Disparities in adherence to diabetes screening guidelines among males and females in a universal care setting: A population-based study of 1,380,697 adults

Padma Kaul,[a,b,c*] Luan Manh Chu,[d] Douglas C. Dover,[a] Roseanne O. Yeung,[b] Dean T. Eurich,[c] and Sonia Butalia [e,f,g,h]

[a]Canadian VIGOUR Centre, University of Alberta, Edmonton, Alberta, Canada
[b]Department of Medicine, Faculty of Medicine & Dentistry, University of Alberta, Edmonton, Alberta, Canada
[c]School of Public Health, University of Alberta, Edmonton, Alberta, Canada
[d]Alberta SPOR Support Unit, Alberta Health Services, Canada
[e]Division of Endocrinology and Metabolism, Department of Medicine, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
[f]Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
[g]O'Brien Institute for Public Health, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada
[h]Libin Cardiovascular Institute, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada

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Summary

Background National guidelines recommend that all adults over the age of 40 years undergo screening for diabetes at least once every 3-years. We examined the adherence to these guidelines among males and females after accounting for age, urban/rural residence, and material deprivation. We also examined the incidence of prediabetes and diabetes in adherent and non-adherent individuals.

Methods Our study is based on a retrospective population-level inception cohort of adults aged 40–79 years without pre-existing diabetes or cardiovascular disease on April 1, 2013. Adherence during a 3-year screening period (2013–2016) and prediabetes and diabetes during a 4-year follow-up period were examined. Multivariate logistic regression was used to examine the adjusted association between sex and adherence.

Findings Among 1,380,697 individuals (49·2% male, 50·8% female) adherence rates were 69·9% in males and 79·8% in females. Sex-differences in adherence were largest in younger individuals (58·0% and 72·6% and in males and females aged 40–44 years, respectively) and consistent across rural/urban residence and material deprivation. Females were more adherent (adjusted odds ratio 1·92; 95% confidence interval 1·89 to 1·95) than males. Prediabetes and diabetes rates among individuals who adhered to screening guidelines were 15·7% and 2·6% among males and 13·4% and 1·5% among females. During the follow-up period, an additional 3·2% and 1·9% of adherent males and females had diabetes. Incidence rates of prediabetes and diabetes during the follow-up period among individuals who did not adhere to screening guidelines were 8·8% and 2·1% among males and 7·3% and 1·3% among females.

Interpretation Adherence to diabetes screening guidelines is sub-optimal, especially among young males. Despite lower rates of adherence to screening, males have higher rates of prediabetes and diabetes compared to females. There is a need for education campaigns to improve diabetes screening rates in young adults, especially males.

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Keywords: Diabetes; Pre-diabetes; Screening; Adherence

*Corresponding author at: Professor of Medicine, University of Alberta, 4-120 Katz Group Centre for Pharmacy and Health Research, Edmonton, Alberta T6G2E1, Canada.
E-mail address: pkaul@ualberta.ca (P. Kaul).

Research in context

Evidence before this study

Early detection and treatment of diabetes is crucial to prevent adverse outcomes such as cardiovascular disease (CVD) and death. North American guidelines recommend that all adults ≥40 years undergo screening for diabetes at least once every 3 years. There are currently limited population-level data on adherence to these guidelines and whether they differ among males and females. Suboptimal screening rates may reveal missed opportunities for early detection and have a direct impact on the assessment of the true burden of diabetes in specific segments of the population.

Added value of this study

We used a large population-based inception cohort with universal health insurance to examine adherence to diabetes screening guidelines among males and females during a 3-year screening period. Females were almost twice as likely to be adherent to guidelines than males. Young males had the lowest rates of adherence. Sex differences in adherence were maintained even after accounting for age, urban/rural residence, and material deprivation. Incidence of prediabetes and diabetes was higher in males than females. During a 4-year follow-up phase, individuals who were adherent had higher rates of prediabetes and diabetes than individuals who were non-adherent to screening guidelines.

Implications of all the available evidence

Adherence to diabetes screening guidelines is sub-optimal, especially among young males. Despite lower rates of screening, males have higher rates of prediabetes and diabetes compared to females. Our study highlights the need to develop education campaigns and targeted interventions at the local and population level to raise awareness and improve diabetes screening rates in young adults, especially males.

Introduction

It is estimated that almost half of adults living with diabetes remain undiagnosed.[1] Early detection and treatment is crucial as diabetes has been shown to be associated with a two-fold increase in the risk of developing cardiovascular disease (CVD).[2] The excess risk of CVD associated with diabetes appears to be even higher in females and in younger individuals.[3,4] In addition to being a preclinical phase of diabetes, prediabetes has been shown to be associated with a higher risk of CVD, renal disease, and mortality.[5,6] Clinical trials have demonstrated the efficacy of lifestyle interventions in individuals with prediabetes on the incidence of diabetes in the long-term.[6]

National guidelines in Canada recommend that, in the absence of risk factors, all adults ≥40 years undergo screening for diabetes at least once every 3 years.[7] These guidelines are similar to those of the American Diabetes Association which recommend universal screening at least once every 3 years for adults ≥35 years with no known risk factors, and the American Association of Clinical Endocrinology which recommends universal screening at least once every 3-years for adults ≥45 years of age.[8,9] There are currently limited population-level data on adherence to these guidelines and whether differences exist among males and females. Suboptimal screening rates may reveal missed opportunities for early detection and have a direct impact on the assessment of the true burden of diabetes in specific segments of the population.

