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A large decrease in the prevalence of chronic kidney disease among the older Polish population. Results from two national cross-sectional studies: PolSenior (2009) and PolSenior2 (2019)

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Abstract

Background

Data on the epidemiology of chronic kidney disease (CKD) in Eastern and Central Europe are scarce. Two population-based studies with a similar methodology – PolSenior – PS (2009) and PolSenior2 – PS2 (2019) – provided a unique opportunity for assessing CKD trends in the older Polish population over the last decade and to identify explanatory factors.

Methods

Among participants in the PS (N = 3881) and PS2 (N = 4779) serum creatinine and urinary albumin-to-creatinine ratio (ACR) enable to distinguish subjects with CKD, classified according to standard eGFR (< 60 ml/min/1.73 m²) criteria, and age-adjusted eGFR criteria (< 45 ml/min/1.73 m²) and ACR ≥ 30 mg/g.

Results

The prevalence of CKD across the decade (PS vs. PS2), adjusted for demographic changes, decreased from 39.8% by 18.1 percentage points using the standard eGFR criteria, and from 19.0% by 6.0 percentage points using age-adjusted criteria. CKD subjects were older in the PS2 vs PS by 3.8 and 2.7 years on average, using two different diagnostic criteria. The percentage of subjects with hypertension treated with ACE-I/ARB in the PS2 vs PS increased mainly in non-CKD participants. In the PS2, blood pressure control improved, and the rate of subjects with uncontrolled hypertension decreased in both CKD and non-CKD compared with the PS study.

Conclusions

Our data show that, after a decade, the Polish population with CKD became significantly older, likely reflecting the widespread implementation of nephroprotective drugs, improved blood pressure control, and better survival in subjects with arterial hypertension.

Background

The global prevalence of chronic kidney disease (CKD), estimated at 9.1% of the worldwide population, is increasing in parallel with the aging of societies. From 1990 to 2017, the prevalence increased by 29.3%, while the age-standardized rate remained stable [1]. Diabetes mellitus and arterial hypertension are the leading causes of CKD with progression to end-stage kidney disease (ESKD) [2]. In the pre-pandemic period, the effect of CKD on cardiovascular diseases resulted in 2.6 million deaths yearly, and 35.8 million disability-adjusted life-years (DALYs). However, according to these statistics, the increase in disease burden in several regions, including central, eastern, and western Europe, was lower than

expected [3]. High mortality rates among hemodialysis patients during the early COVID-19 pandemic led to a transient decline in the number of treated patients, estimated at 9.6% in Poland at the end of 2021 compared to the prepandemic period (2019) [4].

It is well established that CKD, as a non-traditional risk factor, is associated with an increased risk for cardiovascular disease (CVD) mortality, which is further multiplied by the coexistence of hypertension and diabetes mellitus (DM) [5–7]. Early detection and effective treatment of CKD (nephroprotection), DM, and hypertension may slow or even prevent progression to ESKD and improve cardiovascular outcomes [8–10].

Data on CKD epidemiology in Eastern and Central Europe are scarce. The first Polish epidemiological study assessing the prevalence of CKD in the adult population was the PolNef study (2004–2006), which estimated the prevalence of albuminuria > 20 mg/L among adult inhabitants of a single town (Starogard) at 15.6% [11]. The first population-based study performed in Eastern Europe was PolSenior – PS (2007–2010), which assessed CKD prevalence at 29.4% in people aged 65 years and older, based on the estimated glomerular filtration rate (eGFR) threshold of 60 ml/min 1.73m^2 and urinary albumin-to-creatinene ratio (ACR) ≥ 30 mg/g assessment [12]. A decade later, a population-based study with a similar methodology – PolSernior2 – PS2 (2018–2019) [13] – provided a unique opportunity to examine CKD trends before the widespread implementation of modern nephroprotection in Europe.

This analysis aimed to assess changes in the epidemiology of CKD in the older Polish population over the last decade and to identify explanatory factors based on two cross-sectional studies PS and PS2.

Methods

The PolSenior (PS) and Polsenior2 (PS2) studies were nationwide, population-based projects that analyzed various medical and socioeconomic aspects of aging in a carefully selected cohort of individuals aged 65 or older in Poland. The methodologies in both studies were similar and based on a multistage, stratified, and clustered sampling design. The PS study enrolled subjects mostly in 2009, while the PS2 study enrolled subjects in 2019. Equally sized age cohorts of men and women (aged 65–69, 70–74, 75–79, 80–84, 85–89, and 90+) were enrolled [13–14]. The study protocols included questionnaires, anthropometric measurements, and blood pressure measurements, all conducted by trained nurses during three visits to participants' homes. Additionally, blood and urine samples were collected for laboratory testing. Medical, socio-economic, and self-completed questionnaires are described elsewhere [13–14]. The projects were approved by the Independent Bioethics Commissions of the Medical University of Silesia (PS – KNW-6501-38/I/08) and the Medical University of Gdansk (PS 2 – NKBBN/257/2017).

