Prevalence estimates of chronic kidney disease in Canada: results of a nationally representative survey

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Abstract

Background: Chronic kidney disease is an important risk factor for death and cardiovascular-related morbidity, but estimates to date of its prevalence in Canada have generally been extrapolated from the prevalence of end-stage renal disease. We used direct measures of kidney function collected from a nationally representative survey population to estimate the prevalence of chronic kidney disease among Canadian adults.

Methods: We examined data for 3689 adult participants of cycle 1 of the Canadian Health Measures Survey (2007–2009) for the presence of chronic kidney disease. We also calculated the age-standardized prevalence of cardiovascular risk factors by chronic kidney disease group. We cross-tabulated the estimated glomerular filtration rate (eGFR) with albuminuria status.

Results: The prevalence of chronic kidney disease during the period 2007–2009 was 12.5%, representing about 3 million Canadian adults. The estimated prevalence of stage 3–5 disease was 3.1% (0.73 million adults) and albuminuria 10.3% (2.4 million adults). The prevalence of diabetes, hypertension and hypertriglyceridemia were all significantly higher among adults with chronic kidney disease than among those without it. The prevalence of albuminuria was high, even among those whose eGFR was 90 mL/min per 1.73 m^2 or greater (10.1%) and those without diabetes or hypertension (9.3%). Awareness of kidney dysfunction among adults with stage 3–5 chronic kidney disease was low (12.0%).

Interpretation: The prevalence of kidney dysfunction was substantial in the survey population, including individuals without hypertension or diabetes, conditions most likely to prompt screening for kidney dysfunction. These findings highlight the potential for missed opportunities for early intervention and secondary prevention of chronic kidney disease.

Chronic kidney disease is defined as the presence of kidney damage or reduced kidney function for more than 3 months and requires either a measured or estimated glomerular filtration rate (eGFR) of less than 60 mL/min per 1.73 m^2, or the presence of abnormalities in urine sediment, renal imaging or biopsy results.[1] Between 1.3 million and 2.9 million Canadians are estimated to have chronic kidney disease, based on an extrapolation of the prevalence of end-stage renal disease.[2] In the United States, the 1999–2004 National Health and Nutrition Examination Survey reported a prevalence of 5.0% for stage 1 and 2 disease and 8.1% for stage 3 and 4 disease.[3,4]

Chronic kidney disease has been identified as a risk factor for death and cardiovascular-related morbidity and is a substantial burden on the health care system.[1,5] Hemodialysis costs the Canadian health care system about $60 000 per patient per year of treatment.[1] The increasing prevalence of chronic kidney disease can be attributed in part to the growing elderly population and to increasing rates of diabetes and hypertension.[1,6,7]

Albuminuria, which can result from abnormal vascular permeability, atherosclerosis or renal disease, has gained recognition as an independent risk factor for progressive renal dysfunction and adverse cardiovascular outcomes.[8–10] In earlier stages of chronic kidney disease, albuminuria has been shown to be more predictive of renal and cardiovascular events than eGFR.[4,9] This has prompted the call for a new risk stratification for cardiovascular outcomes based on both eGFR and albuminuria.[11]

A recent review advocated screening people for chronic kidney disease if they have hypertension, diabetes, clinically evident cardiovascular disease or a family history of kidney failure or are more than 60 years old.[4] The Canadian Society of Nephrology published guidelines on the manage-

ment of chronic kidney disease but did not offer guidance on screening.[1] The Canadian Diabetes Association recommends annual screening with the use of an albumin:creatinine ratio,[12] and the Canadian Hypertension Education Program guideline recommends urinalysis as part of the initial assessment of hypertension.[13] Screening for chronic kidney disease on the basis of eGFR and albuminuria is not considered to be cost-effective in the general population, among older people or among people with hypertension.[14]

The objective of our study was to use direct measures (biomarkers) of kidney function to generate nationally representative, population-based prevalence estimates of chronic kidney disease among Canadian adults overall and in clinically relevant groups.

Methods

Study sample

For our analysis, we used data from cycle 1 of the Canadian Health Measures Survey. This survey is a population-based survey designed and implemented by Statistics Canada to collect health information on Canadians aged 6–79 years.[15,16] Cycle 1 of the survey was conducted between 2007 and 2009; multistage cluster sampling was used so that the data would be representative of 96.3% of Canadians when weights were applied. A Statistics Canada interviewer administered a detailed in-home health question-

naire. Participants were then asked to visit a mobile examination centre, where biological samples and physical measurements were taken.

