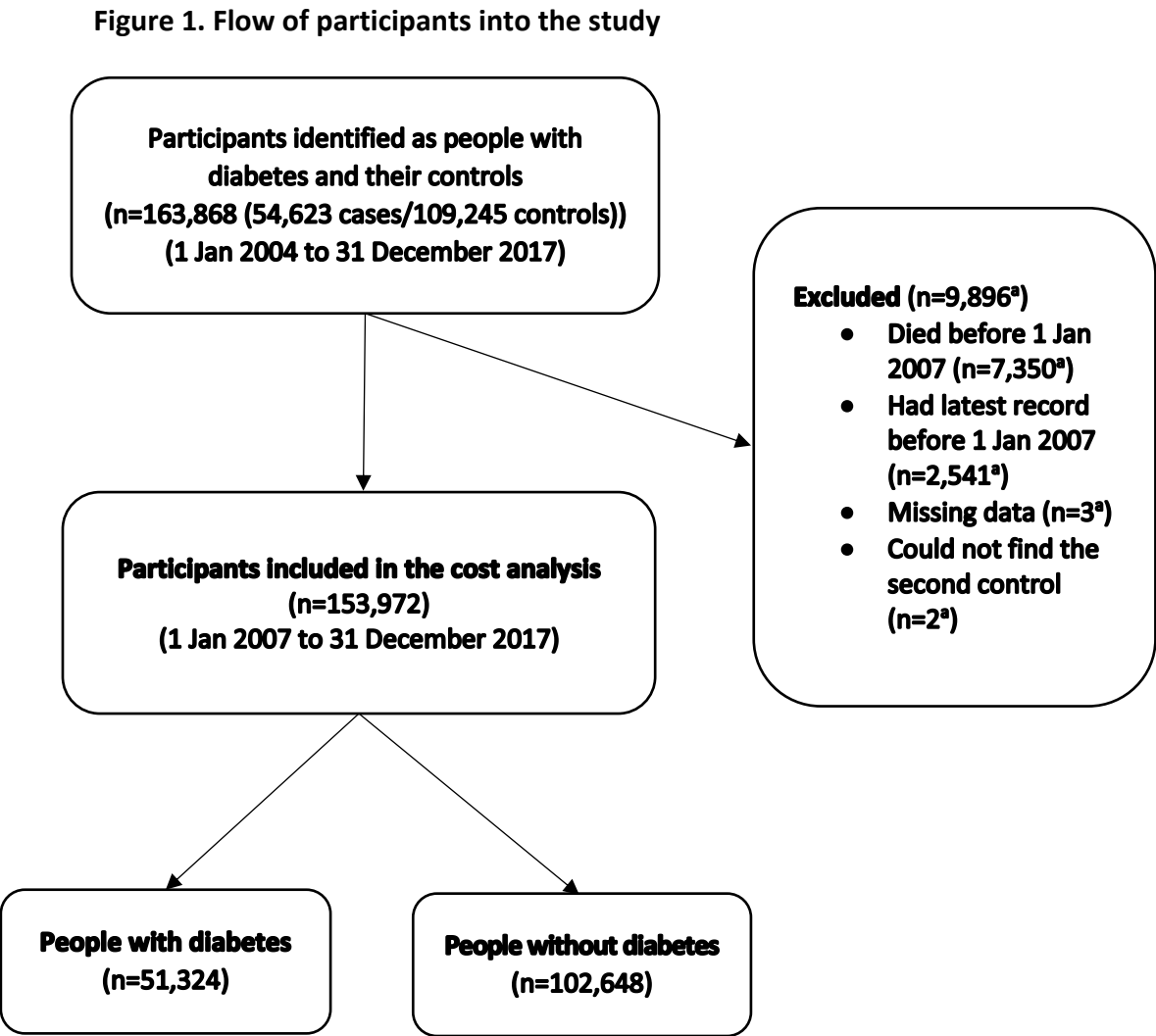97 criteria between 01/01/2004 to 31/12/2017.

98   1. ≥1 HbA1c test ≥ 48 mmol/mol (6.5%).

99   2. ≥1 FPG tests ≥ 7.0 mmol/l (126 mg/dl).

100   3. ≥1 RPG test ≥ 11.1 mmol/l (200 mg/dl).

101   4. ICD-10-AM diagnosis code (primary or other) in the E10-E14 ranges recorded in either
102   AP or ED.

103   5. A primary or underlying ICD-10-AM coded cause of death in the E10-E14 ranges
104   recorded in DEATH.

105   Criteria 1-3 were based on diabetes diagnostic criteria published by the Australian Diabetes
106 Society,[12] while using ICD codes to identify people with diabetes (criteria 4,5) was widely used
107 in studies based on administrative data.[7,10]

108   The corresponding controls were sourced from the remaining individuals. Matching was
109 based on age decile, sex, Statistical Areas Level 4 (SA4) of residence, year of first serum
110 creatinine test in RHHPATH or DSPL and follow-up time (years) in the datasets, with a ratio of
111 1 case to 2 controls. Follow-up time for each person was calculated from the first and the last
112 records during the study period. Exact matching was made on categorical variables (age decile,
113 sex, and SA4 of residence) with the nearest neighbour scoring for year of first appearance and
114 follow-up time.

115   There were 54,623 cases and 109,245 controls identified. After excluding those who died
116 or had the latest records before the inclusion date for the cost analysis (1 January 2007), and

participants with missing data; 51,324 cases and 102,648 controls were included in the cost analysis (Figure 1).