The study flow analysis is presented in Fig. 1.

Data analysis

Chronic kidney disease (CKD) was diagnosed in participants with an eGFR below 60 ml/min/1.73 m^2, and/or ACR ≥ 30 mg/g. According to the NKF-K/DOQI recommendations [15] and maintained by the KDIGO guidelines from 2024 [16], CKD stages were divided based on eGFR: G1-2 (≥ 60), G3A (45–59), G3B (30–44), G4 (15–29), and G5 (< 15 ml/ min/1.73 m^2). In addition, we subdivided the G3A stage into two groups: those with ACR ≥ 30 mg/g – G3A Alb (+), and those with ACR < 30 mg/g – G3A Alb (-).

eGFR values were calculated using the $MDRD_{full}$ formula [17] for PS and the CKD-EPI formula [18] for PS2, because the two studies used different methods to measure serum creatinine concentration. In the PS, we used the Jaffe method (Modular PPE, Roche Diagnostics GmbH, Mannheim, Germany). In the second project (PS2), an enzymatic method standardized for IDMS (Atellica Solution Immunoassay & Clinical Chemistry Analyzers, Siemens Healthineers) was employed.

We applied standard criteria for eGFR, with a cut-off of < 60 ml/min/1.73 m^2, and age-adjusted criteria for eGFR < 45 ml/min/1.73 m^2, as per Delanaye et al. [19], to account for age-related kidney function decline [20].

Hypertension was diagnosed based on the use of antihypertensive medication and the average of 4 measurements performed on two separate visits, according to the ESH/ESC Guidelines for the Management of Arterial Hypertension [21].

Obesity was defined according to WHO criteria, based on body mass index (BMI) ≥ 30.0 kg/m^2 [22].

Diabetes was diagnosed based on the use of antidiabetic medications or a fasting serum glucose level ≥ 126 mg/dl [23].

Data concerning heart failure (HF), kidney stones, recurrent urinary tract infections, and a history of stroke were analyzed based on the participants' reports and hospital discharge cards.

Statistical analysis

Statistical analyses were performed using SAS 9.4 TS Level 1M5 (SAS Institute, Cary, NC, USA) and the R version 3.6.3 R (R Foundation for Statistical Computing, Vienna, Austria). The qualitative data were presented as numbers and percentages or percentages with 95% confidence intervals. The quantitative data were presented as means with 95% confidence intervals (CI).

Sampling weights and age-standardization were used to adjust for demographic changes over the decade. Each respondent was assigned a weight, defined as the estimated number of people in the target population in a two-step procedure. In the first step, a base weight was calculated, defined as the inverse of the probability of selecting a respondent from the population. In the second step, a corrective weight was calculated to account for disparities in the age and gender distributions between the sample and the population. The R 'survey' package was used in part of the statistical calculations to account for the complex survey design. An univariate logistic regression models were used to determine the

association between the binary dependent variable and covariates. The proportions were compared with a χ^2-test. We also performed the Cochran-Armitage test for trend.

The comparison of odds ratios across the PS and PS2 studies has been performed using the Breslow-Day-Tarone test for homogeneity of odds ratios across strata. A *p*-value less than 0.05 indicated heterogeneity in the odds ratios and thus a statistically significant effect of the study on the odds ratio (difference between odds ratios).

All tests were two-tailed. For all statistical analyses, the level of significance was set at 0.05.

Results

The prevalence of CKD in the Polish population aged 65 and older

The prevalence of CKD, for both eGFR thresholds (< 60 or < 45 ml/min/1.73 m^2), decreased substantially in the cohort analyzed in the PS2 (2019) compared with the previous study (PS 2009). For eGFR < 60 ml/min/1.73 m^2 and/or ACR ≥ 30 mg/g, the prevalence decreased from 39.8% (95% CI: 36.7–43.0) to 21.7% (95% CI: 20.3–23.2), p < 0.001. Similarly, for age-adjusted criteria (eGFR < 45 ml/min/1.73 m^2 and/or ACR ≥ 30 mg/g), a decrease was also significant, from 19.0% (95% CI: 17.0–21.1) to 13.0% (95% CI: 11.8–14.2), p < 0.001 – Table. 1.

