Family Medicine and Community Health

Glycaemic monitoring and control among high-risk patients with type 2 diabetes in Australian general practice during COVID-19

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To cite: Barlow KJ, Fahey PP, Atlantis E. Glycaemic monitoring and control among high-risk patients with type 2 diabetes in Australian general practice during COVID-19. *Fam Med Com Health* 2023;**11**:e002271. doi:10.1136/fmch-2023-002271

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/fmch-2023-002271).

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ABSTRACT

Background The COVID-19 pandemic disrupted general practice worldwide, primarily due to public health measures that restricted access to care for chronic diseases, such as type 2 diabetes. These measures disproportionately affected higher risk groups with type 2 diabetes, such as older people and those with obesity. This study aims to identify factors that may have influenced the rates of compliance with testing guidelines and target glycaemic control in Australian general practice settings during the COVID-19 pandemic.

Methods We used a serial cross-sectional study design of patient record data from general practices representative of the Nepean Blue Mountains Local Health District between 2020 and 2022. Aggregated patient records were analysed to determine percentages of subgroups with a blood glycaemic testing interval consistent with guidelines (≥1 within 15 months) and achieving target glycaemic control (by glycated haemoglobin of ≤7%). Linear regression models were used to test the association between independent and dependent variables, and to generate regression coefficients and 95% CI, corrected for time trends.

Results Of the average 14 356 patient records per month, 55% were male, 53% had a body mass index (BMI) <30 and 55% were aged 55–74 years. Compliance to testing guidelines slightly decreased (75–73%) but was positively associated with male sex (2.5%, 95% CI 1.7%, 3.4%), BMI≥30 (9.6%, 95% CI 8.8%, 10.4%) and 55–74 years (7.5%, 95% CI 6.6%, 8.5%) and 75 years and over age groups (7.1%, 95% CI 6.2%, 7.9%). Mean percentage of patient records achieving target glycaemic control slightly increased and was negatively associated with male sex (−3.7%, 95% CI −5.2%, −2.2%), but positively associated with 55–74 years (4.5%, 95% CI 3.8%, 5.1%) and 75 years and over age groups (12.2%, 95% CI 4.5%, 20.0%). Compliance to testing guidelines increased with each additional general practice per 10 000 persons (8.4%, 95% CI 4.9%, 11.8%).

Conclusions During the COVID-19 pandemic, people with type 2 diabetes in Australia continued to follow glycaemic testing guidelines at the same rate. In fact, there was a slight improvement in glycaemic control among all subgroups of patients, including those at higher risk. These findings are encouraging, but the longer term impact of COVID-19 on type 2 diabetes care is still unclear.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The COVID-19 pandemic caused worldwide disruption to general practice care primarily due to public health measures restricting access to care.

WHAT THIS STUDY ADDS

⇒ Compliance rates to glycaemic testing guidelines remained unaffected during the COVID-19 pandemic in the Australian general practice setting.

⇒ There was a slight improvement in glycaemic control among all subgroups of patients during this period.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The longer term impact of COVID-19 on type 2 diabetes care is still unclear.

INTRODUCTION

Type 2 diabetes (T2D) is a chronic condition in which the body does not produce or use insulin effectively.[1] If T2D is not managed well, it can lead to a number of serious complications, including hypertension, end-stage renal disease, retinopathy and neuropathy, and cardiovascular diseases.[2] Therefore, it is important for patients with T2D to continue to receive routine care, even during times of disruptions, such as a pandemic, to reduce the risk of serious complications and death.

The COVID-19 pandemic interrupted general practice care worldwide, primarily due to a range of social distancing and lockdown measures implemented by many governments to prevent the spread of infections and excess cases of severe disease.[3] In Australia, all states announced border restrictions and the suspension of non-essential activities and businesses in 2020.[4] Strict restrictions and social distancing rules were effective from December 2020 until October 2021 across Greater Sydney, New South Wales.[5] Despite the improvement in telehealth access,[6] accessing general practice became more difficult and confusing for many higher risk patients.

Although the COVID-19 measures were officially lifted on 30 November 2021, they limited the type and frequency of care that patients could receive from their general practitioners during that time.[7] This could have compromised the management of their T2D. Studies conducted before the pandemic have shown that even short-term delays in routine care can have negative consequences for people with T2D.[8] These delays can lead to worse control of risk factors, such as blood sugar, blood pressure and cholesterol levels resulting in worse microvascular, macrovascular and mortality outcomes.

During the COVID-19 pandemic, it was especially important for people with T2D to maintain good blood sugar control. People with T2D are at a higher risk of severe COVID-19 complications, including hospitalisation and death.[8–10] High blood sugar levels can weaken the immune system, damage the lungs and make people with diabetes more susceptible to infections.[11] The potential role of molecular pathways, such as ACE 2 and transmembrane protease serine 2, in explaining susceptibility to COVID-19 infection in T2D has also been proposed.[12 13]

Furthermore, research has consistently shown that COVID-19 social distancing and lockdown measures have increased behavioural risk factors associated with poor glycaemic control in patients with T2D.[14 15] These risk factors can lead to weight gain and other health problems. Indeed, a systematic review found that half of the observational studies in patients with T2D reported short-term deterioration in glycaemic control and increases in weight during this period.[16] However, another and more recent systematic review found insufficient evidence of adverse changes in glycaemic control from COVID-19.[17] The impact of COVID-19 on glycaemic control in people with T2D who see a general practitioner in Australia is unclear, especially for those at higher risk. This study aims to identify factors that may have influenced the rates of compliance with testing guidelines and target glycaemic control in Australian general practice settings during the COVID-19 pandemic.