Of 8772 dwellings approached, 6106 (69.6%; 7478 individuals) agreed to participate. Of the 6604 (88.3%) people who completed the in-home questionnaire, 5604 (84.9%) attended a mobile clinic.[17] The overall response rate was 51.7%.[17] Residents of First Nations reserves, Crown lands, certain remote regions and institutions, and full-time members of the Canadian Forces were excluded from the survey. For our analysis, we excluded participants under 18 years of age (n = 1883) and pregnant women (n = 32), which left 3689 participants.

Biomarkers and estimation of kidney function

All biological samples and physical measurements for the survey were collected during the single visit to a mobile clinic. About 80 mL of blood and 70 mL of urine were collected and processed immediately. Both blood and urine samples were aliquoted into smaller tubes and either refrigerated or frozen. Urine creatinine levels were measured using the Jaffe method at the Institut national de santé publique du Québec. Serum creatinine levels, measured using VITROS CREA Slides (Ortho-Clinical Diagnostics), and urine albumin levels were measured at Health Canada's laboratories in Ottawa. Full details of the procedures at the mobile clinics and laboratory measurements are provided elsewhere.[18,19]

We followed Canadian guidelines to classify participants by stage of chronic kidney disease based on the eGFR and the presence of albuminuria, the only markers of renal pathology available.[1] Albuminuria was defined as a urine albumin:creatinine ratio greater than 2.0 mg/mmol for men and greater than 2.8 mg/mmol for women.[1] Missing values of urine albumin (n = 1651) and urine creatinine (n = 8), owing to a level below the lower limit of detection (< 3 mg/L for urine albumin and < 0.34 mmol/L for urine creatinine), were imputed by using a random value less than the lower limit of detection. Unless otherwise indicated, we calculated eGFR using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, because this equation estimates the glomerular filtration rate more accurately than the Modification of Diet in Renal Disease (MDRD) equation does.[20–22] For our analysis, we grouped participants with stage 4 (n = 14) and 5 (n = 3) chronic kidney disease with those who had stage 3 disease. The definitions and equations used for the stages of chronic kidney disease are presented in Box 1.[1,23]

Box 1: Classification of the stages of chronic kidney disease*[1,23]

- Normal: glomerular filtration rate (GFR) ≥ 60 mL/min per 1.73 m² with no kidney damage
- Stage 1: normal or increased GFR (≥ 90 mL/min per 1.73 m²) with kidney damage†
- Stage 2: mildly decreased GFR (60–89 mL/min per 1.73 m²) with kidney damage†
- Stage 3: moderately decreased GFR (30–59 mL/min per 1.73 m²)
- Stage 4: severely decreased GFR (15–29 mL/min per 1.73 m²)
- Stage 5: kidney failure (GFR < 15 mL/min per 1.73 m²)

Equations used to calculate estimated GFR

Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation‡[21]

$$eGFR = 141 \times \min(Scr/\kappa, 1)^{\alpha} \times \max(Scr/\kappa, 1)^{-1.209} \times 0.993^{age} \times 1.018 \text{ (if female)} \times 1.159 \text{ (if black)}$$

Modification of Diet in Renal Disease Equation‡[3]

$$eGFR = 175 \times (Scr)^{-1.154} \times (age)^{-0.203} \times 0.742 \text{ (if female)} \times 1.212 \text{ (if black)}$$

*Kidney damage or GFR < 60 mL/min per 1.73 m² for 3 or more months.
†Pathologic abnormalities or markers of damage, including persistent proteinuria, abnormalities in urine sediment (persistent presence of erythrocytes, erythrocyte casts, leukocytes or leukocyte casts) or abnormal results in imaging studies (evidence of scarring or small kidneys on ultrasound or bilateral cystic changes consistent with polycystic kidney disease).
‡Scr = serum creatinine level in mg/dL (converted from μmol/L to mg/dL by dividing value by 88.4), κ = 0.7 for women and 0.9 for men, α = –0.329 for women and –0.411 for men, min = minimum of Scr/κ or 1, max = maximum of Scr/κ or 1. Race is either black or not black.