Table 1
The prevalence of chronic kidney disease according to the two different criteria: standard (eGFR < 60 ml/min/1.73 m^2 or ACR ≥ 30 mg/g creatinine) and age-adjusted (eGFR < 45 ml/min/1.73 m^2 or ACR ≥ 30 mg/g creatinine) in the PolSenior (2007–2010) and PolSenior 2 (2017–2019) studies, weighted for the structure of the Polish population. EGFR was calculated using the $MDRD_{full}$ formula for PolSenior and the CKD-EPI formula for PolSenior 2.

	Polsenior	**Polsenior 2**	**p**
eGFR < 60 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g			
All, % (95% CI)	39.8 (36.7–43.0)	21.7 (20.3–23.2)	< 0.001
Men, % (95% CI)	35.5 (29.6–41.3)	20.4 (18.4–22.3)	< 0.001
Women, % (95% CI)	42.8 (39.5–46.1)	22.7 (20.6–24.7)	< 0.001
eGFR < 45 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g			
All, % (95% CI)	19.0 (17.0-21.1)	13.0 (11.8–14.2).	< 0.001
Men, % (95% CI)	18.6 (15.7–21.4)	12.7 (11.2–14.1)	< 0.001
Women, % (95% CI)	19.4 (16.7–22.1)	13.2 (11.7–14.8)	< 0.001

The prevalence of CKD has decreased in both women and men (Table 1). However, the observed greater prevalence of CKD in women in the PS project, scored with an eGFR < 60 ml/min/1.73 m^2 threshold ($p < 0.05$), became nonsignificant when age-adjusted criteria of CKD were applied in PS2 study (Table 1).

The CKD subjects in PS2 were older than those in the PS cohorts, as assed by standard and age-adjusted criteria (by 3.8 and 2.7 years, respectively). This older age in subjects with CKD in PS2 was also evident across all age strata (Table 2). In addition, the comparison between both cohorts showed a decrease in CKD prevalence in all age cohorts except the oldest-old group (age > 90 years). Narrow 95% confidence intervals for CKD prevalence indicate high accuracy of the obtained estimates. A similar pattern of age changes across the two studies, PS and PS2, was observed in both men and women (Fig. 2). Notably, the greatest changes occurred in the youngest strata.

Table 2

The frequency (%) with 95% CI of chronic kidney disease diagnosed using two eGFR thresholds (eGFR < 60 ml/min/1.73 m^2 or < 45 ml/min/1.73 m^2) and/or ACR ≥ 30 mg/g creatinine in the consecutive age groups from the two cohorts: Polsenior (2007–2010) and PolSenior 2 (2017–2019). The eGFR was cslculated using $MDRD_{full}$ formula for PolSenior and the CKD-EPI formula for PolSenior 2.

Age (years)	**eGFR < 60 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g % (95% CI)**			**eGFR < 45 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g % (95% CI)**		
	PolSenior	**PolSenior2**	**p**	**PolSenior**	**PolSenior2**	**p**
65–69	23.6 (20.4–26.8)	8.7 (7.0–10.4)	< 0.001	12.1 (9.6–14.6)	5.8 (4.4–7.2)	< 0.001
70–74	35.0 (31.6–38.4)	13.7 (11.6–15.8)	< 0.001	16.4 (13.8–19.0)	8.3 (6.6–10.0)	< 0.001
75–79	41.6 (37.9–45.3)	29.0 (26.0–32.0)	< 0.001	19.9 (16.9–22.9)	15.1 (12.7–17.5)	< 0.05
80–84	54.1 (50.1–58.1)	38.9 (35.5–42.3)	< 0.001	27.9 (24.3–31.5)	20.1 (17.3–22.9)	< 0.001
85–89	60.8 (57.1–64.5)	52.0 (47.9–56.1)	0.002	37.0 (33.3–40.7)	32.0 (28.1–35.8)	0.07
≥ 90	70.0 (66.2–73.8)	68.3 (64.0–72.5)	0.58	49.4 (45.2–53.7)	47.1 (42.5–51.7)	0.48

The structure of CKD stages

There were only minor changes in the structure of CKD stages between the two cohorts – a mild shift in the percentage of albuminuric G3A (decline) to G1-2 participants (increase), and a borderline decrease in the rate of non-albuminuric G3A in the PS2 cohort (Table 3).