METHODS

We present our study according to the Strengthening the Reporting of Observational Studies in Epidemiology checklist for reporting cross-sectional studies.[18]

Study design, setting and participants

We used a serial cross-sectional study design of patient record data that were variably available from general practices representative of the Nepean Blue Mountains (NBM) Local Health District between September 2020 and the most recently available month of June 2022. The NBM Local Health District contains four local government areas (LGAs) on the western edge of Greater Sydney with a combined population of approximately 386 000. The number of participating practices ranged from 88 to 100 per month. Each practice contributed a data record for each patient visit each month. The General Practice Data Sharing Head Agreement (Head Agreement) with the NBM Primary Health Network (NBMPHN) allowed aggregate patient record data from each participating practice to be collected and analysed for research purposes. If the practice provided a complete set of data items as specified in the Health Data Set Appendix under the Head Agreement with the NBMPHN, the practice was included in this study. All patient records from adults aged 18 years and over, with an existing T2D diagnosis, were reviewed. Patients with T2D were identified using their Systematized Nomenclature of Medicine-Clinical Terms codes, coded into the diagnostic field of the general practice clinical information software. We defined ‘active’ patients as those who attended a general practice at least three times in the past 2 years, consistent with the definition used by the Royal Australian College of General Practitioners (RACGP).[19] The inclusion criteria for this study were ‘active’ adult patients with T2D having their first visit no less than the preceding 12 months with an HbA1c test result in the past 15 months. These inclusion criteria aimed to minimise selecting records from transient patients and those who only recently encountered a general practice in the region.

Patient and public involvement

As the data were derived from patient records, there was no patient involvement.

Data sources and variables

We analysed deidentified cross-sectional data sets containing aggregate results from the above-described patient records. These data were routinely captured from the general practice clinical information system and the aggregated results were produced by a Patient Aggregation Clinical Audit Tool. Each month, the previous 15 months of HbA1c test results were reviewed for each eligible patient. Where more than one test result was available the most recent result was included. Where there was no record of an HbA1c test in the previous 15 months, that patient was recorded as overdue for testing. We used a 15-month glycaemic control testing interval rather than the guideline recommendation of 12 months for eligible patient records to allow for minor variations and delays in appointments. Only aggregate data were available for analysis, which included frequency counts for each variable of interest.

Based on available information captured relevant to the study aims, independent variables of interest included numbers of patients in demographic groups including age (18–54 years, 55–74 years and 75 years and over), sex (male and female) and LGA (Penrith, Lithgow, Blue Mountains and Hawkesbury), and clinical diagnosis groups of body mass index (BMI) score (BMI<30 and BMI≥30). Age categories were selected according to clinical relevance and to maximise group size for reliable statistical analysis. The default BMI threshold of ≥30 for grouping is consistent with the internationally recognised standard for classifying obesity in adults. Behavioural risk factors and interventions are not included as these data were not reliably recorded in the system. We further added general practice density (general practice per 10 000 persons) for each LGA from 2021 census data.

Dependent variables were the percentages for HbA1c tests recorded, consistent with RACGP guidelines (at least one within the past 15 months, allowing up to 3 months for delayed testing), and for test results consistent with achieving target glycaemic control. The 22-month study period returned 22 data points, each a record of the percentage who had at least one HbA1c test recorded within the past 15 months. Target glycaemic control was defined as HbA1c levels of ≤7% according to the RACGP.[20]

Bias

The NBMPHN receives deidentified data from the majority of general practices (range: 63–72%) in the health region. The focus on patients with a 12-month or longer history of T2D at that practice minimised the risk of bias from the incomplete information associated with transient patients. Pathology results were recorded in an automated format in the data extraction tool to minimise bias of missing data or errors arising from manual entry within practices.

Sample size

A common measure of effect size in regression analysis is $f^2 = R^2/\left(1 - R^2\right)$, where R^2 is the coefficient of determination, a measure of the variation in monthly observations which is explained by the regression model. Using the 'pwr.t2()' command in the 'pwr' app in R software, n=22 months data provide 80% power to detect an effect size of $f^2 = 0.38$ or higher although this estimate is conservative if there is correlation between months.

The data sets were obtained from 88 to 100 general practices captured over 22 months. The participating practices had aggregated data representing, on average, 14 000 eligible patients with a coded diagnosis of T2D over the study period. Most individuals contribute data across multiple months likely producing correlations between months.

Statistical methods

Analysis commenced with graphs and descriptive statistics. Histograms were used to check for extreme outliers or large skew in the outcome variables. Mean frequency counts across the 22 months and mean percentages of included patient records were calculated, as previously reported for aggregated data.[21] For each outcome of interest, the mean percentage and the associated 95% CI were reported.

Scatterplots showing each outcome measure by month for each categorical predictor were created to present visual understanding of trends over time for both HbA1c testing within the past 15 months and target glycaemic control.

We created subgroups of interest, including sex (male and female), age (18–54 years, 55–74 years and 75 years and over), BMI category (BMI<30 and BMI≥30) and general practice density represented by LGA and COVID-19 lockdown periods (COVID-19 lockdown and no COVID-19 lockdown).