Figure 1. Flow of participants into the study

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┌─────────────────────────────────────┐
│ Participants identified as people with│
│     diabetes and their controls      │
│ (n=163,868 (54,623 cases/109,245     │        ┌──────────────────────────┐
│             controls))               │        │ Excluded (n=9,896[a])    │
│   (1 Jan 2004 to 31 December 2017)   │───────▶│  • Died before 1 Jan     │
└─────────────────────────────────────┘        │    2007 (n=7,350[a])     │
                  │                             │  • Had latest record     │
                  ▼                             │    before 1 Jan 2007     │
┌─────────────────────────────────────┐        │    (n=2,541[a])          │
│ Participants included in the cost    │        │  • Missing data (n=3[a]) │
│         analysis                     │        │  • Could not find the    │
│          (n=153,972)                 │        │    second control        │
│   (1 Jan 2007 to 31 December 2017)   │        │    (n=2[a])              │
└─────────────────────────────────────┘        └──────────────────────────┘
          │              │
          ▼              ▼
┌──────────────────┐  ┌──────────────────┐
│ People with      │  │ People without   │
│   diabetes       │  │   diabetes       │
│   (n=51,324)     │  │   (n=102,648)    │
└──────────────────┘  └──────────────────┘
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[a] Total number of cases and controls. If a participant was excluded, their corresponding case/controls were also excluded.

2.3. Estimation of healthcare costs and the incremental costs

Within the dataset, hospital episodes with similar levels of resource consumption were classified into AR-DRGs. Each AR-DRG was allocated a cost, sourced from the Independent Hospital Pricing Authority (IHPA).[13] Similarly, each emergency department presentation was classified into an Urgency Related Group (URG), with costs extracted from validated IHPA sources.[13] In terms of pathology costs, unit costs for each test were sourced from the Medicare Benefits Schedule (MBS).[14] Because of data availability, only cost data for tests conducted on the same day as the serum creatinine test were included. The costs were aggregated for each year, then adjusted to 2020-2021 Australian dollars using the price index for Government Final Consumption Expenditure (GFCE) on hospitals and nursing homes index. This index was chosen because of its appropriateness for healthcare expenditure analysed in our cost analysis.[15] For years that were not included in the index, the corresponding inflators were calculated using the average increase of the included years (Appendix 2).[16]

For ED presentations with missing URGs (146,219 records; 3.5% of total records), mapping the primary diagnostic codes with the corresponding URGs was undertaken. The proportion of each URG during the study period was also considered to generate the average cost weight for each group. The cost analysis was performed from the healthcare system perspective and considered hospital, ED, and pathology costs.

The incremental costs were expressed as the absolute difference and the cost ratio between mean annual costs of people with diabetes and their controls. To investigate the impact of diabetes on costs in different sub-groups, we stratified the incremental costs by sex, age group and Index of Relative Socioeconomic Disadvantage (IRSD) score. This was assigned based data from the Australian Bureau of Statistics which assigns socioeconomic levels based on the residential address of participants (Statistical area level 2).[17] We divided the IRSD score into five categories reflecting the socioeconomic levels of participants, with level 1 is the most disadvantaged level and level 5 is the least disadvantaged level.

The incremental costs were then multiplied by the prevalence of diabetes in Tasmania and the total number of Tasmanians in 2017 to estimate the incremental direct healthcare expenditure in people with diabetes in Tasmania. The same methods were applied to estimate the incremental costs in Australia.

2.4. Method of analysis

Our analyses focused on the arithmetic mean of costs because it has been considered the most informative measure for policymakers.[18,19] Although our costs data were right skewed, we used t-tests to compare mean annual costs between people with diabetes and their controls because it has been proven that with sufficiently large samples, t-test still perform well regardless of the non-normal distribution of the data.[20] We calculated two-tailed p values, and $p \leq 0.05$ was considered statistically significant. The confidence intervals of mean annual costs per person, the incremental costs and the cost ratio between people with diabetes and their controls were calculated using a bias-corrected bootstrapping method with 1000 resamples.

190   One limitation of AR-DRG costing is that it is based on national average costs, therefore
191   potential differences in length of hospital stay between different patient groups such as those
192   with diabetes versus those without are not reported. In order to account for that, we
193   conducted a sensitivity analysis using a costing method that was based on the exact length of
194   hospital stay. We replaced the cost buckets (ward medical, ward nursing, non-clinical salaries,
195   allied, pharmacy, ward supplies, and hotel) calculated by average length of stay (ALOS) in each
196   AR-DRG by the corresponding cost buckets calculated using the exact length of stay (LOS) for
197   each hospitalisation recorded in our dataset. To do that, we first calculated the unit cost (costs
198   for a one day stay) for each cost bucket by dividing the total costs of each bucket by the ALOS,
199   both of which are published by the IHPA.[13,21] The resulting unit cost was then multiplied by
200   the actual LOS recorded for each individual patient's hospital admission.

201   To deal with coding errors that happen when physicians make a coding of diabetes if there
202   is only an indication for diabetes or an incorrect coding is made, we conducted a second
203   sensitivity analysis excluding 1,610 people with diabetes who were identified with only a single
204   coding of ICD diabetes.

205   All statistical analyses were conducted using Stata version 17. The matching process was
206   performed using R version 4.0.3. Joinpoint software version 4.9.0.0 was used for analysing
207   cost trends during the study period.[22]

208   **Results**

209   In 2017, there were 33,144 people with diabetes identified from our dataset (Table 1). This
210   corresponds to a crude prevalence of 6.3% and an age/sex standardised prevalence of 5.7%
211   (based on direct standardisation method using the Australian age and sex distribution in
212   2017).[23]

213   **Table 1: Matched cohort size by follow-up years**

Follow-up year	People with diabetes n (%)	People without diabetes n (%)	Total
0	41,011 (33.3)	82,179 (66.7)	123,190
1	42,629 (33.0)	86,438 (67.0)	129,067
2	43,359 (32.9)	88,555 (67.1)	131,914
3	43,398 (32.8)	88,954 (67.2)	132,352
4	43,067 (32.7)	88,613 (67.3)	131,680
5	42,625 (32.6)	87,955 (67.4)	130,580
6	41,848 (32.6)	86,572 (67.4)	128,420
7	40,815 (32.6)	84,523 (67.4)	125,338
8	39,464 (32.7)	81,335 (67.3)	120,799
9	37,587 (33.1)	75,869 (66.9)	113,456
10	33,144 (34.6)	62,727 (65.4)	95,871

The characteristics of participants in our study are described in Table 2. In both groups, 55.6% were men, and the mean age was approximately 59 years. As anticipated, people with diabetes had a higher rate of deaths (20.1% versus 12.9%; p<0.001), more hospitalisations (6.0 ± 34.1 versus 3.2 ± 22.0; p<0.001), ED presentations (3.8 ± 7.8 versus 2.6 ± 5.0; p<0.001), longer length of hospital stay (5.0 ± 12.6 days versus 4.4 ± 15.1 days; p<0.001) and ED stay (405 ± 373 minutes versus 352 ± 401 minutes; p<0.001) than people without diabetes.