Table 3
The structure of CKD in the PolSenior (2007–2010) and PolSenior 2 (2017–2019) cohorts. The eGFR was calculated based on the $MDRD_{full}$ formula for PolSenior and the CKD-EPI formula for PolSenior 2.

CKD stage	PolSenior N = 3881	PolSenior2 N = 4779	P
Non-CKD, N	2117	3403	
G1-2 Alb (+), N (%)	319 (18.1)	302 (21.9)	< 0.01
G3A Alb (-), N (%)	764 (43.3)	548 (39.8)	0.054
G3A Alb (+), N (%)	172 (9.8)	106 (7.7)	0.052
G3B, N (%)	406 (23.0)	322 (23.4)	0.83
G4, N (%)	92 (5.2)	87 (6.3)	0.21
G5	11 (0.6)	11 (0.8)	0.71

Co-morbidity in CKD subjects

There was a higher prevalence of hypertension, heart failure, diabetes mellitus, and history of past strokes or kidney stones in CKD participants than in non-CKD participants in both PS and PS2 cohorts, regardless of the used criteria. In addition, in the PS2 cohort, CKD participants were more likely to be obese than those without CKD. Furthermore, there was a greater increase in the percentage of diabetes mellitus and past stroke in CKD than in non-CKD participants in both studies (Table 4a and b).

The comparative analysis of study cohorts revealed an increased impact of a history of kidney stones or diabetes on the occurrence of CKD diagnosed using age-adjusted criteria in the PS2 cohort.

The rates of hypertension, heart failure, and past stroke between CKD and non-CKD participants remained unchanged in the PS2 cohort in comparison to the PS study. On the other hand, the percentage of subjects with hypertension treated with ACE-I/ARB increased mainly in non-CKD participants in the PS2 cohort in comparison to the PS study. Notably, blood pressure (BP) control improved (both systolic (SBP) and diastolic (DBP) blood pressure values as well as the percentage of those with uncontrolled hypertension, decreased) in the PS2 cohort in comparison to the PS study (Table 4a and b). The observed decrease in BP values in the PS2 cohort was similar in CKD participants (-4.4 to -5.2 and − 5.2 to -7.0 mmHg for SBP and DBP) and in non-CKD participants (-5.2 to -5.5 and − 6.0 to -6.2 mmHg for SBP and DBP). In parallel, the percentages of participants with uncontrolled hypertension decreased from 73.4% and 75.6% to 54.9% and 55.8% in CKD, and from 78.6% and 77.4% to 56.7% and 56.4% in non-CKD, for standard and age-adjusted eGFR thresholds (Table 4a and b).

Table 4

a: Prevalence (%) of comorbidities in participants with and without chronic kidney disease (CKD) in PolSenior (2007–2010) and PolSenior 2 (2017–2019) studies. CKD defined according to general criteria: eGFR < 60 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g creatinine. Weighed means with 95% CI in brackets.

	PolSenior			**PolSenior 2**			**OR difference**
	Non-CKD	**CKD**	**OR (95% CI)**	**Non-CKD**	**CKD**	**OR (95% CI)**	**p**
Age, years (95% CI)	72.3 (71.9–72.7)	76 (75.3–76.7) *	-	72.4 (72.3–72.6)	79.8 (79.3–80.3) *#	-	–
Women, N (%)	934 (44.1)	940 (51.3) *	1.33 (1.18–1.51)	1726 (50.7)	699 (49.5)	0.95 (0.84–1.08)	< 0.001
Hypertension, N (%)	1497 (70.9)	1397 (76.7) *	1.35 (1.17–1.56)	2633 (77.4)	1182 (84.1) *	1.54 (1.30–1.81)	0.25
Treated with ACE-I or ARB, N (%)	802 (38.5)	915 (50.8) *	1.65 (1.45–1.87)	1553 (45.6)	745 (52.8) *	1.33 (1.18–1.51)	< 0.05
SBP mmHg (95% CI)	144.6 (142.9-146.2)	144.8 (142.6–147.0)	-	139.1 (138.1-140.1) ^	140.4 (138.4-142.4) #	-	–
DBP mmHg (95% CI)	85.1 (84.2–85.9)	83.9 (83-84.9)	-	78.9 (78.4–79.4) ^	76.9 (75.9–77.9) *#	-	–
Uncontrolled hypertension (SBP > 140 or DBP > 90)	1178 (78.6)	1025 (73.4)	0.75 (0.63–0.89)	1495 (56.7) ^	650 (54.9) #	0.93 (0.81–1.07)	0.06
Heart failure, N (%)	405 (20.1)	670 (42.4) *	2.93 (2.53–3.40)	611 (18.2)	499 (35.8) *	2.52 (2.19–2.89)	0.14
Past stroke, N (%)	136 (6.4)	195 (10.7) *	1.73 (1.38–2.18)	265 (7.8) ^	206 (14.6) *#	2.05 (1.69–2.49)	0.28
Obesity – BMI \≥ 30.0, N (%)	668 (32.4)	546 (32.2)	0.99 (0.86–1.13)	1216 (36.3)	486 (36.5) *	1.01 (0.89–1.15)	0.82
Diabetes, N (%)	316 (15.0)	397 (21.9) *	1.59 (1.35–	730 (21.5) ^	458 (32.5)	1.76 (1.53–	0.35