Linear regression models were fit to test associations between independent and dependent variables, correcting for any time trends. Unstandardised regression coefficients and associated 95% CI were used to document the strength of association between independent and dependent variables in these models. Modelling assumptions of linearity, independence, homoscedasticity and normality of residuals were reviewed using scatterplots and histograms of residuals. Newey-West estimates of SEs were applied to adjust for the violation of the independence assumption (via autocorrelation) in the time series. For categorical predictor variables the equality of variance assumption was reviewed by Levene's test of equity of variance and the rule of thumb that the ratio between SDs should be less than 2.[22]

Data analysis was conducted using SPSS V.28.0.1.1 software.[23] For cross-sectional analyses, CIs for mean percentages were calculated using MedCalc software,[24] and for longitudinal models the Newey-West SEs, calculated using the 'NewyWest()' command from the Sandwich package in R V.4.1.1, were used in CIs and hypothesis tests.

RESULTS

Participants

In June 2022, the final month of the series, there were a total of 22 312 patient records aged 18 years and over and diagnosed with T2D recorded in general practices sharing data with the NBMPHN (online supplemental appendix 1). Due to not being considered 'active patients', 31% (n=6976) of patient records with T2D in the data set were excluded. Of the patient records identified, 15 336 met this study's inclusion criteria. Inclusion patterns were similar across all months, but the overall number of patient records included increased over time with increasing population and an increasing number of general practices including data. In the most recent month, June 2022, each LGA had over 65% of general practices contributing data to the NBMPHN (LGA 1, 68.2%; LGA 2, 75%; LGA 3, 62.5%; LGA 4, 65.4%).

Descriptive analyses

Characteristics of patient records are presented by LGA, sex, BMI status and age groups (table 1). Highest mean percentages for patient records were in LGA 4 (60%, n=8611), male sex (55%, 95% CI 53%, 56%), BMI<30 (53%, 95% CI 51%, 54%) and 55–74 years age group (55%, 95% CI 54%, 57%). Similar mean percentages of these characteristics were found across the LGAs except for LGA 3 which had the highest mean percentage of patients with a BMI≥30 (54%, 95% CI 49%, 59%).

Table 1 Mean number and mean percentages of patients with T2D by subgroups

Patients	Total health districts	LGA 1	LGA 2	LGA 3	LGA 4
Total	14 356*	2135*	2813*	796*	8611*
Male					
Mean number	7834	1144	1572	467	4650
Percentage (95% CI)	55 (53, 56)	54 (51, 57)	56 (53, 59)	59 (53, 64)	54 (52, 56)
Female					
Mean number	6366	976	1217	324	3849
Percentage (95% CI)	44 (43, 45)	46 (43, 49)	43 (41, 46)	43 (36, 45)	45 (43, 46)
BMI≥30					
Mean number	6752	993	1386	426	3947
Percentage (95% CI)	47 (46, 48)	47 (44, 50)	49 (47, 52)	54 (49, 59)	46 (44, 47)
BMI<30					
Mean number	7604	1142	1427	371	4664
Percentage (95% CI)	53 (51, 54)	53 (50, 57)	51 (48, 53)	47 (42, 52)	54 (53, 56)
18–54 years					
Mean number	2939	275	479	107	2077
Percentage (95% CI)	20 (20, 21)	13 (11, 15)	17 (16, 19)	13 (11, 16)	24 (23, 25)
55–74 years					
Mean number	7945	1114	1558	413	4860
Percentage (95% CI)	55 (54, 57)	52 (49, 55)	55 (53, 58)	52 (47, 57)	56 (55, 58)
75+ years					
Mean number	3319	731	753	271	1564
Percentage (95% CI)	23 (22, 24)	34 (32, 37)	25 (25, 29)	34 (30, 38)	18 (17, 19)

Mean number and mean percentages of active patients with T2D by sex, obesity status and age across the Nepean Blue Mountains Local Health District and local government areas from September 2020 to June 2022. Results are total % (95% CI).
*Mean number per month.
BMI, body mass index; LGA, local government area; T2D, type 2 diabetes.

There was an average of 3.7 (95% CI 3.1, 4.4) general practices per 10 000 patients in the total NBM Local Health District in July 2021 (table 2). However, LGA 1 had the lowest density of 2.8 general practices per 10 000 patients (95% CI 1.8, 4.3) at that time.

Of the patient records included in this study, 74.4% (95% CI 74.0%, 74.8%) of patients across the region had an HbA1c result in their general practice record within the previous 15 months (table 3). Male sex (75.7%, 95% CI 74.2%, 76.1%) and BMI≥30 groups (79.5%, 95% CI 79.1%, 79.9%) had notably higher rates of HbA1c testing than female sex (73.1%, 95% CI 72.7%, 73.3%) and BMI<30 groups (69.9%, 95% CI 69.5%, 70.3%), respectively. The percentage of eligible patients with HbA1c testing was notably higher for 55–74 years (76.2%, 95% CI 75.7%, 76.6%) and 75 years and over age groups (75.7%, 95% CI 75.3%, 76.2%) compared with the 18–54 years age group (68.6%, 95% CI 68.3%, 69.0%). Similar patterns were observed across all four LGAs.

Of the patients who had a recent (15 months) HbA1c test result in their general practice record, 57.1% (95% CI 56.7%, 57.4%) had achieved target glycaemic control (HbA1c ≤7%, table 4). While having a lower percentage of testing within the last 15 months, female sex (59.2%, 95% CI 58.8%, 59.6%) and BMI<30 groups (57.7%, 95% CI 57.3%, 58.0%) had slightly higher percentages for

Table 2 General practice density per 10 000 population in July 2021

	Total health districts	LGA 1	LGA 2	LGA 3	LGA 4
General practice density					
Mean number	3.7	2.8	4.1	3.8	0.6
(95% CI)	(3.1, 4.4)	(1.8, 4.3)	(2.8, 6.0)	(1.7, 7.6)	(2.8, 4.4)

Data are mean number of general practices in each LGA from July 2021 (median time point month over the 22-month period) divided by the total population in the LGA from 2021 census data by 10 000 (95% CI of numbers counted).
LGA, local government area.