The objective of our study was to examine the association between sex and adherence to diabetes screening after accounting for age, urban/rural residence and material deprivation. We also examined the subsequent incidence of prediabetes and diabetes in males and females who were adherent and non-adherent to screening guidelines.

Methods

Study design and setting

The **R**eal-world **E**vidence on the association between **DI**abetes and **S**ex on **C**ardi**OV**ascular **E**vent **R**ates (REDISCOVER) Study is designed to gather population-level data on sex differences in the screening, treatment, and cardiovascular outcomes associated with diabetes.[10] As part of the study, a retrospective, population-based inception cohort of ~4 million people residing in the province of Alberta, Canada has been created. Canada has universal healthcare insurance and residents are covered for premium-free laboratory, physician, and hospital services by the Alberta Health Care Insurance Plan (AHCIP). Alberta residents are assigned a unique patient healthcare number which allows for data capture and linkage of hospitalizations, emergency department visits, ambulatory clinic visits, physician billing claims, pharmaceutical claims, and centralized laboratory data, as well as to vital statistics death registry and to census data at the neighbourhood level.

Study time period

The study time period was from April 1, 2013 to March 31, 2020, which included a 3-year screening period (April 1, 2013 to March 31, 2016) and a 4-year follow-up period (from April 1, 2016 to March 31, 2020).

Study population

Individuals were included in the study if they were residents of Alberta aged between 40 and 79 years on April 1, 2013 and had a valid primary health number. Individuals were excluded if they had diabetes prior to the

study inception date. An expanded version of the algorithm used by the National Diabetes Surveillance System (NDSS) was used to identify individuals with diabetes as those with any of the following in the three years before the study inception date: a hospitalization, ambulatory clinic, or emergency department record with an International Classification of Disease version 10 (ICD-10) code for diabetes in any diagnosis field; or at least two physician claims within 1-year with an ICD-9 code for diabetes (Supplementary Table S1).[11] In addition, individuals with one or more pharmaceutical dispensations for an anti-hyperglycaemic agent or insulin in the previous three years, or with a laboratory test consistent with a Diabetes Canada diagnosis of diabetes in the year before were considered to have pre-existing diabetes and were excluded.[12] The primary outcome of interest of the REDISCOVER Study is the long-term development of cardiovascular disease (CVD), therefore individuals with pre-existing CVD defined as a hospitalization, ambulatory clinic, emergency department, or two physician claims within 1-year with an ICD-9 or ICD-10 code for CVD (Supplementary Table S1) in the previous three years were excluded. Finally, individuals who died or moved out of the province during the screening period or the follow-up period were excluded.

Definition of adherence, prediabetes, and diabetes

Diabetes Canada guidelines recommend that adults ≥40 years of age in the absence of diabetes risk factors or diabetes symptoms undergo diabetes screening once every three years using either a fasting plasma glucose (FPG) or a Haemoglobin A1C (HbA1c); although a 75g oral glucose tolerance test (75g-OGTT) can be used when diabetes or prediabetes is suspected.[7] For our study, we considered any individual who had at least one glucose test (FPG, HbA1c, OGTT, or RPG) during the 3-year screening period to be adherent.

We identified individuals with prediabetes as those with any one of the following: FPG of 6·1 to 6·9 mmol/L; 2-h PG on a 75-OGTT ≥7·8 to 11·0 mmol/L; or an HbA1c of 6·0% to 6·4%. We identified individuals with diabetes as those with ≥2 abnormal laboratory tests (FPG ≥7·0 mmol/L, HbA1c ≥6·5%, 2-h PG on a 75-OGTT ≥11·1 mmol/L, or a random plasma glucose (RPG) ≥11·1 mmol/L).[12] In the presence of symptoms, a single abnormal test is considered diagnostic of diabetes. Accordingly, we also examined the proportion of males and females with one laboratory test consistent with diabetes during the screening and follow-up period.

Definition of geography, material deprivation, comorbidity burden, and primary care visits

Rural-urban residence was determined using the second character of the postal code in which the individual resides. This methodology is consistent with that employed by Statistics Canada and previous studies.[13] The material deprivation component of the Pampalon Index was used to categorise individuals into quintiles (1st quintile being least deprived and 5th quintile being most deprived) based on education, employment, and income at the neighbourhood level.[14] A modified Charlson Comorbidity Index (CCI), a measure of comorbidity burden, was calculated based on both primary and secondary diagnoses from hospitalization or outpatient records in the three years prior to study inception.[15] The CCI was modified because individuals with diabetes and CVD were excluded from the study population. The screening and diagnosis of diabetes occurs principally in the primary care setting. Accordingly, we examined the number of visits that an individual had to his/her family physician or general practitioner during the screening period.