Statistical differences: *CKD vs Non-CKD #PS2 vs PS for CKD, ^PS2 vs PS for Non-CKD; CI – confidence interval

	PolSenior			PolSenior 2			OR difference
	Non-CKD	CKD	OR (95% CI)	Non-CKD	CKD	OR (95% CI)	p
			1.87)		*#	2.02)	
Undiagnosed diabetes, N (%)	77 (3.6)	80 (4.4)	-	84 (2.5)	52 (3.7)	-	–
History of kidney stones, N (%)	198 (9.4)	226 (12.4) *	1.38 (1.12–1.68)	291 (8.6)	229 (16.3) *	2.14 (1.77–2.57)	< 0.01
Recurrent urinary tract infections, N (%)	143 (6.8)	114 (6.2)	0.92 (0.71–1.19)	453 (13.3) ^	202 (14.4) #	1.12 (0.93–1.33)	0.22

Statistical differences: *CKD vs Non-CKD #PS2 vs PS for CKD, ^PS2 vs PS for Non-CKD; CI – confidence interval

Table 4

b: Prevalence (%) of comorbidities in participants with and without chronic kidney disease (CKD) in PolSenior (2007–2010) and PolSenior 2 (2017–2019) studies. The CKD defined according to age-adjusted criteria: eGFR < 45 ml/min/1.73 m^2 and /or ACR ≥ 30 mg/g creatinine. Weighed means with 95% CI in brackets.

	PolSenior			**PolSenior 2**			**OR difference**
	Non-CKD	**CKD**	**OR (95% CI)**	**Non-CKD**	**CKD**	**OR (95% CI)**	**p**
Age, years (95% CI)	72.9 (72.7–73.2)	77.1 (76.4–77.7) *		73.1 (73.0-73.2)	79.8 (79.2–80.5) *#		–
Women, N (%)	1342 (46.6)	501 (49.5)	1.12 (0.97–1.30)	2014 (51.0)	390 (47.0)	0.85 (0.73–0.99)	< 0.01
Hypertension, N (%)	2092 (72.8)	772 (76.7) *	1.23 (1.04–1.46)	3091 (78.3)	700 (84.6) *	1.52 (1.24–1.87)	0.11
Treated with ACE-I or ARB, N (%)	1200 (42.3)	496 (50.1) *	1.37 (1.18–1.58)	1857 (47.0)	427 (51.4) *	1.19 (1.03–1.39)	0.20
SBP, mmHg (95% CI)	144.2 (142.5–146)	147.0 (144.9-149.1) *	-	139.0 (138.1–140) ^	141.8 (138.9-144.7) #	-	–
DBP, mmHg (95% CI)	84.7 (83.8–85.5)	84.6 (83.3–86)	-	78.7 (78.2–79.2) ^	77.1 (75.9–78.3) *#	-	–
Uncontrolled hypertension (SBP > 140 mmHg or DBP > 90 mmHg)	1600 (76.4)	584 (75.6)	0.96 (0.79–1.16)	1743 (56.4) ^	392 (55.8) #	0.98 (0.83–1.15)	0.89
Heart failure, N (%)	647 (23.7)	409 (50.0) *	3.22 (2.74–3.79)	784 (20.1)	317 (38.7) *	2.50 (2.13–2.94)	< 0.05
Past stroke, N (%)	206 (7.2)	116 (11.5) *	1.68 (1.32–2.14)	332 (8.4) ^	134 (16.1) *	2.10 (1.69–2.61)	0.17
Obesity – BMI \≥ 30.0, N (%)	930 (33.3)	273 (29.8)	0.85 (0.72-1.00)	1406 (36.2)	289 (37.3) *	1.05 (0.89–1.23)	0.08

Statistical differences: *CKD vs Non-CKD #PS2 vs PS for CKD, ^PS2 vs PS for Non-CKD; CI – confidence interval