Table 3 Mean percentages of patients with T2D with an HbA1c result recorded

Patients	Total health districts	LGA 1	LGA 2	LGA 3	LGA 4
Total	74.4 (74.0, 74.8)	81.2 (80.8, 81.5)	76.5 (76.1, 77.0)	83.7 (83.1, 84.2)	71.2 (70.7, 71.6)
Sex					
Male	75.7 (74.2, 76.1)	83.1 (82.7, 83.5)	77.3 (76.6, 77.9)	86.0 (85.5, 86.4)	72.3 (71.8, 73.7)
Female	73.1 (72.7, 73.5)	79.2 (78.8, 79.5)	5.9 (75.6, 76.2)	80.5 (79.6, 81.4)	70.1 (69.6, 81.4)
BMI					
BMI≥30	79.5 (79.1, 79.9)	84.5 (84.2, 84.8)	80.2 (79.8, 80.5)	84.9 (84.3, 85.6)	77.4 (76.9, 77.8)
BMI<30	69.9 (69.5, 70.3)	78.3 (77.7, 78.8)	73.0 (72.5, 73.6)	82.2 (81.5, 82.9)	65.9 (65.5, 66.3)
Age (years)					
18–54	68.6 (68.3, 69.0)	76.2 (75.7, 76.6)	74.4 (73.7, 76.4)	70.9 (69.5, 72.3)	66.2 (65.9, 66.5)
55–74	76.2 (75.7, 76.6)	83.5 (83.1, 83.9)	77.4 (77.2, 77.7)	85.1 (84.5, 85.7)	73.4 (72.8, 73.9)
75+	75.7 (75.3, 76.2)	79.8 (79.3, 80.2)	76.5 (75.8, 77.2)	86.6 (85.6, 87.6)	71.5 (71.1, 72.0)

Mean percentages of active patients with type 2 diabetes mellitus with an HbA1c test result in their general practice record from September 2020 to June 2022. Data are percentage of eligible patients (95% CI).
BMI, body mass index; LGA, local government area; T2D, type 2 diabetes.

achieving target HbA1c compared with male sex (55.5%, 95% CI 55.1%, 55.8%) and BMI≥30 groups (56.5%, 95% CI 56.0%, 56.9%), respectively. The 75 years and over age group (63.6%, 95% CI 63.3%, 65.0%) showed a notably higher percentage for achieving target HbA1c compared with the 18–54 years (51.4%, 95% CI 50.8%, 51.9%) and 55–74 years age groups (56.3%, 95% CI 55.9%, 56.8%).

These patterns were consistent across all LGAs except for LGA 2 which had similar percentages for achieving target HbA1c for the BMI≥30 groups (63.1%, 95% CI 62.5%, 63.8%) compared with the BMI<30 groups (62.9%, 95% CI 62.5%, 63.4%). The same percentage for target HbA1c was observed for the BMI≥30 groups (54.2%, 95% CI 53.5%, 54.8%) compared with the BMI<30 groups (54.2%, 95% CI 53.8%, 54.6%) in LGA 4.

Further, similar percentages for target HbA1c were observed for the 55–74 years age group (62.3%, 95% CI 61.6%, 62.9%) compared with the 75 years and over age group (64.6%, 95% CI 64.3%, 69.2%) in LGA 2.

Time trends

The longitudinal change in the percentage of patients with HbA1c tests in the past 15 months for each subgroup is presented in figure 1. The period with COVID-19 social distancing restrictions and lockdowns is identified between the vertical dotted lines in December 2020 and October 2021. Overall, the percentage with HbA1c tests was relatively stable during the lockdown period and showed a slightly decreasing trend from approximately 75% to 73% after the lockdown period (figure 1A).

Table 4 Mean percentages of patients with T2D achieving target HbA1c levels

Patients	Total health districts	LGA 1	LGA 2	LGA 3	LGA 4
Total	57.1 (56.7, 57.4)	58.2 (57.7, 58.6)	63.0 (62.5, 63.6)	61.4 (60.5, 62.4)	54.2 (53.7, 54.7)
Sex					
Male	55.5 (55.1, 55.8)	58.4 (57.7, 59.2)	60.3 (59.6, 61.1)	60.2 (59.3, 61.1)	52.3 (51.8, 52.9)
Female	59.2 (58.8, 59.6)	58.0 (57.6, 58.3)	66.7 (66.2, 67.3)	63.5 (62.3, 64.7	56.5 (56.1, 57.0)
BMI					
BMI≥30	56.5 (56.0, 56.9)	55.5 (55.1, 55.9)	63.1 (62.5, 63.8)	58.0 (57.1, 58.8)	54.2 (53.5, 54.8)
BMI<30	57.7 (57.3, 58.0)	60.6 (60.0, 61.2)	62.9 (62.5, 63.4)	65.6 (64.4, 66.8)	54.2 (53.8, 54.6)
Age (years)					
18–54	51.4 (50.8, 51.9)	56.9 (55.2, 58.6)	63.4 (62.4, 64.3)	46.8 (45.5, 48.0)	47.6 (46.8, 48.5)
55–74	56.3 (55.9, 56.8)	55.7 (55.2, 56.1)	62.3 (61.6, 62.9)	60.4 (59.4, 61.5)	54.1 (53.6, 54.6)
75+	63.6 (63.3, 65.0)	62.8 (62.2, 63.4)	64.6 (64.3, 65.0)	67.8 (66.3, 69.2)	62.7 (62.4, 62.9)

Mean percentages of active patients with type 2 diabetes mellitus who achieved the target level for HbA1c from September 2020 to June 2022. Data are percentage of eligible patients (95% CI). Target level for HbA1c ≤7%.
BMI, body mass index; LGA, local government area; T2D, type 2 diabetes.