Statistical analysis

Data are summarized as means (± standard deviation (SD)) and as medians with interquartile ranges (IQR) for continuous variables and as percentages for categorical variables. Males and females were categorized into 5-year age groups based on their age on April 1, 2013. The proportion of males and females who were adherent was calculated with additional analyses stratified by age category, urban/rural residence, and material deprivation. Baseline characteristics of individuals were examined according to both sex and adherence status (adherent and non-adherent). Formal statistical tests of significance were not applied to descriptive statistics given that the data were at the population-level. Multivariate logistic regression was used to examine the association, presented as adjusted odds ratios (aOR) and 95% confidence intervals (CI), between sex and adherence to diabetes screening after adjusting for age category, urban/rural residence, and material deprivation. The model included both main effects and an interaction term for sex*age. The number of physician visits and presence of comorbidities may mediate or moderate the effect of sex and adherence. Accordingly, we conducted sensitivity analyses in which we stratified individuals according to tertiles of primary care visits and the presence of comorbidities and examined the adjusted odds of females versus males undergoing screening within each strata by age category.

Rates of prediabetes and diabetes during the screening and follow-up period were calculated for individuals who had adhered to guidelines. Incident rates during the follow-up period among these individuals were calculated after excluding those who had diabetes (≥2 abnormal laboratory tests) during the screening period. For individuals who were non adherent, i.e., had not undergone any glucose testing during the screening

period, we examined rates of prediabetes and diabetes among those who were screened for the first time during the follow-up period.

All statistical analyses were performed using SAS version 9·4 (SAS Institute Inc., Cary, NC, USA). Statistical significance was set at a *P*-value of 0·05 and all statistical tests were 2-sided. Our study has been reported according to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines.[16]

Ethics

Ethics approval for the study was received from the Institutional Review Board of the University of Alberta (Pro00100060). The ethics panel determined that the research is a retrospective database review for which subject consent for access to personally identifiable health information would not be reasonable, feasible, or practical.

Role of the funding source

Funding received as part of Dr. Kaul's Canadian Institutes of Health Research (CIHR) Sex and Gender Science Chair was used for the study. Dr. Kaul holds a Heart & Stroke Foundation Chair in Cardiovascular Research. Neither agency had any involvement in the design, collection, analysis, or interpretation of the study.

Results

On April 1 2013, there were 4,068,062 residents with active health care coverage in the province of Alberta, Canada. Among these, 1,380,697 individuals met the study's inclusion/exclusion criteria, of whom 679,501 (49·2%) were male and 701,196 (50·8%) were female (Supplementary Figure S1).

Overall females were slightly older, and the proportion of females in older age categories (>65 years) was higher than in males (Table 1). Rural residence, material