	PolSenior			PolSenior 2			OR difference
	Non-CKD	CKD	OR (95% CI)	Non-CKD	CKD	OR (95% CI)	p
Diabetes, N (%)	466 (16.2)	238 (23.9) *	1.62 (1.36–1.93)	857 (21.7)	322 (38.8) *#	2.29 (1.95–2.68)	< 0.01
Undiagnosed diabetes, N (%)	104 (3.6)	47 (4.7)	-	107 (2.7)	26 (3.1)	-	–
History of kidney stones, N (%)	275 (9.6)	144 (14.2)	1.59 (1.28–1.98)	361 (9.2)	155 (18.8) *	2.35 (1.91–2.88)	< 0.05
Recurrent urinary tract infections, N (%)	193 (6.7)	62 (6.1)	0.91 (0.68–1.23)	530 (13.4) ^	122 (14.8) #	1.13 (0.91–1.40)	0.25
Statistical differences: *CKD vs Non-CKD #PS2 vs PS for CKD, ^PS2 vs PS for Non-CKD; CI – confidence interval							

Discussion

In the present study we were able to demonstrate that that the prevalence of CKD in older Polish population across the decade (between 2009 and 2019), adjusted for demographic changes, decreased from 39.8% by 18.1 percentage points using the standard criteria (eGFR < 60 ml/min/1.73 m^2 and/or ACR ≥ 30 mg/g), and from 19.0% by six percentage points, using age-adjusted criteria (eGFR < 45 ml/min/1.73 m^2 and/or ACR ≥ 30 mg/g). As shown, CKD subjects in the PS2 cohort were 3.8 and 2.7 years older than in the PS study, using standard and age-adjusted criteria, respectively. Only in the oldest age strata (> 90 y.o.), in both men and women, the frequency of CKD remained unchanged. These data reflect improvements in cardiovascular and CKD prevention, increased effectiveness of interventions, and the affordability of kidney-protective drugs for younger, high-risk adults. As a consequence, the predicted increase in CKD burden, related to the population ageing [9] will require revision, especially when the inevitable process of age-related kidney decline is taken into account [20]. There is an urgent need to verify whether the isolated moderate decrease in glomerular filtration rate (45–60 ml/min/1.73 m^2) estimated based on the commonly used formula (CKD-EPI) is associated with increased cardiovascular risk independently of comorbidities and their management in the oldest part of the population.

The observed older age of CKD in the PS2 cohort did not affect the structure of CKD stages, which remained essentially unchanged, with the highest rates in stages G3A and G3B. The only change was a significant increase (from 18.1% by 3.8 percentage points) in albuminuric G1-2 subjects, and a borderline opposite trend (from 9.8% by 2.1 percentage points) in albuminuric G3A.

The comparative analysis of PS study cohorts revealed stable rates of hypertension, heart failure, and past stroke episodes in CKD subgroups, and an increasing rate of a history of kidney stones or diabetes using age-adjusted CKD criteria. The use of ACE-I/ARB increased significantly only among non-CKD participants, resulting in improved blood pressure control. The percentages of participants with uncontrolled hypertension significantly decreased from 73.4% and 75.6% to 54.9% and 55.8% in CKD, and from 78.6% and 77.4% to 56.7% and 56.4% in non-CKD, for both standard and age-adjusted eGFR criteria. We suppose that the widespread use of antihypertensive drugs, including ACE-I or ARB and other modern nephroprotection like sodium-glucose transport proteins 2 (SGLT2) inhibitors, with improvement of blood pressure control, was the trigger for the age shift in the incidence of CKD in the population of Polish older adults, which led to the reduction in CKD rates in younger age groups. Our findings are consistent with the current state of renal replacement therapy in Poland [4]. Despite the progressive aging of the population, since 2017, the rates of starting renal replacement therapy have plateaued at about 150 pmp, excluding a short decline during the COVID-19 pandemic (2020–2021) [4]. The incidence of end-stage renal disease (ESRD) in Poland is lower compared to that for White individuals in the US, estimated at 248 pmp in 2022 [24]. The explanation for this discrepancy is complex, but it appears to be primarily related to the lower prevalence of obesity and its complications in the Polish older adult population. In 2021, the prevalence of obesity in the US was rising with age, peaking at 48.7% for women aged 50–54 years, and 46.8% among men aged 45–49 years. In adults aged 65–69 years, 42.9% (95% CI: 37.7–48.0%) of men and 47.0% (95% CI: 40.5–53.3%) of women were obese. In Poland, the prevalence of obesity in 65-year-olds and older was estimated at 39.9% [25]. However, over a decade, general obesity increased by 2.1%, primarily due to a 3.9% increase in men [25].