Cardiovascular risk factors

We assessed the prevalence of risk factors for cardiovascular disease after excluding participants who reported having current or previous heart disease and those who were taking medication for any cardiovascular condition (n = 297). Participants were considered to have diabetes if they reported having received a diagnosis of diabetes (type 1 or 2) by a health professional, had a glycated hemoglobin concentration of 6.5% or greater or had a fasting plasma glucose level of 7 mmol/L or greater.[24] Hypertension was deemed present if participants reported having received a diagnosis of "high blood pressure" by a health professional or reported using blood pressure medication in the past month.

Among participants who met the fasting criteria (n = 1659), risk factors for cardiovascular disease were deemed present if the ratio of total to high-density lipoprotein (total:HDL) cholesterol was higher than 5, the low-density lipoprotein (LDL) cholesterol level was above 3.5 mmol/L, the HDL cholesterol was below 1.03 mmol/L for men and below 1.3 mmol/L for women, and the level of triglycerides was greater than 1.7 mmol/L.[5]

Statistical analysis

We calculated weighted prevalence and mean estimates using sampling weights provided by Statistics Canada that accounted for representativeness and nonresponse.[19] Frequencies were reported as unweighted counts. To account for the effect of age on the prevalence of risk factors for cardiovascular disease or the progression of chronic kidney disease, estimates were age-standardized to the weighted survey population aged 18–79 (excluding pregnant women) by 20-year age groups.

We followed Statistics Canada reporting guidelines and indicated where sampling variability was high. We calculated prevalence estimates with the SAS 9.3 program (SAS Institute Inc., Cary, North Carolina) using survey-specific procedures and bootstrap weights for variance estimates.

Results

Chronic kidney disease

The demographic characteristics of the study population, weighted to be representative of the Canadian adult population, are presented in Table 1.

We estimated the overall prevalence of chronic kidney disease (any stage) to be 12.5% using the Chronic Kidney Disease Epidemiology Collaboration equation and 13.4% using the Modification of Diet in Renal Disease equation (Table 2). The prevalence of stage 3–5 disease was slightly lower when estimated with the Chronic Kidney

Table 1: Demographic characteristics of survey participants (n = 3689*)

Characteristic	Weighted prevalence or mean estimate† (95% CI)
Age, yr, mean	44.7 (44.5–44.9)
Age group, yr, %	
18–39	39.5 (38.9–40.0)
40–64	47.9 (46.5–49.2)
≥ 65	12.7 (11.7–13.8)
Sex, %	
Male	49.8 (49.4–50.2)
Female	50.2 (49.8–50.6)
Ethnicity,‡ %	
White	82.4 (73.0–89.0)
Asian§	9.9 (5.3–17.7)
Other§	4.8 (2.7–8.5)
Unknown	2.9 (2.0–4.1)
Education level, %	
Less than secondary school	12.8 (10.3–15.8)
Secondary school or graduate	18.9 (14.7–23.8)
Other postsecondary	9.4 (7.4–11.9)
Postsecondary graduate	59.0 (50.5–67.0)
Income adequacy group, %	
Lowest	5.1 (3.4–7.5)
Lower middle	14.4 (12.4–16.6)
Upper middle	32.7 (29.7–35.8)
Highest	47.9 (43.2–52.6)
Body mass index, mean	27.1 (26.7–27.6)
Physical activity,¶ %	
Active	20.5 (16.8–24.9)
Moderate	24.7 (21.8–27.8)
Inactive	54.8 (48.2–61.2)
Smoking status, %	
Daily smoker**	21.8 (19.2–24.6)
Former daily smoker**	27.9 (24.8–31.2)
Never smoked	50.3 (47.0–53.6)
Has a family doctor,†† %	
Yes	84.2 (80.8–87.1)
No	15.8 (12.9–19.2)