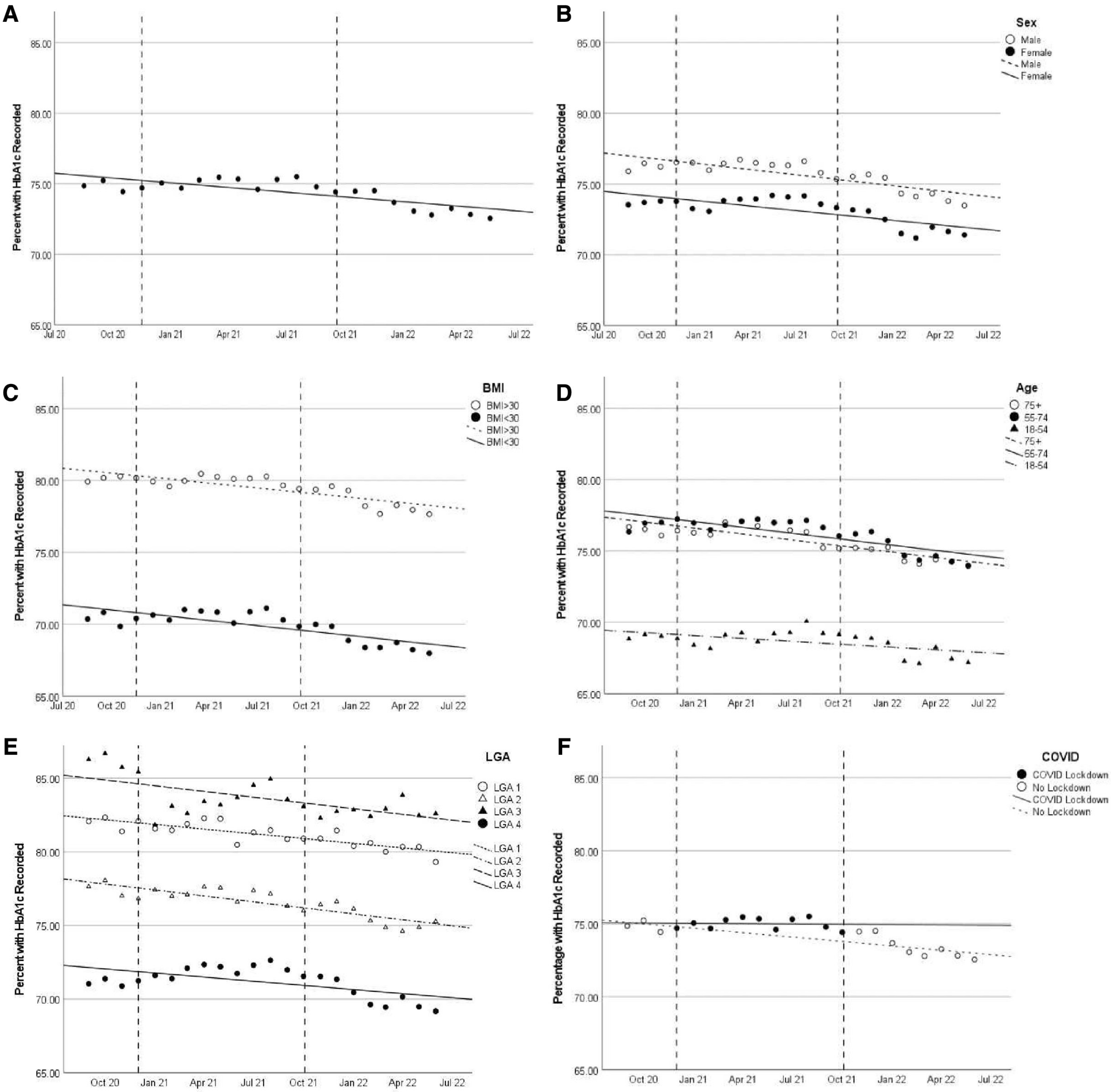

Figure 1 Percentage of patients with type 2 diabetes (T2D) with an HbA1c test result recorded by month. Percentage of active patients with T2D with an HbA1c test result in their general practice record from September 2020 to June 2022 (dotted vertical lines; December 2020 and October 2021, denoting Greater Sydney COVID-19 lockdown). (A) All patients, (B) by sex (male and female), (C) by BMI status (BMI<30 and BMI≥30), (D) by age groups (18–54 years, 55–74 years and 75 years and over), (E) by LGA and (F) by COVID-19 lockdown restrictions (COVID-19 lockdown and no COVID-19 lockdown). BMI, body mass index; LGA, local government area.