The strongest data describe the prevalence of ESKD (patients on hemodialysis, peritoneal dialysis, and living with a kidney graft). In Poland in 2024, the prevalence was 991 pmp. Since 2010, the rate has increased from 694 pmp, mainly due to a rise in the number of transplanted patients (+ 75.6%) [4]. The United States Renal Data System (USRDS) showed a 31.3% increase in newly registered ESRD between 2002 and 2022; however, age-adjusted rates fell by 18.6% during this period. These data support a delay in the onset of ESKD related to the improvement of nephroprotective therapies, regardless of unfavorable forecasts for the obesity pandemic. Increasing awareness of CKD may improve adherence to nephroprotective therapies. Awareness was low in the first PS cohort (3.2%) [12], which corresponds with high rates of undiagnosed stage 3 CKD in France (95.5%), Germany (84.3%), and Italy (77.0%) [26]. The awareness was not assessed in the second cohort; however, even if it has improved, there is still a lot to do in this regard.

We can expect further improvement in CKD epidemiology with the broader implementation of sodium-glucose cotransporter-2 inhibitors (SGLT2i) and other modern nephroprotective drugs. SGLT2 inhibitors were initially used to treat diabetes mellitus and, since 2022, have been recommended for the management of CKD [10]. The analysis of medications revealed no SGLT2i prescriptions among PS2 participants. Further improvement may be expected with the implementation of finerenone and glucagon-like peptide 1 (GLP-1) agonists, which were approved in the European Union in 2022, in line with CKD-KDIGO guidelines [16].

Study limitations relate to changes in the methodology for serum creatinine concentration assessment in the PS2 project compared to that used in the PS study. As recommended by CKD-KDIGO guidelines [16], the old Jaffa method utilised in the first project was replaced with an enzymatic assay. As a consequence, the equation used for eGFR estimation was changed from $MDRD_{full}$ to CKD-EPI. This may be considered an important, but inevitable, source of bias. A similar change in the methodology was reported in the NHANES project [27]. For longitudinal analyses, this was solved by calculating conversion rates for serum creatinine levels after reassessment using the newer method in a subset of stored, frozen samples [27]. We decided to use validated but different equations for eGFR < 60 ml/min/1.73 m^2, appropriate for the methodology of creatine assessment. Both methods applied in the NHANES and PS projects generate some bias. Therefore, reported changes in CKD prevalence over time can be smaller than reported. Moreover, our study analyzed numerous established and potential factors that might influence changes in CKD prevalence.

Conclusions

In conclusion, our data show that, after a decade, the Polish population with CKD became significantly older, likely reflecting the widespread implementation of nephroprotective drugs, improved blood pressure control, and better survival in subjects with arterial hypertension.

Abbreviations

ACE-I/ARB - A*ngiotensin-Converting Enzyme Inhibitors/Angiotensin Receptor Blockers*

ACR - albumin-to-creatinine ratio

CKD - chronic kidney disease

KDIGO - Kidney Disease: Improving Global Outcomes

CKD-EPI - Chronic Kidney Disease Epidemiology Collaboration

CVD - cardiovascular disease

DALYs - disability-adjusted life-years

DBP – diastolic blood pressure

DM – diabetes mellitus

eGFR - estimated glomerular filtration rate

ESKD - end-stage kidney disease

GLP-1 - **Glucagon-Like Peptide-1**

HF - heart failure

NHANES - National Health and Nutrition Examination Survey

PS - Polsenior

PS2 – Polsenior 2

SBP – systolic blood pressure

SGLT2 - S**odium-Glucose Cotransporter 2**

USRDS - United States Renal Data System

WHO - World Health Organization

Declarations

Ethics approval and consent to participate

The projects were approved by the Independent Bioethics Commissions of the Medical University of Silesia (PS – KNW-6501-38/I/08) and the Medical University of Gdansk (PS 2 – NKBBN/257/2017).

All procedures were performed in accordance with relevant guidelines and regulations (Declaration of Helsinki) after obtaining informed consent from the participant or caregiver.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Conceptualization (J.T.C.), data curation (Ł.W., M.M.), formal analysis and software (K.J. and A.J.O.), funding acquisition (M.M and T.Z.), methodology (J.T.C, K.J.), supervision (A.W.), validation (M.M.), visualization (A.J.O.), writing – original draft (J.T.C.), and writing – review & editing (A.D-Ś., K.W-T., A.O., and A.W.). All authors approved the final version of the manuscript.