Note: CI = confidence interval.
*Unweighted number of participants aged 18–79 years (excluding 32 pregnant participants).
†Weighted prevalence and mean estimates were calculated with the use of sampling weights provided by Statistics Canada that accounted for representativeness and nonresponse.
‡Ethnicity was collapsed into 3 groups: white, Asian (Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian, Arab and West Asian) and other (black, Latin American and mixed).
§Coefficient of variation (CV) > 25% and < 30% (all other CV values < 16%).
¶Characterized using a measure of the average daily energy expended during leisure activities reported by the respondent in the past 3 months, as described elsewhere.[19]
**Daily smoker = respondents who reported smoking daily and those who reported smoking occasionally but who were former daily smokers; former daily smokers = respondents who reported being nonsmokers but who were former daily smokers. Occasional smokers (n = 57) were not included in the calculation of smoking status owing to small numbers. Smoking exposure (average number of pack-years) was 20.7 for daily smokers and 14.0 for former daily smokers. The average time since quitting among former daily smokers was 15.9 years.
††The concept of having a family doctor was captured by asking participants if they had a "regular" medical doctor.

Table 2: Prevalence of chronic kidney disease among Canadian adults

Group; stage of chronic kidney disease*†	No. of participants‡	Weighted prevalence,§ % (95% CI)
All (CKD-EPI equation)¶ (*n* = 3589)		
Normal	3073	87.4 (85.6–89.1)
Stage 1 or 2	353	9.4 (7.9–11.3)
Stages 3–5	163	3.1 (2.4–3.9)
All (MDRD equation)** (*n* = 3591)		
Normal	3028	86.6 (84.7–88.3)
Stage 1 or 2	350	9.4 (7.8–11.2)
Stages 3–5	213	4.0 (3.1–5.1)
Men (*n* = 1698)		
Normal	1436	87.6 (85.1–89.7)
Stage 1 or 2	185	9.6 (7.8–11.9)
Stages 3–5	77	2.8 (2.1–3.8)
Women (*n* = 1891)		
Normal	1637	87.3 (85.3–89.1)
Stage 1 or 2	168	9.3 (7.5–11.5)
Stages 3–5	86	3.4 (2.3–4.9)
All, age 18–40 yr (*n* =1314)		
Normal	1181	90.2 (87.8–92.2)
Stage 1 or 2	131	9.6 (7.6–11.9)
Stages 3–5	2	NA‡‡
All, age 40–64 yr (*n* = 1593)		
Normal	1428	90.0 (87.2–92.3)
Stage 1 or 2	138	8.6 (6.6–11.2)
Stages 3–5	27	1.3 (0.7–2.7)§§
All, age ≥ 65 yr (*n* = 682)		
Normal	464	69.2 (65.7–72.5)
Stage 1 or 2	84	12.2 (9.6–15.5)
Stages 3–5	134	18.6 (14.2–23.9)
All, without diabetes or hypertension†† (*n* = 2730)		
Normal	2450	90.3 (88.0–92.2)
Stage 1 or 2	231	8.4 (6.9–10.2)
Stages 3–5	49	1.3 (0.7–2.4)§§

Note: CI = confidence interval, CKD-EPI = Chronic Kidney Disease Epidemiology Collaboration, MDRD = Modification of Diet in Renal Disease, NA = not available.
*See Box 1 for classification of the stages of chronic kidney disease.
†Missing observations = 100 (owing to missing values for serum creatinine).
‡Unweighted numbers of participants aged 18–79 years (excluding pregnant women).
§Weighted prevalence was calculated with the use of sampling weights provided by Statistics Canada that accounted for representativeness and nonresponse.
¶Unweighted numbers of participants (and weighted proportions with 95% CIs) by stage of disease according to the CKD-EPI equation are as follows: normal: 3073 (87.4%, 85.6–89.1%); stage 1: 238 (6.9%, 5.7%–8.4%); stage 2: 115 (2.5%, 1.9%–3.3%); stage 3: 151 (2.9%, 2.3%–3.6%); stage 4: 9 (prevalence estimate NA‡‡); stage 5: 3 (prevalence estimate NA‡‡).
**Unweighted numbers of participants (and weighted proportions with 95% CIs) by stage of disease according to the MDRD equation are as follows: normal: 3028 (86.6%, 84.7%–88.3%); stage 1: 197 (5.4%, 4.2%–7.1%); stage 2: 153 (3.9%, 3.2%–4.9%); stage 3: 202 (3.8%, 3.0%–4.8%); stage 4: 8 (prevalence estimate NA‡‡); stage 5: 3 (prevalence estimate NA‡‡).
††Excludes participants with diabetes (*n* = 300 [7.2%]) and hypertension (*n* = 759 [17.6%]), as defined in Methods.
‡‡Prevalence estimate cannot be reported (coefficient of variation [CV] > 33.3%).
§§Marginal sampling variability (16% < CV < 33%); interpret with caution.