Table 2. Characteristics of participants

Characteristics	People with diabetes n=51,324	People without diabetes n=102,648	p
Sex			
Men	28,524 (55.6)	57,048 (55.6)	
Women	22,800 (44.4)	45,600 (44.4)	
Age (years)[a]	59.1 ± 15.5	58.7 ± 15.6	
Age groups (years)[a]			
0-39	5,286 (10.3)	10,755 (10.5)	
40-49	7,273 (14.2)	14,616 (14.2)	
50-59	12,102 (23.6)	24,706 (24.1)	
60-69	13,493 (26.3)	26,768 (26.1)	
≥70	13,170 (25.7)	25,803 (25.1)	
IRSD			
1 (most disadvantaged)	10,601 (20.7)	15,940 (15.5)	
2	9,829 (19.2)	17,778 (17.3)	
3	10,810 (21.1)	21,073 (20.5)	
4	9,901 (19.3)	22,409 (21.8)	
5 (least disadvantaged)	10,183 (19.8)	25,448 (24.8)	
Number of hospital admissions[b]	6.0 ± 34.1	3.2 ± 22.0	<0.001[d]
Median (IQR)	2 (0, 5)	1 (0, 3)	
Length of hospital stay (days)[c]	5.0 ± 12.6	4.4 ± 15.1	<0.001[d]
Number of ED presentations[b]	3.8 ± 7.8	2.6 ± 5.0	<0.001[d]
Median (IQR)	2 (0, 5)	1 (0, 3)	
Length of ED stay (minutes)[c]	405 ± 373	352 ± 401	<0.001[d]
Number of deaths	10,318 (20.1)	13,229 (12.9)	<0.001[e]
Follow up time (years)	8.0 ± 3.2	8.1 ± 3.1	

Data are presented as mean ± standard deviation or n (%) unless otherwise stated
IRSD, Index of Relative Socioeconomic Disadvantage, calculated using statistical area level 2 (SA2) of residence.
IQR, Interquartile range. ED, Emergency Department
[a] calculated from recorded age at date of the first pathology recorded
[b] calculated for the whole study period
[c] average length of stay per admission
[d] derived from two-sample t-test
[e] derived from Chi-square test

Table 3 illustrates the incremental costs in people with diabetes in terms of the absolute and relative differences. On average, the annual costs of people with diabetes ($5,209 (95% confidence interval (CI) 5,112-5,317)) were almost double those of their counterparts without diabetes ($2,782 (95% CI 2,738-2,826); difference: $2,427 (95% CI $2,322-2,543); ratio 1.87 (95% CI 1.85-1.91); p<0.001). When standardised based on the Australian age and sex distribution in 2017,[23] these correspond to $2,397 (95% CI 2,057-2,745). Most of the costs

were related to hospital admission costs ($2,190; 90.2%); with ED presentations and pathology tests only accounting for small proportions (ED: $162, 6.7%; pathology: $75; 3.1% respectively). Extrapolating annual mean direct costs using our prevalence estimate, this corresponds to $173 million for total costs and $80 million of incremental costs due to diabetes in Tasmania in 2017. In the same year, approximately 1.2 million Australians were living with diabetes,[24] this corresponds $2.9 billion of incremental costs due to diabetes.

Both the incremental costs and the cost ratio were higher in women (by 8.8% and 11.2%, respectively). In terms of age, trends in incremental costs were found in people aged over 40. Although the incremental costs were higher in older age groups (e.g., ≥70: $2,498 (95% CI 2,265-2,754); 40-49: $2,117 (95% CI 1,887-2,384)), the cost ratios were higher in younger age groups (≥70: ratio 1.52 (95% CI 1.48-1.56); 40-49: ratio 2.37 (95% CI 2.25-2.61)). Regarding socioeconomic status, while the relative impact of diabetes decreased by the disadvantaged status (most disadvantaged: ratio 1.69 (95% CI 1.57-1.80); least disadvantaged: ratio 2.13 (95% CI 2.01-2.19)), no pattern was observed for the absolute difference