	All individuals		Males		Females	
Description	**Males**	**Females**	**Adherent**	**Non-adherent**	**Adherent**	**Non-adherent**
N	679,501	701,196	475,187	204,314	559,344	141,852
Age, in years, Mean (SD)	53·5 (9·4)	54·3 (9·8)	54·6 (9·6)	50·7 (8·4)	54·8 (9·9)	52·0 (9·2)
Age, in years, Median (IQR)	52·0 (46·0, 60·0)	53·0 (46·0, 61·0)	54·0 (47·0, 61·0)	49·0 (44·0, 56·0)	54·0 (47·0, 62·0)	50·0 (44·0, 58·0)
Age groups, in years (*n*,%)						
40-44	137,264 (20·2)	131,154 (18·7)	79,558 (16·7)	57,706 (28·2)	95,229 (17·0)	35,925 (25·3)
45-49	131,124 (19·3)	128,806 (18·4)	83,880 (17·7)	47,244 (23·1)	99,048 (17·7)	29,758 (21·0)
50-54	131,297 (19·3)	132,289 (18·9)	90,837 (19·1)	40,460 (19·8)	105,327 (18·8)	26,962 (19·0)
55-59	108,939 (16·0)	110,313 (15·7)	81,141 (17·1)	27,798 (13·6)	89,672 (16·0)	20,641 (14·6)
60-64	73,900 (10·9)	79,081 (11·3)	58,396 (12·3)	15,504 (7·6)	66,159 (11·8)	12,922 (9·1)
65-69	48,503 (7·1)	56,465 (8·1)	40,176 (8·5)	8327 (4·1)	48,695 (8·7)	7770 (5·5)
70-74	29,535 (4·3)	36,903 (5·3)	25,132 (5·3)	4403 (2·2)	32,332 (5·8)	4571 (3·2)
75-79	18,939 (2·8)	26,185 (3·7)	16,067 (3·4)	2872 (1·4)	22,882 (4·1)	3303 (2·3)
Rural residence (*n*,%)	105,659 (15·5)	106,747 (15·2)	74,943 (15·8)	30,716 (15·0)	84,980 (15·2)	21,767 (15·3)
Pampalon material deprivation index category (*n*,%)						
1 (Least deprived category)	123,428 (18·2)	127,767 (18·2)	84,740 (17·8)	38,688 (18·9)	100,159 (17·9)	27,608 (19·5)
First intermediate deprivation	115,353 (17·0)	122,919 (17·5)	81,968 (17·2)	33,385 (16·3)	98,466 (17·6)	24,453 (17·2)
Second intermediate deprivation	125,064 (18·4)	131,455 (18·7)	88,168 (18·6)	36,896 (18·1)	105,372 (18·8)	26,083 (18·4)
Third intermediate deprivation	142,413 (21·0)	148,033 (21·1)	100,716 (21·2)	41,697 (20·4)	118,969 (21·3)	29,064 (20·5)
5 (Most deprived category)	141,641 (20·8)	140,590 (20·1)	98,272 (20·7)	43,369 (21·2)	112,310 (20·1)	28,280 (19·9)
Unknown	31,602 (4·7)	30,432 (4·3)	21,323 (4·5)	10,279 (5·0)	24,068 (4·3)	6364 (4·5)
Charlson comorbidity index score, (*n*,%)						
0	551,716 (81·2)	569,769 (81·3)	357,681 (75·3)	194,035 (95·0)	437,079 (78·1)	132,690 (93·5)
≥1	127,785 (18·8)	131,427 (18·8)	117,506 (24·7)	10,279 (5·0)	122,265 (21·9)	9162 (6·5)
Physician visits, mean, SD	10·2 (12·2)	14·0 (14·1)	13·1 (12·8)	3·5 (7·3)	16·3 (14·2)	5·3 (9·8)
Physician visits, median, IQR	7·0 (3·0, 14·0)	11·0 (5·0, 18·0)	10·0 (6·0, 16·0)	1·0 (0·0, 4·0)	13·0 (8·0, 20·0)	2·0 (0·0, 7·0)
Type of glucose testing						
HbA1c, *n* (%)			310,203 (65·3)	-	362,610 (64·8)	-
Fasting glucose, *n* (%)			391,410 (82·3)	-	460,494 (82·3)	-

***Table 1*: Baseline characteristics of study population by sex and adherence to diabetes screening guidelines.**

deprivation, and comorbidity burden were similar in males and females. Females had a higher number of physician visits (median 11·0, IQR 5·0–18·0) than males (median 7·0, IQR 3·0–14·0). Males and females who adhered to diabetes screening guidelines were 475,187 (69·9%) and 559,344 (79·8%), respectively. Males who were adherent were older, had lower levels of material deprivation, and higher comorbidity burden than non-adherent males. Adherent males had a median number of 10·0 primary care physician visits (IQR 6·0–16·0) during the screening period compared to 1·0 visit (IQR 0·0–4·0) among non-adherent males. Adherent females were also older and had higher comorbidity burden than non-adherent females. The median number of primary care physician visits among adherent females was 13·0 (IQR 8·0–20·0) compared to 2·0 (IQR 0·0–7·0) among those who were non-adherent. Among adherent individuals, 310,203 (65·3%) males and 362,610 (64·8%) females had at least one HbA1c; and 391,410 (82.3%) males and 460,494 (82.3%) females had at least one FPG test during the screening period.

Sex-differences in adherence were larger in younger individuals aged 40–44 years than in older individuals aged 75–79 years (Figure 1). The higher rates of adherence in females were consistent in individuals living in urban and rural areas and across all levels of material deprivation.

In multivariate analyses, females had a significantly higher likelihood of being adherent (main effect aOR 1·92, 95% CI 1·89–1·95) than males (Table 2). Older individuals were more likely to be adherent, while rural compared to urban residence was associated with a lower likelihood of adherence. Individuals living in neighbourhoods with lower levels of material deprivation had higher likelihood of adherence relative to individuals living in the least deprived neighbourhoods. However, individuals for whom material deprivation was unknown had a lower likelihood of adherence. The interaction between sex and age was significant in the model. When stratified by age categories, the aOR of adherence among females compared to males in the age category 40–45 years was 1·93, 95% CI 1·90–1·97. While females continued to have a higher likelihood of adherence relative to males in older categories, the sex-difference was attenuated (adjusted OR 1·36, 95% CI 1·29–1·44, Supplementary Figure S2). The number of visits that an individual made to primary care physicians mediated the association between sex and adherence to screening guidelines. When individuals were grouped into tertiles based on their number of primary care physician visits during the screening period as follows: <6 visits, 6–13 visits, and >13 visits, females had a higher likelihood of adherence relative to males in all three groups, but only for age categories <60 years (Supplementary Figure S3). The presence of comorbidities modified the effect of sex and adherence. There were significant sex differences in adherence across all age categories among individuals with no comorbidities. However, among patients with comorbidities, sex differences in adherence were restricted to younger age (<60 years) categories only (Supplementary Figure S4).