Percentages of patients with an HbA1c test result in the past 15 months were consistently higher for male sex than female sex groups (figure 1B) and for BMI≥30 compared with BMI<30 groups over the COVID-19 pandemic period (figure 1C). The 55–74 years age group had a higher percentage of test results recorded in the past 15 months than the 75 years and over age group (figure 1D). Both 55–74 years and 75 years and over age groups were consistently higher than the 18–54 years age group (figure 1D). Percentages were consistently higher for patients in LGAs 1 and 3 compared with LGAs 2 and 4 (figure 1E). Percentages of test results in LGA 2 were also consistently higher than in LGA 4 (figure 1E). The percentage of patients with HbA1c results recorded remained consistent during the COVID-19 lockdown

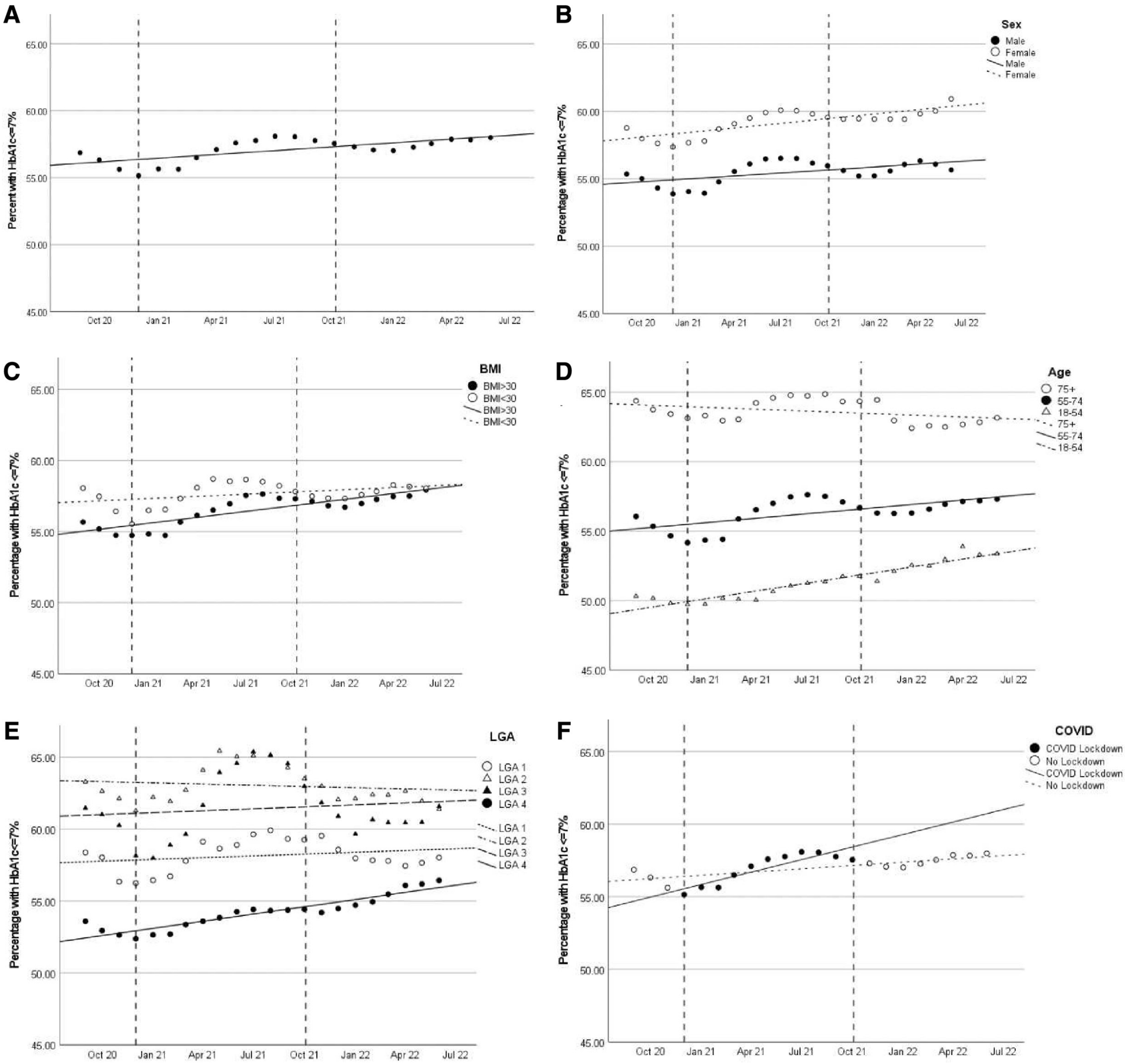

Figure 2 Percentage of patients with type 2 diabetes (T2D) who achieved target HbA1c levels by month. Percentage of active patients with T2D who achieved the target level for HbA1c from September 2020 to June 2022 (dotted vertical lines; December 2020 and October 2021, denoting Greater Sydney COVID-19 lockdown). (A) All patients, (B) by sex (male and female), (C) by BMI status (BMI<30 and BMI≥30), (D) by age group (18–54 years, 55–74 years and 75 years and over), (E) by LGA and (F) by COVID-19 lockdown restrictions (COVID-19 lockdown and no COVID-19 lockdown). BMI, body mass index; LGA, local government area.

period. However, these percentages notably decreased after the lockdown period (figure 1F).

Trends in study participants achieving target levels for HbA1c over the course of the study period are presented (figure 2). Mean percentages for achieving target HbA1c fell until the beginning of lockdown and increased steadily throughout the lockdown period. It remained relatively stable thereafter (figure 2A).