250 **Table 3. Mean annual costs of people with diabetes and their controls, by participants' characteristics and health service**
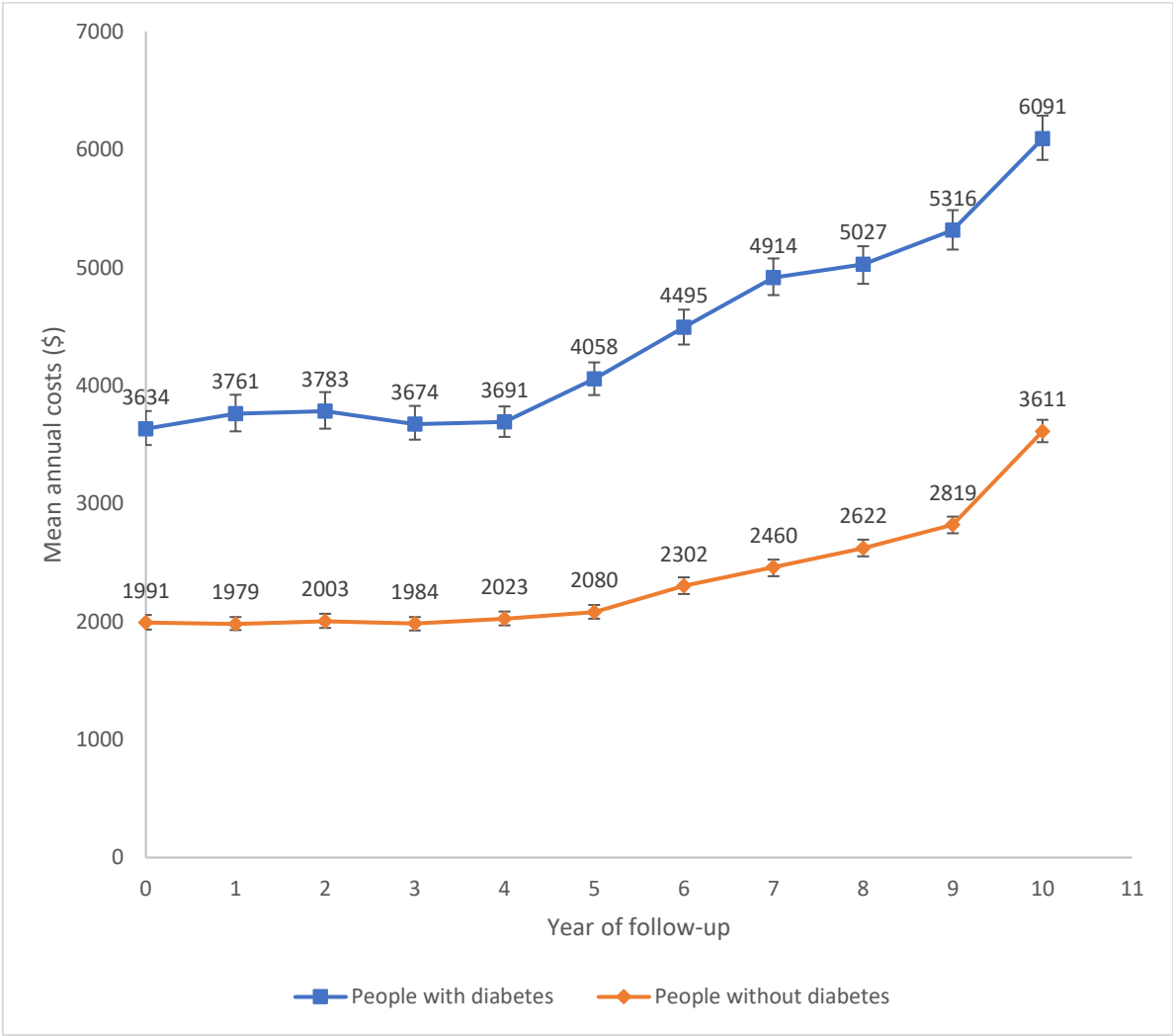
	People with diabetes n=51,324 mean AUD (95% CI)[a]	People without diabetes n=102,648 mean AUD (95% CI)[a]	P[b]	Incremental costs AUD (95% CI)[a]	Cost ratio AUD (95% CI)[a]
Sex					
Men	5,300 (5,157-5,424)	2,964 (2,907-3,031)	< 0.001	2,336 (2,182-2,496)	1.79 (1.74-1.88)
Women	5,096 (4,947-5,268)	2,555 (2,493-2,609)	< 0.001	2,541 (2,388-2,710)	1.99 (1.89-2.07)
Age group (years)[c]					
0-39	4,598 (4,244-4,986)	1,871 (1,771-1,968)	< 0.001	2,727 (2,352-3,150)	2.46 (2.28-2.64)
40-49	3,665 (3,411-3,911)	1,547 (1,459-1,656)	< 0.001	2,117 (1,887-2,384)	2.37 (2.25-2.61)
50-59	4,077 (3,903-4,279)	1,737 (1,679-1,803)	< 0.001	2,339 (2,162-2,544)	2.35 (2.26-2.44)
60-69	5,251 (5,061-5,431)	2,835 (2,741-2,922)	< 0.001	2,416 (2,224-2,638)	1.85 (1.79-1.92)
≥70	7,306 (7,083-7,543)	4,808 (4,699-4,911)	< 0.001	2,498 (2,265-2,754)	1.52 (1.48-1.56)
IRSD					
1 (most disadvantaged)	5,849 (5,612-6,104)	3,457 (3,340-3,587)	< 0.001	2,392 (2,132-2,684)	1.69 (1.57-1.80)
2	6,019 (5,784-6,300)	3,448 (3,334-3,560)	< 0.001	2,570 (2,285-2,876)	1.75 (1.63-1.87)
3	5,318 (5,130-5,510)	3,063 (2,956-3,183)	< 0.001	2,255 (2,028-2,469)	1.74 (1.68-1.79)
4	4,741 (4,560-4,997)	2,485 (2,397-2,567)	< 0.001	2,256 (2,049-2,485)	1.91 (1.83-1.99)
5 (least disadvantaged)	4,104 (3,915-4,304)	1,924 (1,858-2,002)	< 0.001	2,180 (1,970-2,399)	2.13 (2.01-2.19)
Health service					
Hospital	4,590 (4,497-4,693)	2,400 (2,359-2,442)	< 0.001	2,190 (2,091-2,297)	1.91 (1.89-1.95)
ED	423 (416-430)	261 (259-265)	< 0.001	162 (154-170)	1.62 (1.60-1.66)
Pathology	196 (194-199)	121 (120-122)	< 0.001	75 (73-78)	1.62 (1.60-1.64)
Total	5,209 (5,112-5,317)	2,782 (2,738-2,826)	< 0.001	2,427 (2,322-2,543)	1.87 (1.85-1.91)

251 [a] 95% confidence interval, derived by bootstrapping method; [b] derived by two-sample t-test; [c] calculated from recorded age at date of the first pathology recorded