In individuals who were adherent, 106,335 (15.7%) males and 93,659 (13.4%) females had prediabetes, and 17,521 (2.6%) males and 10,820 (1.5%) females had diabetes during the 3-year screening period (Figure 2). In general, rates of prediabetes and diabetes increased with increasing age in both sexes.

Overall, 410,310 (89·2%) males and 502,775 (92·0%) females who were adherent had at least one repeat glucose test during the follow-up period (Supplementary Table 2S). After excluding individuals who had diabetes (≥2 abnormal laboratory tests) during the screening period, 110,244 (24·9%) adherent males and 104,752

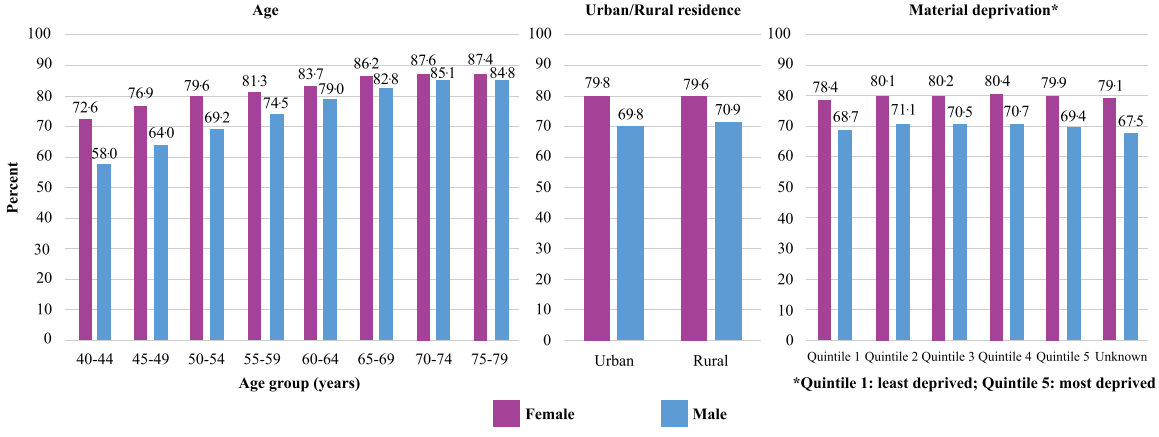

Figure 1. Adherence to diabetes screening guidelines among males and females by age, residence, and material deprivation.

	Unadjusted association odds ratio (95% CI)	Adjusted association odds ratio (95% CI)*
Sex		
Male	1·00	1.00
Female	1·70 (1·68–1·71)	1.92 (1.89–1.95)
Age groups, years old		
40–44 years	1·00	1·00
45–49 years	1·27 (1·26–1·29)	1·29 (1·27–1·31)
50–54 years	1·56 (1·54–1·58)	1·63 (1·60–1·66)
55–59 years	1·89 (1·86–1·91)	2·12 (2·09–2·16)
60–64 years	2·35 (2·31–2·38)	2·74 (2·69–2·80)
65–69 years	2·96 (2·90–3·01)	3·52 (3·43–3·61)
70–74 years	3·43 (3·35–3·51)	4·16 (4·02–4·30)
75–79 years	3·38 (3·29–3·47)	4·08 (3·92–4·25)
Material deprivation index category		
1 (Least deprived category)	1·00	1·00
First intermediate deprivation	1·12 (1·10–1·13)	1·14 (1.12–1·15)
Second intermediate deprivation	1·10 (1·09–1·12)	1·12 (1·10–1·13)
Third intermediate deprivation	1·11 (1·10–1·13)	1·12 (1·11–1·14)
5 (Most deprived category)	1·05 (1·04–1·07)	1·08 (1·06–1·09)
Unknown	0·98 (0·96–1·00)	0·96 (0·94–0·98)
Location of residence		
Urban	1·00	1·00
Rural	1·02 (1·01–1·03)	0·97 (0·96–0·98)
Sex*Age groups		<0·05

***Table 2*: Factors associated with adherence to screening.**
* Multivariable model included age and sex (main effects and interaction term), material deprivation, and location of residence.

(19·5%) adherent females had prediabetes and an additional 13,968 (3·2%) adherent males and 9,931 (1·9%) adherent females had incident diabetes during the follow-up period (Figure 3 – **Left panel**). In contrast, 96,715 (48·2%) males and 71,628 (51·2%) females who were non-adherent had at least one glucose test for the first time during the follow-up period (Supplementary Table 2S). During the follow-up period, 17,732 (8.8%) of non-adherent males and 10,149 (7.3%) of non-adherent females had prediabetes, and 4,147 (2.1%) of non-adherent males and 1,874 (1.3%) of non-adherent females had diabetes **(**Figure 3 – **Right panel)**.