Percentages for achieving target HbA1c were consistently higher for female sex than male sex groups (figure 2B). Percentages were also notably higher for the BMI<30 groups compared with the BMI≥30 groups at the beginning of the data capture period but converged towards the end of the period (figure 2C). Percentages were consistently higher for the 75 years and over age group compared with the 55–74 and 18–54 years age groups during the data capture period (figure 2D). The 55–74 years age group also had consistently higher percentages for target HbA1c than the 18–54 years age group. The 75 years and over age group showed a

Table 5 Beta coefficients for mean percentages of patients with T2D with an HbA1c result recorded

	Beta coefficient	P value
Model 1*		
Sex		
Female	Reference	
Male	2.5 (1.7, 3.4)	<0.001
Model 2*		
Obesity		
BMI<30	Reference	
BMI≥30	9.6 (8.8, 10.4)	<0.001
Model 3*		
Age (years)		
18–54	Reference	
55–74	7.5 (6.6, 8.5)	<0.001
75+	7.1 (6.2, 7.9)	<0.001
Model 4*		
General practice density (for each additional general practice per 10 000 persons)	8.4 (4.9, 11.8)	<0.001
Model 5*		
COVID-19		
No lockdown	Reference	
COVID-19 lockdown	0.8 (0.3, 1.3)	0.003

Beta coefficients for mean percentages of active patients with T2D in their general practice record from September 2020 to June 2022. Data are beta coefficient (95% CI) for mean percentage of patients with an HbA1c test result in the past 15 months (see table 3) after correction for any linear changes over time.
*Corrected for time trend.
BMI, body mass index; T2D, type 2 diabetes.

Table 6 Beta coefficients for mean percentages of patients with T2D who achieved target HbA1c levels

	Beta coefficient	P value
Model 1*		
Sex		
Female	Reference	
Male	−3.7 (−5.2, −2.2)	<0.001
Model 2*		
Obesity		
BMI<30	Reference	
BMI≥30	−1.2 (−3.8, 1.4)	0.19
Model 3*		
Age (years)		
18–54	Reference	
55–74	4.5 (3.8, 5.1)	<0.001
75+	12.2 (4.5, 20.0)	<0.001
Model 4*		
General practice density (for each additional general practice per 10 000 persons)	3.1 (−3.8, 10.0)	0.19
Model 5*		
COVID-19		
No lockdown	Reference	
COVID-19 lockdown	0.4 (−1.0, 1.7)	0.30

Beta coefficients for mean percentages of active patients with T2D who achieved the target level for HbA1c from September 2020 to June 2022. Data are beta coefficient (95% CI) for mean percentage of patients who achieved target level for HbA1c (see table 4) after correction for any linear changes over time.
*Corrected for time trend.
BMI, body mass index; T2D, type 2 diabetes.

downward trend for achieving target HbA1c (figure 2D). Percentages for target HbA1c were consistently higher for LGAs 1, 2 and 3 than for LGA 4 during the data capture period (figure 2E). Trends for LGAs 2 and 4 converged towards the end of the data capture period (figure 2E). Percentages of patients with a target for HbA1c increased during the COVID-19 lockdown period (figure 2F).

Regression analyses

Assumption testing by analysis of residuals (online supplemental appendix 2) revealed month-to-month correlations in the residuals from most models, resulting in the use of Newey-West estimates of the SEs.

Regression coefficients, adjusted for linear trend over time, for patients with an HbA1c test result recorded in their general practice record are presented in table 5. These models confirmed male sex (2.5%, 95% CI 1.7%, 3.4%) and BMI≥30 groups (9.6%, 95% CI 8.8%, 10.4%) were more likely to have a test result recorded in their general practice record within the previous 15 months than their counterparts. The 55–74 years (7.5%, 95% CI 6.6%, 8.5%) and 75 years and over age groups (7.1%, 95% CI 6.2%, 7.9%) were also more likely to have a result recorded compared with the 18–54 years age group. The percentage of patients with an HbA1c test result recorded was, on average, 8.4% (95% CI 4.9%, 11.8%) higher for each additional general practice per 10 000 persons. The percentage of patients with an HbA1c test result recorded was 0.8% (95% CI 0.3%, 1.3%) higher on average during the Greater Sydney COVID-19 lockdown between December 2020 and October 2021 than during months with less severe restrictions.

Males (−3.7%, 95% CI −5.2%, −2.2%) were less likely to have a blood test result consistent with target HbA1c compared with females (table 6). The 55–74 years (4.5%, 95% CI 3.8%, 5.1%) and 75 years and over age groups (12.2%, 95% CI 4.5%, 20.0%) were more likely to have achieved target for HbA1c when compared with the 18–54 years age group. The percentage of patients with a target HbA1c test result was on average 3.1% (95% CI

3.8%, 10.0%) higher for each additional general practice per 10 000 persons, although this did not reach statistical significance. There was no statistically significant evidence of difference in the percentage of those who have a test result in target for HbA1c for BMI≥30 groups (−1.2%, 95% CI −3.8%, 1.4%) compared with BMI<30 groups or during months of COVID-19 lockdown (0.4%, 95% CI −1.0%, 1.7%) than during months with less severe COVID-19 restrictions.

DISCUSSION

This is the first study on the impact of COVID-19 on testing guidelines and target glycaemic control rates for patients with T2D and among higher risk populations in Australian general practice settings. We found that men, older adults and people with obesity were more likely to comply with guidelines for glycaemic testing than their counterparts. This difference was statistically significant and remained consistent over the study period, but with a decreasing trend since the start of the pandemic. These findings are consistent with the fact that T2D is more common in men, older adults and people with obesity in Australia and other high-income countries.[25 26] People with a chronic disease are more likely to use general practice services than people without a chronic disease.[27] Rates of compliance to glycaemic testing guidelines increased with general practice density, potentially reflecting better access than areas with less general practice density per population size. Studies have consistently shown that longer consultations and easier access to general practitioners are associated with higher general practice density.[28] Contrary to our expectations and findings from studies worldwide,[29] compliance to glycaemic testing guidelines was significantly higher during COVID-19 restrictions than after restrictions were lifted in Australia. This finding could have been partly explained by federal government policies which enabled the rapid expansion of telehealth services during COVID-19 restrictions.[6] Although knowledge may be incomplete, recent research suggests that after these restrictions were lifted and access to telehealth was reduced,[30] patients might have avoided seeing their general practitioner for a range of reasons including socioeconomic disadvantage, symptoms of depression and anxiety and COVID-related concerns.[31] Studies suggest that older age and female sex are determinants of general practice avoidance.[31] Similarly, other countries reported that the pandemic drove rapid changes in their health systems, where most general practice and nurse consultations were done remotely.[32–35] Despite the decreasing trend since the start of the study period, our findings indicate that the pandemic and associated restrictions likely had a minimal negative impact on compliance to glycaemic testing guidelines in Australia, especially among higher risk population groups and areas with high general practice density most likely due to the expansion of telehealth services.