252 AUD: Australian dollars. IRSD, Index of Relative Socioeconomic Disadvantage. ED, Emergency Department
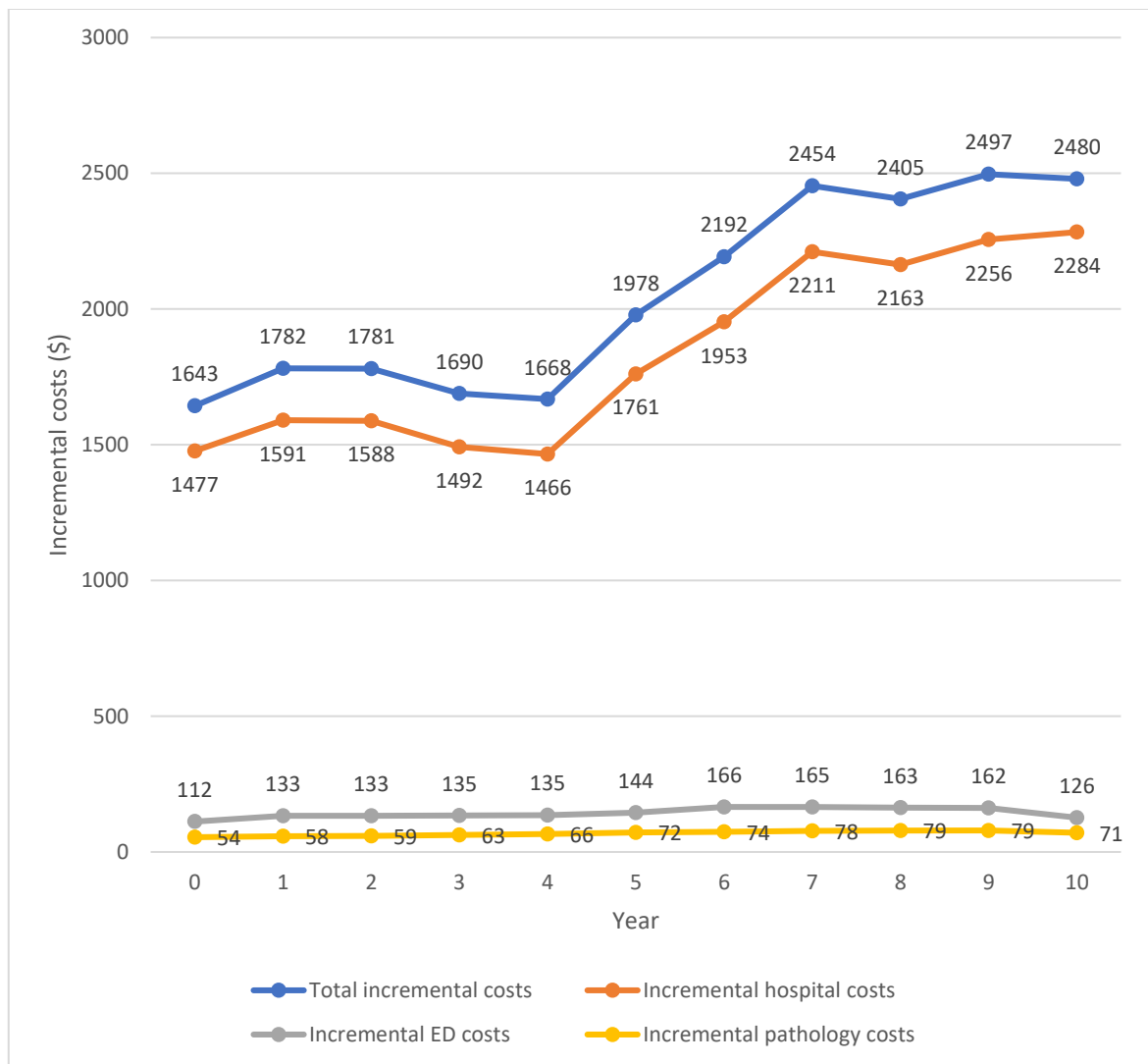
An upward trend in both mean annual costs and incremental costs in people with diabetes over the study period was observed (Figure 2a and Figure 2b). The annual percent change (APC) of the incremental costs was significantly different from zero (APC=5.13, p<0.05) (Appendix 3). While in the first year of follow-up, on average, people with diabetes had medical costs that were $1,643 (95% CI 1,489-1,806) more than their controls, these incremental costs increased to $2,480 (95% CI 2,265-2,680) in the final year.

Figure 2a. Trend in mean annual costs in people with and without diabetes

Costs were expressed as mean (95% confidence interval)
The differences in costs were statistically significant at all time points (p < 0.001, two-sample t test)

Figure 2b. Trend in incremental costs in people with diabetes

The differences in costs were statistically significant at all time points (p < 0.001, two-sample t test)
95% confidence intervals were omitted for clarity
ED, Emergency Department

Results of sensitivity analyses were presented in appendix 4. The first sensitivity analysis indicated that if the actual LOS was considered, the incremental costs would increase to $2,868 (95% CI 2,723-3,024). Although there was similar upward trend, the APC of the excess costs was lower (3.68, p<0.05). The incremental costs obtained from the second sensitivity analysis ($2,385 (2,280-2,503)) were slightly lower than our main analysis.

Discussion

Diabetes prevalence estimated from our study (year 2017: 5.7%) was higher than results from the Australian health survey (5.4%),[24] but lower than estimate from the Tasmanian health survey (year 2016: 8.1%).[3] This might be mostly because of the differences in sample size and diabetes definition. It is likely that we captured the vast majority, if not all people with diabetes in Tasmania.

By using matched controls in a large sample of the Tasmanian population, we have demonstrated that people with diabetes require substantially greater healthcare expenditure than people without diabetes of similar age, sex, and residential area. Health service utilisation in people with diabetes was higher compared to people without diabetes, both in terms of the number of hospital visits and the LOS, which also led to considerable increases in costs.

Our results not only quantified the substantial increase in healthcare expenditure in people with diabetes, but also demonstrated the upward trend over time. More importantly, this trend was more noticeable from the year 3-4 of the follow-up period that corresponds to year 2010-2011 (2007-2010: APC 0.71, p>0,05; 2010-2017: APC 6.44; p<0.05). This is most likely due to the activity-based funding (ABF) agreement between the Commonwealth and Australian states in 2011,[25] which led to the establishment of the IHPA. Based on the national hospital cost data collection, the IHPA determined the national efficient price to estimate the costs of hospital services to support ABF. This reform might have led to more careful clinical coding and AR-DRG assignment, resulting in higher costs being assigned for each hospital admission.