Disease Epidemiology Collaboration equation (3.1%) than with the Modification of Diet in Renal Disease equation (4.0%).

The distribution of stages of chronic kidney disease did not differ remarkably between men and women or between young (aged 18–40 yr) and middle-aged (aged 40–64 years) adults. The prevalence of chronic kidney disease was 3 times higher among those aged 65 or older (30.8% v. < 10% among younger adults). When we excluded participants with hypertension or diabetes, the prevalence of stage 1 or 2 chronic kidney disease dropped slightly, from 9.4% to 8.4%. The difference was more pronounced among those with stage 3–5 disease, dropping from 3.1% to 1.3% after we excluded those with hypertension or diabetes.

Awareness of kidney dysfunction was low: only 5.3% of those with any stage of chronic kidney disease reported ever having been told by a health professional that they had "kidney disease or dysfunction." Only 12.0% of those with stage 3–5 disease reported the same (15.9% of men and 8.9% of women).

Hypertension and diabetes
The age-standardized prevalence of hypertension or diabetes, or both, was significantly higher among adults with than among those without chronic kidney disease (Table 3). Despite the higher prevalence of these comorbidities among those with chronic kidney disease, 72.3% of adults with chronic kidney disease had neither hypertension nor diabetes. The trend in prevalence of hypertension and diabetes increased by stage of kidney disease when we used non–age-standardized estimates: adults with stage 3–5 chronic kidney disease had a prevalence of hypertension that was more than double the prevalence among those with stage 1 or 2 disease (52.8% v. 23.0%). The same was true for the prevalence of diabetes (23.4% v. 10.8%). Of the biomarkers for risk of cardiovascular events, elevated level of triglycerides was the only one that was significantly more prevalent among adults with than without chronic kidney disease (age-standardized prevalence 39.8% v. 21.4%). Notable differences between those with and without chronic kidney disease were observed in age-standardized prevalence rates for high total:HDL cholesterol ratio, low HDL cholesterol level and elevated high-sensitivity C-reactive protein level.

Albuminuria
About 10% of adults screened positive for albuminuria among those with a normal (≥ 90 mL/min per 1.73 m²) or mildly reduced (60–89 mL/min per 1.73 m²) eGFR (Table 4). This prevalence

almost tripled (27.6%) among adults with an eGFR below 60 mL/min per 1.73 m². Among those without hypertension or diabetes, the overall prevalence of albuminuria was 9.3%. Adults with albuminuria were about 3 times more likely than those without albuminuria to have an eGFR below 60 mL/min per 1.73 m² (7.6% v. 2.3%). Of those with albuminuria, most (67.8%) did not have hypertension or diabetes; this estimate did not change appreciably (70.7%) when we limited the analysis to those with an eGFR of 60 mL/min per 1.73 m² or greater (data not shown).

Interpretation

Between 2007 and 2009, an estimated 12.5% of adults in Canada were living with chronic kidney disease. This represents about 2.9 million Can-

adian adults with any chronic kidney disease and 0.73 million with stage 3–5 disease. Our prevalence estimate for any chronic kidney disease are comparable to that of 13.1%[3] in the US (measured with use of the Modification of Diet in Renal Disease equation) but higher than other estimates from Europe (4.7%–8.1%), Asia (2.5%–6.8%) and Australia (11.2%).[25] The prevalence of stage 3–5 disease in our study population is lower than that estimated in the US.[3] In our study, the prevalence of any chronic kidney disease was about the same for both sexes as well as for young and middle-aged adults, but it was markedly higher (about 31%) in older age groups (≥ 65 yr), similar to the few population-based Canadian estimates for chronic kidney disease.[8,26]

Overall awareness of kidney dysfunction in our study was low (5.3%). Even among those