We found that men were significantly less likely to achieve target glycaemic control (defined using an HbA1c of ≤7%) than women. This trend was consistent with the overall increase in glucose control rates over the study period, regardless of any restrictions. These findings are consistent with other studies that have found that higher risk patients, such as men, tend to have poorer glucose control.[35 36] The reasons for this difference are not fully understood, but may include differences in metabolic regulation and diabetes susceptibility,[37] obesity rates[38] and access to general practitioners.[27]

We found that older patients (those aged 55 years and older) were more likely to have achieved target glucose control than younger patients (those aged 18–54 years). Younger patients with T2D have consistently been shown to have poorer glycaemic control than older patients.[39 40] This phenomenon might be partly explained by case detection bias, which occurs when the likelihood of being diagnosed with a condition is influenced by factors other than the actual risk of having the condition. In this case, the age-related differences in guideline recommendations for routine screening might lead to younger patients with T2D being less likely to be diagnosed and treated than older patients.[20 41] Alternatively, some experts believe that T2D in older adults is caused by a decline in beta cell function, which leads to impaired insulin secretion. In younger adults, obesity is thought to be the main cause of T2D, which can lead to more severe disease and insulin resistance than in people who are at a healthy weight.[41]

Although the prevalence of T2D is highest among patients with obesity,[42] target glucose control rates were not statistically different compared with patients without obesity. There was insufficient evidence to conclude that rates of achieving target glucose control changed with general practice density, although the beta coefficient was positive. Uninterrupted access to general practice care, potentially associated with general practice density, has been shown to improve the management of T2D and glucose monitoring. These findings suggest that glucose control rates improved slightly during the pandemic among all subgroups of patients with T2D. This is consistent with other studies conducted during this period.[43] Despite the decreasing trend in compliance rates with glycaemic testing guidelines, there was an interesting trend towards improved glucose control. This trend was unrelated to any COVID-19 restrictions.

This study has several limitations. First, we used aggregate data, which limited the statistical analyses we could perform. Second, we were unable to identify individual-level patient records, which means that the data set may have included duplicate records for 'active patients' at more than one general practice. However, the risk of bias from this source is likely very small. Older Australians rarely attend multiple general practices,[44] so it is unlikely that there would be many duplicate records in the data set. Additionally, the study authors took steps to minimise the risk of bias by using a variety of methods, such as excluding patients with incomplete data. Third, as is common in time series, there was some evidence that the independence assumption of linear regression models was violated (particularly for the HbA1c ≤7% outcome) because high values of residuals tend to be surrounded by other high values and low values tend to be surrounded by other low values. This is understandable given that patient records pertained to mostly the same patients each month, therefore, records across the whole study period for patients with more frequently completed HbA1c testing records might have been duplicated. The Newey-West estimator is asymptomatically accurate and usually recommended for sample sizes of 50 or more. Fourth, although we used the small sample adjustment method, the findings of this study should be confirmed against a purpose-designed study with individual-level data in the future. As the COVID-19 pandemic appears to have varied over time, we acknowledge these more accurate methods are probably unavailable for future research. Fifth, it is important to note that individual patients may have different target blood sugar levels, depending on their individual health status.[45] Finally, our findings are only applicable to the study time from September 2020 and cannot be extended to the beginning of the COVID-19 pandemic in 2019. The main strength of this study is that the population sample from general practices (range: 88–100) within the NBM region is likely representative of 4% of all T2D cases in the region. This estimate is similar to the reported prevalence of T2D in the Australian population (5.3%).[25]

CONCLUSION

The COVID-19 pandemic and associated restrictions had a minimal negative impact on compliance to glucose testing guidelines in Australia, even among higher risk population groups. This was likely due to the rapid expansion of telehealth services, which improved access to general practice. Although compliance rates decreased slightly, glycaemic control rates showed slightly positive trends during the pandemic among all subgroups of patients with T2D. These findings are encouraging, but more research is needed to understand the longer term impact of COVID-19 on T2D care.[8 46]

Contributors KJB accepts full responsibility for the overall content as the guarantor. KJB analysed and interpreted the data. KJB wrote the manuscript with support from student supervisors, PPF and EA. All authors read and approved the final manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Western Sydney University Human Research Ethics Committee (approval number: H14936) on 21 June 2022. General practices in the region have signed a data sharing agreement that allows patient record data to be used for ethics approved research. The data sharing agreement is according to the Privacy Act 1988 (Cth), My Health Records Act 2012 (Cth) and applicable federal, state and territory legislation and regulations in respect to the collection, storage, use and transfer of personal information and health information. A waiver of consent was sought and approved during ethics approval.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data that support the findings of this study are available from Wentworth Health (provider of the Nepean Blue Mountains Primary Health Network), but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission of Wentworth Health.

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