Our findings also highlighted the interaction between diabetes and age. While the incremental costs indicate the absolute difference in costs between people with and without diabetes, the cost ratios enable comparing the relative effect of diabetes in different age groups. The fact that the lower incremental costs in younger age groups corresponded to the higher relative increase in costs demonstrated that the impact of diabetes on health status might be even more devastating in younger age groups. Similar trends were reported in other international studies. A study conducted in Germany found that the cost ratio was approximately 3.3 in people aged <50 years, much higher compared to a cost ratio of 1.6 in those aged >80 years.[26] Another study in Italy even found more remarkable difference, with cost ratio 7.1 in people <45 years and 1.7 in people >74 years.[27]

Previous studies in Australia reported the annual incremental costs per person with diabetes as ranging from $1,861 to $2,534 in 2020-2021 values (ratio 1.22-2.08).[7,9,10] Our results were higher than a study performed in Queensland in 1999 that estimated the incremental costs at $1,861 ($1,006 in 1998-1999 values).[10] Although using the same costing method as ours, this Queensland study focused on hospital costs in people with type 2 diabetes only, and did not include ED and pathology costs. Our estimate was also higher than a study that reported incremental costs of $2,342 ($1,559 in 2004-2005 values). This study used a bottom-up approach, partly based on self-reported diabetes and only included adults aged ≥ 30 years.[9] As a result, it is likely that the majority of participants in this study had type 2 diabetes who have lower incremental costs than patients with type 1 diabetes.[27] However, our results were lower than another Australian study that reported incremental costs of $2,534 ($2,105 in 2012-2013 values).[7] These differences may be due to: 1) the fact that their participants were recruited from hospital admissions versus our broad population-based participant inclusion including ED presentations that did not result in admissions, so were likely to be more unwell than our cohort; 2) the study was based on a bottom-up approach, while our study used a case mix approach for costing hospital and ED admissions.

Results from international studies have likewise demonstrated the profound impact of diabetes on direct healthcare costs. In these studies, the cost ratios of people with diabetes

versus people without diabetes ranged from 1.3 to 4.1.[26-31] Although some of them reported a cost ratio that was relatively close to our estimate,[28,29,31] detailed comparison is problematic due to the discrepancies in healthcare systems and costs between countries.

The strengths of this study included the large sample size and a long study period. Additionally, the availability of pathology results supported by diagnostic codes allowed the accurate identification of people with diabetes and their counterparts without diabetes. However, there were some limitations. First, the dataset was originally developed to investigate chronic kidney disease. Therefore, participants were only included in the cohort if they had a serum creatinine test. This could have led to a selection or overrepresentation of people with kidney disease, or people with long-standing diabetes that already had diabetes related complications. Costs of pathology tests during the study period were only captured if they were performed on the same day as serum creatinine test, leading to a potential underestimation of the costs of pathology tests in our study. However, as serum creatinine tests are common routine blood test, we believe that this limitation does not considerably affect our cost estimates. Second, our dataset did not contain Medicare Benefits Schedule or Pharmaceutical Benefits Scheme data, so information on costs of medical practitioner consultations, physiotherapy, eye and vision therapy, and medication costs were not included in our study. Further, as we adopted the healthcare system perspective, we did not include patient out-of-pocket expenses. In addition, we were not able to calculate indirect costs due to absenteeism, presenteeism, premature death, and early retirement. Because it is challenging to ascertain when exactly people developed diabetes using administrative data, our sample could have included a number of people with prediabetes in some period of the study. Finally, because of the differences between type 1 and type 2 diabetes, these two types should have been reported separately. However, we could not distinguish between type 1 and type 2 diabetes because this information was not available.

The incremental costs estimated in our study may be valuable information to support policymakers to assess the costs potentially saved by implementing diabetes prevention strategies, as well as optimal diabetes management. It is anticipated that these incremental costs will continue increasing over time, and policymakers should consider this information when planning future budgets and to allocate resources adequately and effectively. Our findings not only highlight the economic burden of diabetes, but also identify sub-groups with higher costs. This may allow decision makers to target these groups with suitable interventions to lower these costs, for example older age groups. However, because of their shorter remaining lifetime, people with diabetes diagnosed at older ages had lifetime costs that are less than younger people.[32] Although implementing programs targeting older age groups could gain immediate benefit, focusing on prevention and treatment of diabetes in younger age groups may be more beneficial in the long run, because the relative impact of diabetes is higher in younger age groups, and they also have higher long-term healthcare costs.

Most of the incremental costs associated with diabetes identified in this study may be due to complications. Future research could identify the complications that lead to higher incremental costs, and further explore the most important underlying factors that are associated with long-term incremental costs, such as frequency of hospitalisations or intensity of treatment.[10] Furthermore, estimating the incremental costs before and after diagnosis in

people with diabetes in an Australian setting will also provide more evidence to help identify cost-effective interventions for preventing diabetes.

In conclusion, this study used linked data to determine that the incremental direct medical costs due to hospitalisation, ED visits and pathology tests in people with diabetes were almost double their counterparts without diabetes in Tasmania, Australia. These cost differences have increased over time, most likely due to changes in funding models rather than to changes in management or hospitalisation rates. Additionally, we determined the different impact of diabetes on costs by sex, age group, and socioeconomic status. Our cost estimates will be useful information for full economic evaluations and will support policymakers in allocating resources effectively for possible long-term cost savings.

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Table 1: Matched cohort size by follow-up years

Table 2. Characteristics of participants

Data are presented as mean ± standard deviation or n (%) unless otherwise stated
IRSD, Index of Relative Socioeconomic Disadvantage, calculated using statistical area level 2 (SA2) of residence.
IQR, Interquartile range. ED, Emergency Department
[a] calculated from recorded age at date of the first pathology recorded
[b] calculated for the whole study period
[c] average length of stay per admission
[d] derived from two-sample t-test
[e] derived from Chi-square test

Table 3. Mean annual costs of people with diabetes and their controls, by participants' characteristics and health service

[a] 95% confidence interval, derived by bootstrapping method; [b] derived by two-sample t-test; [c] calculated from recorded age at date of the first pathology recorded
AUD: Australian dollars. IRSD, Index of Relative Socioeconomic Disadvantage. ED, Emergency Department

Figure 1. Flow of participants into the study

[a] Total number of cases and controls. If a participant was excluded, their corresponding case/controls were also excluded.