Table 3: Age-standardized, weighted prevalence of risk factors for cardiovascular events and progression of chronic kidney disease among Canadian adults without a self-reported heart condition

| Variable | Chronic kidney disease group; weighted prevalence,* % (95% CI) | | | |
	All	No disease	Disease present	p_{diff} value†
All participants‡	n = 3392	n = 2874	n = 423	
Diabetes and hypertension§				
Neither	81.1 (79.5–82.6)	82.5 (80.8–84.1)	72.3 (65.7–78.8)	0.01
Hypertension	16.3 (14.9–17.7)	15.0 (13.4–16.6)	24.4 (18.9–29.9)	0.007
Diabetes	6.3 (4.6–7.9)	5.4 (4.0–6.8)	10.9§§ (5.9–15.9)	0.03
Both	3.6§§ (2.5–4.8)	2.9§§ (1.9–3.8)	7.5§§ (3.6–11.4)	0.03
Obesity (BMI > 30)	23.0 (20.2–25.9)	22.2 (19.1–25.2)	28.1 (20.5–35.6)	0.1
Abdominal obesity¶	57.4 (52.8–61.9)	56.7 (51.5–61.9)	63.2 (57.0–69.4)	0.2
Smoking status**				
Daily	20.7 (18.4–23.0)	20.6 (18.0–23.1)	20.2 (16.4–24.0)	0.9
Former daily	26.3 (23.8–28.7)	26.5 (24.0–29.1)	26.0 (19.8–32.2)	0.9
Never	49.1 (46.0–52.2)	48.8 (46.0–51.6)	50.8 (43.1–58.5)	0.5
Lipid levels††	n = 1659	n = 1428	n = 201	
Elevated triglycerdides (> 1.7 mmol/L)	23.5 (19.2–27.8)	21.4 (17.0–25.9)	39.8 (27.9–51.8)	0.02
Elevated high-sensitivity CRP (> 2 mg/L)	35.6 (32.6–38.6)	34.3 (31.1–37.5)	43.5 (33.9–53.1)	0.1
Elevated total cholesterol (≥ 5 mmol)	44.4 (39.7–49.0)	43.9 (38.4–49.4)	49.2 (39.2–59.1)	0.5
Elevated LDL cholesterol (> 3.5 mmol)	31.1 (28.0–34.3)	30.8 (27.0–34.7)	32.9§§ (19.5–46.3)	0.8
Elevated total:HDL cholesterol ratio (> 5)	16.3 (13.4–19.1)	14.7 (11.5–18.0)	28.1§§ (15.7–40.5)	0.08
Low HDL cholesterol‡‡	29.9 (24.7–35.1)	28.6 (23.3–33.9)	40.0 (27.6–52.4)	0.1

Note: BMI = body mass index, CI = confidence interval, CRP = C-reactive protein, HDL = high-density lipoprotein, LDL = low-density lipoprotein.
*Prevalence estimates are age-standardized to the weighted survey population aged 18–79 (excluding pregnant women) by 20-year age groups.
†p < 0.05 for test of difference in prevalence of risk factor for cardiovascular disease between participants with and without chronic kidney disease.
‡Unweighted numbers of study participants aged 18–79 years (excluding those reporting previous or existing heart condition, n = 297). Missing observations = 95 (presence of chronic kidney disease unknown owing to missing values for serum creatinine). Reports of previous or existing heart condition defined as participant having heart disease, ever having had a heart attack, having a heart condition that limited physical activity or taking drugs for any cardiovascular condition.
§See Methods for definitions of diabetes and hypertension.
¶Defined as waist circumference ≥ 94 cm for men and ≥ 80 cm for women.
**Daily smoker = respondents who reported smoking daily and those who reported smoking occasionally but who were former daily smokers; former daily smokers = respondents who reported being nonsmokers but who were former daily smokers. Occasional smokers (n = 57) were not included in the calculation of smoking status owing to small numbers.
††A total of 1796 participants met the fasting criteria; 137 were excluded from this table because they had a current or previous heart condition. Missing observations = 30 (presence of chronic kidney disease unknown owing to missing values for serum creatinine).
‡‡Defined as < 1.03 mmol/L for men and < 1.3 mmol/L for women.
§§Marginal sampling variability (coefficient of variation [CV] > 16% and < 33%); interpret with caution. All other estimates had CV values < 16.6%.

with stage 3–5 disease, when more intensive medical and lifestyle management is recommended, awareness was low (12.0%), with more awareness among men than among women (15.9% v. 8.9%). These percentages are slightly higher than US estimates (11.6% of men and 5.5% of women with stage 3 disease).[3]

Our results support the association of diabetes, hypertension and hypertriglyceridemia with chronic kidney disease. Previous work has shown increased prevalence of hypertension and diabetes by stage of chronic kidney disease.[27] Although we saw a similar trend in non–age-standardized results, interpretation is limited by the potential confounding by age, a known risk factor for chronic kidney disease.