Over the entire 7-year time period of the study, 556,550 (84.3%) males and 618,336 (90.1%) females had at least one glucose test (Supplementary Table 3S). Approximately 20% of young males (<50 years) did not have even one single glucose test compared to 10% of young females. The cumulative number of individuals with prediabetes and diabetes (≥2 abnormal laboratory tests) was 175,830 (26·6%) and 36,245 (5·5%) among males and 154,822 (22·6%) and 23,143 (3·4%) among females.

As mentioned previously, in the presence of symptoms, a single abnormal test could be considered diagnostic of diabetes. In individuals who were adherent, 38,883 (5.7%) males and 27,939 (4.0%) females had one laboratory test indicative of diabetes during the screening period (Table 3, **top panel**). During the follow-up period, among adherent individuals, 39,741 (9.0%) males and 32,488 (6.1%) females had one laboratory test indicative of diabetes (Table 3 – **middle panel**); and among non-adherent individuals, 9226 (4·6%) males and 4473 (3·2%) females had one laboratory test indicative of diabetes (Table 3 – **bottom panel**). Over the entire 7-year time period of the study, the number of males and females who had one abnormal laboratory test indicative of diabetes was 73,315 (11·1%) and 53,657 (7·8%), respectively (Supplementary Table 3S).

Discussion

Our study, based on a large, population-based inception cohort of approximately 1·4 million adults with no pre-existing diabetes or CVD with universal health coverage, found sub-optimal rates of adherence to diabetes screening guidelines, especially among males compared to females. This sex-difference was most pronounced in the young, with adherence rates in males being approximately 15% lower than in females in age category 40 to 44 years. In individuals ≥65 years, adherence rates increased to >80% in both sexes, and although still lower, adherence rates among males 'caught up' to those among females (<4% difference). Females had higher adherence to diabetes screening in both rural and urban populations, as well as across levels of material deprivation. After adjusting for age, residence

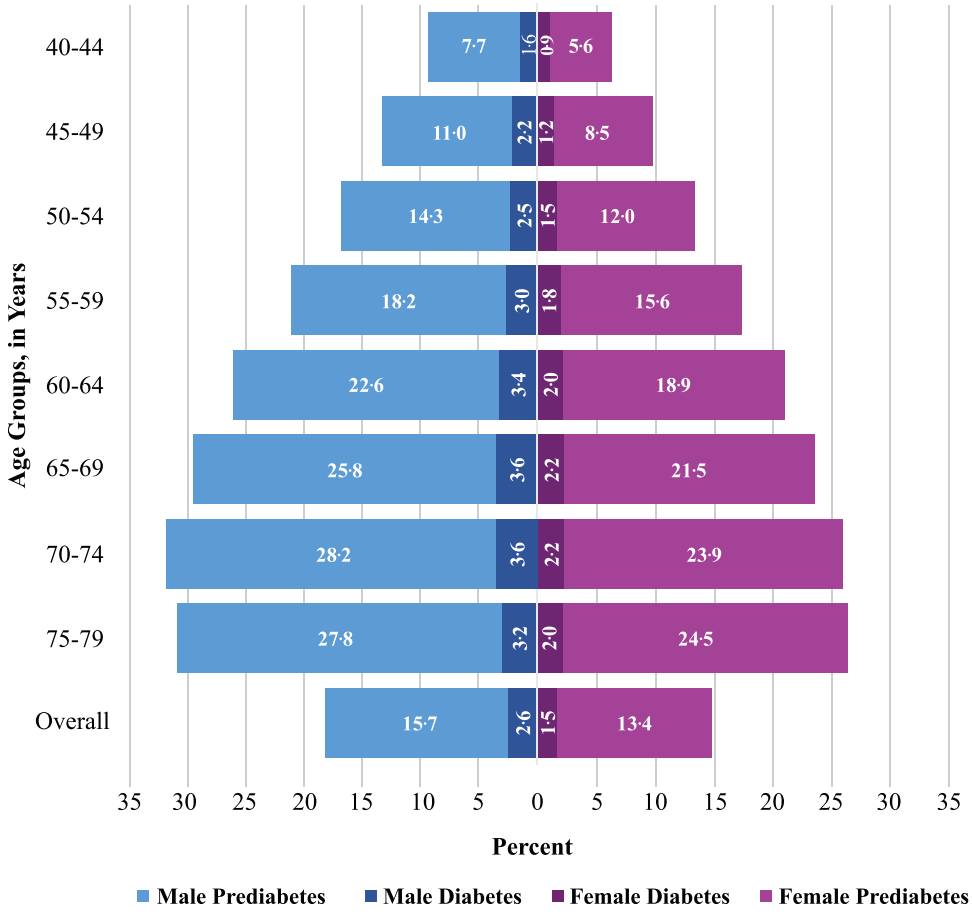

Figure 2. Rates of prediabetes and diabetes (≥2 abnormal laboratory tests) during the screening period among adherent individuals by sex and age.

location, material deprivation and comorbidity burden, females were almost twice as likely to adhere to screening guidelines than males.