Figure 2a. Trend in mean annual costs in people with and without diabetes

Costs were expressed as mean (95% confidence interval)
The differences in costs were statistically significant at all time points (p < 0.001, two-sample t test)

Figure 2b. Trend in incremental costs in people with diabetes

The differences in costs were statistically significant at all time points (p < 0.001, two-sample t test)
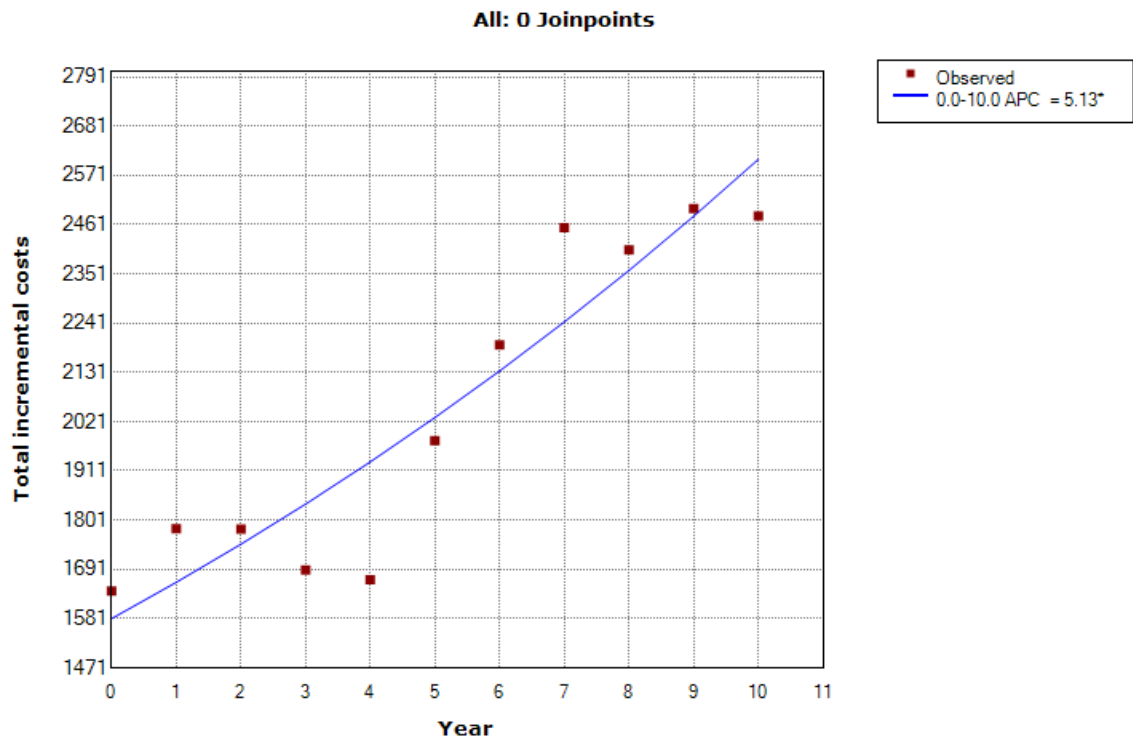95% confidence intervals were omitted for clarity
ED, Emergency Department

Appendix 1: Pathology tests included

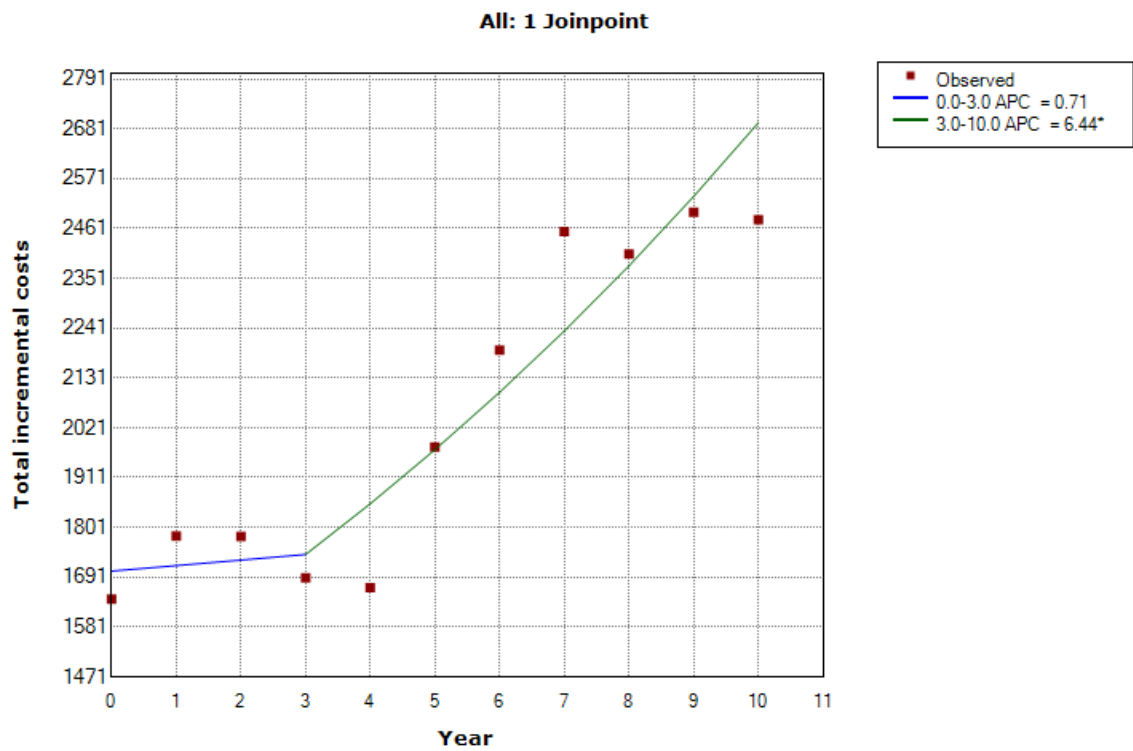| Name of test	Units
Cholesterol	mmol/L
HDL Cholesterol	mmol/L
LDL Cholesterol	mmol/L
Triglyceride	mmol/L
Sodium	mmol/L
Potassium	mmol/L
Chloride	mmol/L
Bicarbonate	mmol/L
Creatinine	umol/L
eGFR	mL/min/1.7
Uric Acid	mmol/L
Glucose Fasting	mmol/L
Glucose Random	mmol/L
Albumin	g/L
Phosphate	mmol/L
Total Calcium	mmol/L
Ferritin.	ug/L
C-Reactive Protein	mg/L
Creat Rand Ur	mmol/L
Urine Protein	g/L
Urine Albumin	mg/L
Albumin Creatinine Ratio	mg/mmol
HbA1c	%
HbA1c (IFCC)	mmol/mol
25-OH Vit.D	nmol/L
Haemoglobin	g/L
Classical-ANCA (C-ANCA)	
Perinuclear-ANCA (P-ANCA)	
Proteinase 3 Ab (PR3-ANCA)	U/mL
Proteinase 3 Ab (PR3-ANCA)	U/mL
Proteinase 3 Ab (PR3-ANCA)	IU/mL
Myeloperoxidase Ab (MPO-ANCA)	U/mL
Myeloperoxidase Ab (MPO-ANCA)	U/mL
Myeloperoxidase Ab (MPO-ANCA)	IU/mL