The overall prevalence of albuminuria, an independent predictor of kidney dysfunction and cardiovascular risk, was about 10% in our study population, and was almost 3 times higher (27.6%) among adults with an eGFR below 60 mL/min per 1.73 m². Our estimates of albuminuria prevalence are similar to those in the US (9.5% overall, and 24.4% among adults with an eGFR of 30–59 mL/min per 1.73 m²).[3] Surprisingly, even among adults without hypertension or diabetes, the overall prevalence of albuminuria was still high (9.3%).

Most (92.4%) of adults with albuminuria fell into the category of stage 1 or 2 chronic kidney disease, with a normal or mildly reduced eGFR. Our findings are similar to that found in a large Canadian cohort study, in which 89% of people with proteinuria had an eGFR greater than 60 mL/min per 1.73 m².[8] This represents about 9.4% of the total population and is of particular interest, because the presence of albuminuria is an independent risk factor for cardiovascular disease.[8] Adults with stage 1 or 2 chronic kidney disease may benefit from screening for albuminuria to reduce their risk of adverse outcomes; however, without other risk factors, this population

may be missed. The 2 most common conditions that may prompt screening for albuminuria are diabetes and hypertension; however, only 29.3% of Canadian adults with stage 1 or 2 disease had either of these conditions. The proportion of this population with other risk factors for screening, such as a family history of kidney disease, is unknown. Given that population-based screening for kidney disease is not cost-effective,[1,14] further research is required to identify populations that could benefit from screening for kidney dysfunction.

Limitations

Our study was limited by the small sample in stratified analyses, which resulted in significant sampling variability in some cases. Small cell sizes prevented reliable estimation of stage-specific risk factors. A single measure of renal biomarkers is not sufficient to diagnose chronic kidney disease. However, it is reasonable to assume that most of the people surveyed had nonacute kidney dysfunction, given that participants were well enough to travel to a mobile examination centre and participate in a number of physical measures. It is reassuring that our results are comparable to estimates from other recent studies.[3,8] Self-reported disease status and medication use may have introduced measurement error in our study. However, for diabetes, we included biomarkers (fasting plasma glucose level and glycated hemoglobin concentration) in addition to self-reports to improve accuracy. Hypertension cannot be diagnosed on the basis of a single visit, even if multiple blood pressure measurements are taken; in keeping with previously published work,[28] we chose not to use these measurements to assess the prevalence of hypertension in our population.

Conclusion

Our study presents biomarker-based, nationally representative prevalence estimates of chronic kidney disease in Canada. Between 2007 and 2009, 12.5% of Canadian adults (2.9 million people) were living with chronic kidney disease, an important risk factor for end-stage renal disease and all-cause mortality. About 10% of the population had stage 1 or 2 chronic kidney disease. Because most of these people did not have diabetes or hypertension, conditions most likely to prompt screening for kidney dysfunction, they may be easily missed based on current practices. A comprehensive, evidence-based Canadian guideline for screening adults for chronic kidney disease would be useful to optimize early intervention and secondary prevention of chronic kidney disease and its associated outcomes.

Table 4: Proportion of adults with and without albuminuria, by estimated glomerular filtration rate (eGFR) group

| Albuminuria present‡ | eGFR group,* mL/min per 1.73 m²; no. (%) of participants† | | | |
	≥ 90	60–89	< 60	All
Yes	238 (10.1)	116 (8.9)	39 (27.6)	393 (10.3)
No	2088 (89.9)	984 (91.1)	108 (72.4)	3180 (89.7)
All	2326 (100.0)	1100 (100.0)	147 (100.0)	3573 (100.0)

*Measured by means of Chronic Kidney Disease Epidemiology Collaboration equation. Missing observations = 100.
†Numbers are unweighted; percentages are weighted.
‡Defined as a urine albumin:creatinine ratio of > 2.0 mg/mmol for men or > 2.8 mg/mmol for women. Missing observations = 16.

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