The rates of new diabetes detected during the 3-year screening period in our study (2·6% in males and 1·5% in females) were slightly higher than those reported in the Anglo-Danish-Dutch Study of Intensive Treatment in People with Screen-detected Diabetes in Primary Care (ADDITION-Europe) study (range 0·33% to 1·9%).[17] The ADDITION-Europe study assessed diabetes rates in those with previously unknown diabetes who participated in screening programmes undertaken in general practices in the UK, Denmark and the Netherlands. In addition, we found 15·7% of males and 13·4% of females with prediabetes, and 5·7% males and 4·0% females with one abnormal glucose test indicative of diabetes. These findings indicate the diagnostic yield associated with universal screening at the population-level.

In both sexes, rates of prediabetes and incident diabetes during the follow-up period were higher among those who adhered to screening guidelines than among those who were non-adherent. The higher rates among adherent individuals suggest that individuals who may be at higher risk for diabetes are being screened early. However, the combined incidence of prediabetes and diabetes was substantial among non-adherent individuals (10·9% among males and 8·6% among females) indicating potential missed opportunities to identify these individuals earlier. To the extent that screening could have facilitated early diagnosis, these rates reflect the potential costs of non-adherence.

Rates of prediabetes and diabetes during both the screening and follow-up period were higher in males than females. However, the rates among males are likely to be an underestimate as >20% of young males age ≤50 years had not undergone a single glucose test during the entire 7-year period. Given the high risk of CVD complications and mortality associated with prediabetes and diabetes, our findings highlight the need for further research to better understand the individual-, provider-, and system-level issues that may be contributing to underscreening in this segment of the population.[18,19]

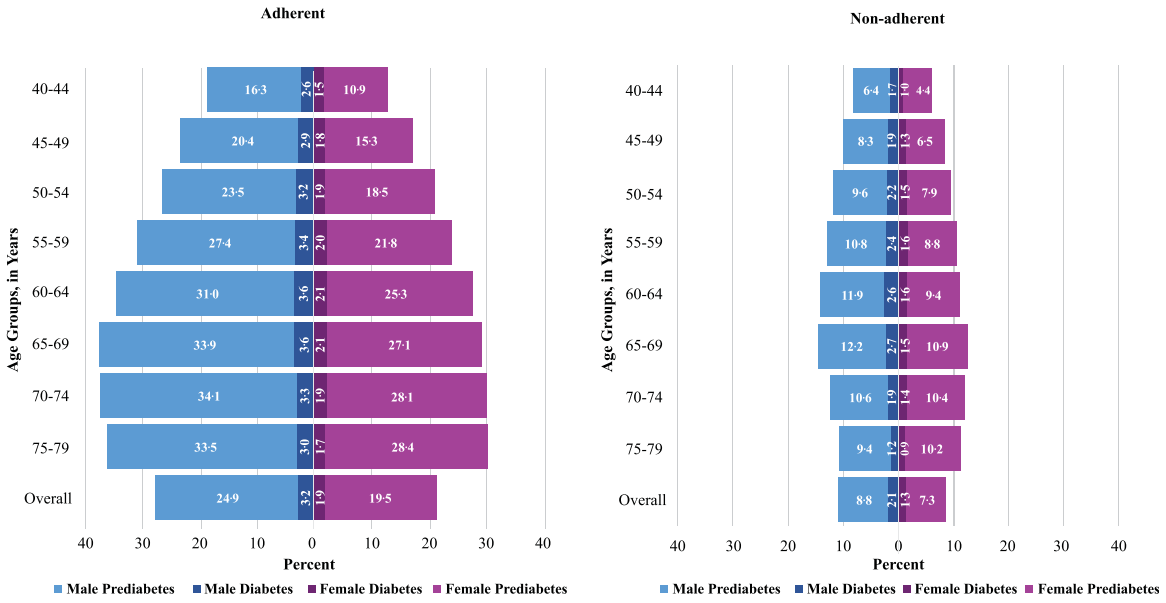

Figure 3. Rates prediabetes and diabetes (≥2 abnormal laboratory tests) during follow-up period among males and females by age and adherence to diabetes screening status. Footnotes: 1) Rates of prediabetes and diabetes are based on all individuals who were adherent or non-adherent (excluding those who had died or moved out of the province during the follow-up period) regardless of whether they underwent glucose testing in the follow-up period; 2) Individuals in the adherent group who had diabetes during the screening period (≥2 abnormal laboratory tests) were excluded; therefore, the rates of diabetes among adherent individuals are based on new (incident) cases; 3) Denominators by age and sex for the graph are provided in Supplementary Table S2.