Appendix 2: NATIONAL EFFICIENT PRICE (NEP) AND THE PRICE INDEX FOR GOVERNMENT FINAL CONSUMPTION EXPENDITURE (GFCE) ON HOSPITALS AND NURSING HOMES INDEX (REFERENCE YEAR 2018-2019)

Year	NEP	GFCE
2003-2004		67.30
2004-2005		69.48
2005-2006		71.66
2006-2007	4095	73.84
2007-2008	4216	76.02
2008-2009	4337	78.20
2009-2010	4497	81.10
2010-2011	4558	82.20
2011-2012	4669	84.20
2012-2013	4808	86.70
2013-2014	4993	89.10
2014-2015	5007	91.20
2015-2016	4971	93.00
2016-2017	4883	94.70
2017-2018	4910	97.10
2018-2019		100.00
2019-2020		102.18
2020-2021		104.36

Appendix 3: Trend in incremental costs in people with diabetes

All: 0 Joinpoints

* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 0 Joinpoints.

All: 1 Joinpoint

* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 0 Joinpoints.

Appendix 4: Sensitivity analysis

Table A1. Mean annual costs of people with diabetes and their controls, by participants' characteristics and health service

	People with diabetes mean AUD (95% CI)[a]	People without diabetes mean AUD (95% CI)[a]	P[b]	Incremental costs AUD (95% CI)[a]	Cost ratio AUD (95% CI)[a]
1st sensitivity analysis (Using exact length of hospital stay to calculate costs)					
Sex	6,261 (6,089-6,440)	3,610 (3,525-3,713)	< 0.001	2,651 (2,461-2,862)	1.73 (1.67-1.80)
Women	6,469 (6,237-6,684)	3,330 (3,225-3,425)	< 0.001	3,138 (2,900-3,382)	1.94 (1.86-2.01)
Age group (years)[c]					
40-49	3,919 (3,642-4,192)	1,583 (1,483-1,713)	< 0.001	2,335 (2,064-2,630)	2.48 (2.27-2.67)
50-59	4,519 (4,302-4,748)	1,890 (1,822-1,977)	< 0.001	2,629 (2,406-2,861)	2.39 (2.29-2.54)
60-69	6,132 (5,905-6,391)	3,221 (3,107-3,333)	< 0.001	2,911 (2,679-3,186)	1.90 (1.83-2.01)
≥70	10,257 (9,913-10,619	7,013 (6,799-7,219)	< 0.001	3,244 (2,861-3,689)	1.46 (1.38-1.52)
IRSD 1 (most disadvantaged)	6,823 (6,535-7,145)	4,212 (4,048-4,392)	< 0.001	2,611 (2,287-2,963)	1.62 (1.57-1.73)
2	7,376 (7,018-7,739)	4,470 (4,286-4,677)	< 0.001	2,905 (2,506-3,319)	1.65 (1.53-1.69)
3	6,965 (6,641-7,306)	4,090 (3,890-4,272)	< 0.001	2,874 (2,537-3,267)	1.70 (1.61-1.79)
4	5,563 (5,334-5,860)	2,963 (2,841-3,080)	< 0.001	2,600 (2,340-2,878)	1.88 (1.80-1.96)
5 (least disadvantaged)	4,996 (4,730-5,282)	2,302 (2,206-2,401)	< 0.001	2,694 (2,395-2,973)	2.17 (2.09-2.26)
Health service Hospital	5,734 (5,614-5,861)	3,103 (3,038-3,176)	< 0.001	2,630 (2,490-2,783)	1.85 (1.80-1.90)
ED	423 (416-430)	261 (259-265)	< 0.001	162 (154-170)	1.62 (1.60-1.66)
Pathology	196 (194-199)	121 (120-122)	< 0.001	75 (73-78)	1.62 (1.60-1.64)
Total	6,353 (6,230-6,483)	3,486 (3,419-3,560)	< 0.001	2,868 (2,723-3,024)	1.82 (1.79-1.87)
2nd sensitivity analysis (excluding 1,610 people with diabetes who were identified with only a single coding of ICD diabetes					
Total	5,144 (5,043-5,256)	2,759 (2,715-2,800)	< 0.001	2,385 (2,280-2,503)	1.86 (1.82-1.92)

[a] 95% confidence interval, derived by bootstrapping method; [b] derived by two-sample t-test; [c] calculated from recorded age at date of the first pathology recorded
AUD: Australian dollars. IRSD, Index of Relative Socioeconomic Disadvantage. ED, Emergency Department

Figure A1: Trend in incremental costs in people with diabetes (sensitivity analysis 1)

All: 0 Joinpoints

* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 0 Joinpoints.