Consistent with previous studies, we found females had substantially higher rates of use of primary care physician services than males. [20] Accounting for the number of primary care physician visits appeared to partially explain the sex-differences in adherence rates in older (age ≥60 years) but not in younger age categories. The presence of comorbidities modified the effect of sex on adherence, with sex-differences being observed across all age categories in individuals without comorbidities and only in younger (<60 years) individuals with comorbidities. Public health campaigns about the importance of annual check-ups, diabetes screening, and interventions such as workplace screening programs, particularly targeted towards young males need to be considered.

Although our study has the strength of being based on a large, unselected, population-level cohort, in a universal care setting, it has a few limitations. First, we grouped individuals according to sex (a biological concept) and not on gender (a social construct). Examining gender differences may offer further insights; however, these data are not available in the population data sets available and exploring these associations remains an important area for further study. Second, our measure of adherence was based on laboratory tests and not on the number of laboratory requisitions. It has been shown that, in paediatric populations, males are less likely to have screening tests ordered; however, we were unable to examine this issue in our study.[21] Third, we did not account for the initiation of-any glucose-lowering therapies during the screening or follow-up period. Fourth, our measurement of material deprivation was not at the individual level but at the neighbourhood level and we did not have data on other demographic factors such as marital status, ethnicity, or indigenous status which may be important factors associated with adherence. And lastly, we excluded individuals with CVD prior to the inception date of the study who may be more likely to adhere to screening guidelines and have higher rates of prediabetes and diabetes.

In summary, females are more adherent to diabetes screening guidelines compared to males, regardless of age, urban/rural residence, or material deprivation. Adherence to screening guidelines are the lowest among young males. Despite lower rates of screening, males have higher rates of prediabetes and diabetes compared to females. Further research is needed to understand the underlying causes of sex differences in adherence to diabetes screening and to develop targeted strategies at the local and population level to raise awareness and improve screening rates in young people, especially males.

Age group	Males		Females	
	# in category	# with diabetes based on 1 abnormal test (%)	# in category	# with diabetes based on 1 abnormal test (%)
During the screening period				
40–44	137,264	4435 (3.2)	131,154	2567 (2.0)
45–49	131,124	5698 (4.3)	128,806	3659 (2.8)
50–54	131,297	6897 (5.3)	132,289	4803 (3.6)
55–59	108,939	7152 (6.6)	110,313	5039 (4.6)
60–64	73,900	5966 (8.1)	79,081	4220 (5.3)
65–69	48,503	4228 (8.7)	56,465	3486 (6.2)
70–74	29,535	2803 (9.5)	36,903	2431 (6.6)
75–79	18,939	1704 (9.0)	26,185	1734 (6.6)
Total	679,501	38,883 (5.7)	70,1196	27,939 (4.0)
During follow-up among adherent individuals**				
40–44	76,634	4916 (6.4)	93,592	3668 (3.9)
45–49	79,944	6109 (7.6)	96,640	4988 (5.2)
50–54	85,872	7440 (8.7)	102,148	5799 (5.7)
55–59	75,771	7247 (9.6)	86,162	5709 (6.6)
60–64	53,586	5809 (10.8)	62,875	4734 (7.5)
65–69	36,034	4238 (11.8)	45,455	3585 (7.9)
70–74	21,683	2578 (11.9)	29317	2392 (8.2)
75–79	12,790	1404 (11.0)	19,699	1613 (8.2)
Total	44,2314	39,741 (9.0)	535,888	32,488 (6.1)
During follow-up among non-adherent individuals				
40–44	57,361	1972 (3.4)	35,774	808 (2.3)
45–49	46,834	1998 (4.3)	29,567	867 (2.9)
50–54	39,871	1971 (4.9)	26,683	927 (3.5)
55–59	27,162	1533 (5.6)	20,366	752 (3.7)
60–64	14,954	918 (6.1)	12,632	533 (4.2)
65–69	7924	501 (6.3)	7479	326 (4.4)
70–74	4104	231 (5.6)	4299	170 (4.0)
75–79	2579	102 (4.0)	3011	90 (3.0)
Total	200,789	9226 (4.6)	139,811	4473 (3.2)

***Table 3*: Proportion of individuals with diabetes based on one abnormal* laboratory test.**

* Abnormal test defined as a FPG ≥7·0 mmol/L, HbA1c ≥6·5%, 2-h PG on a 75-OGTT ≥11·1 mmol/L, or a random plasma glucose (RPG) ≥11·1 mmol/L.

** Individuals who had diabetes (≥2 abnormal laboratory tests) during the screening period are excluded.

Contributors

Dr. Kaul was responsible for the study design, data interpretation, drafting the manuscript, study supervision and procuring funding. Dr. Chu was responsible for methodology, data analysis, data interpretation, visualization, and drafting the manuscript. All other authors reviewed the data analyses and results, critically reviewed the manuscript and suggested revisions. Dr. Kaul and Dr. Chu verified the underlying data reported in the manuscript.

Data sharing statement

The data underlying this article were provided by Alberta Health Services under the terms of a research agreement. Inquiries respecting access to the data can be made directly to them.

Declaration of interests

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lana.2022.100320.

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