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Figures

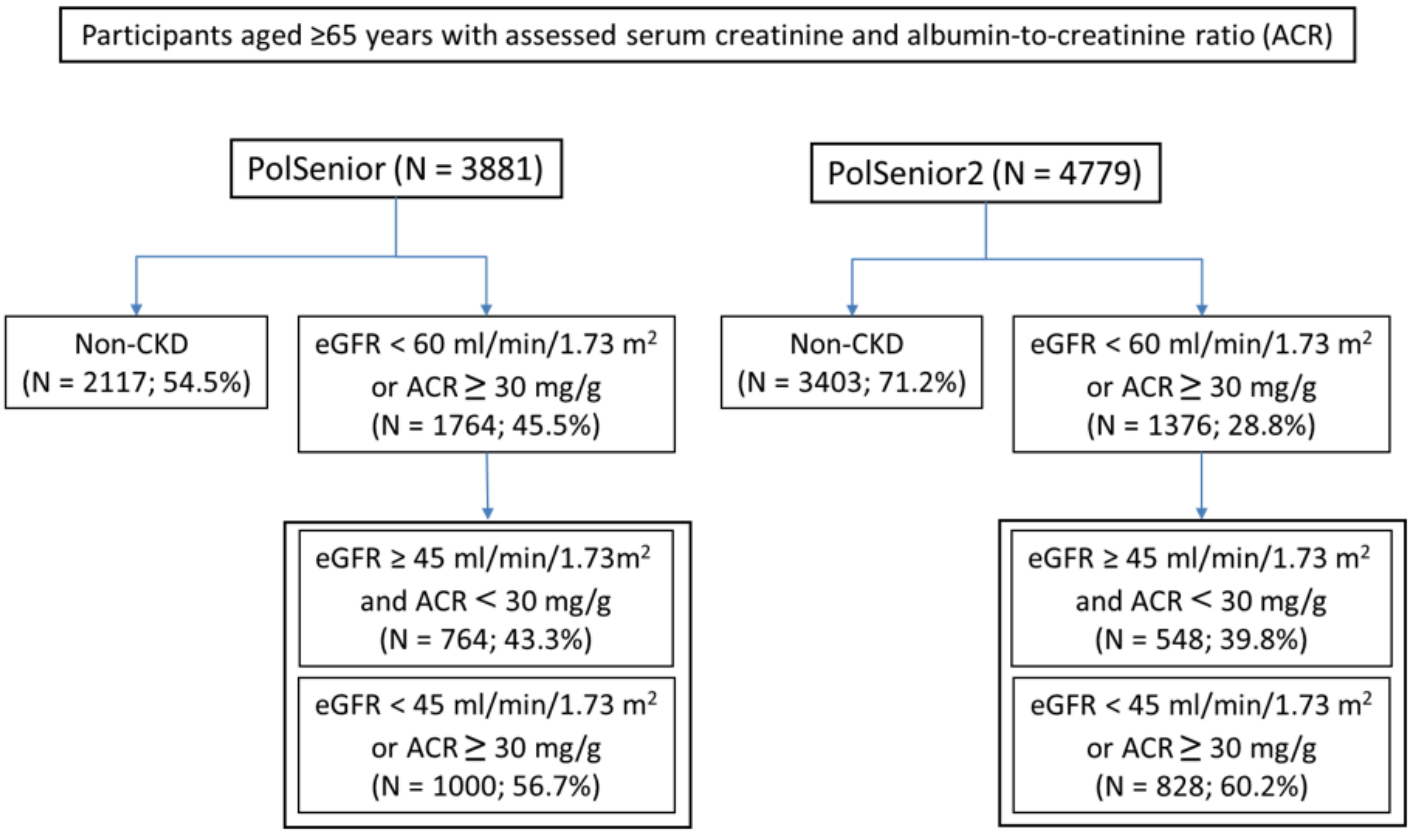


Figure 1

Flow chart of analysis of both study cohorts (Polsenior and Polsenior2). The analysis distinguished subgroups of subjects with chronic kidney disease, categorized according the definition maintained by KDIGO 2024[16] or based on age-adapted eGFR thresholds for CKD diagnosis[19] eGFR < 45 ml/min/1.73 m² and/or ACR ≥ 30 mg/g (age-adjusted criteria), and those with eGFR ≥ 45 ml/min/1.73 m² and ACR < 30 mg/g (non-meeting age-adjusted criteria).

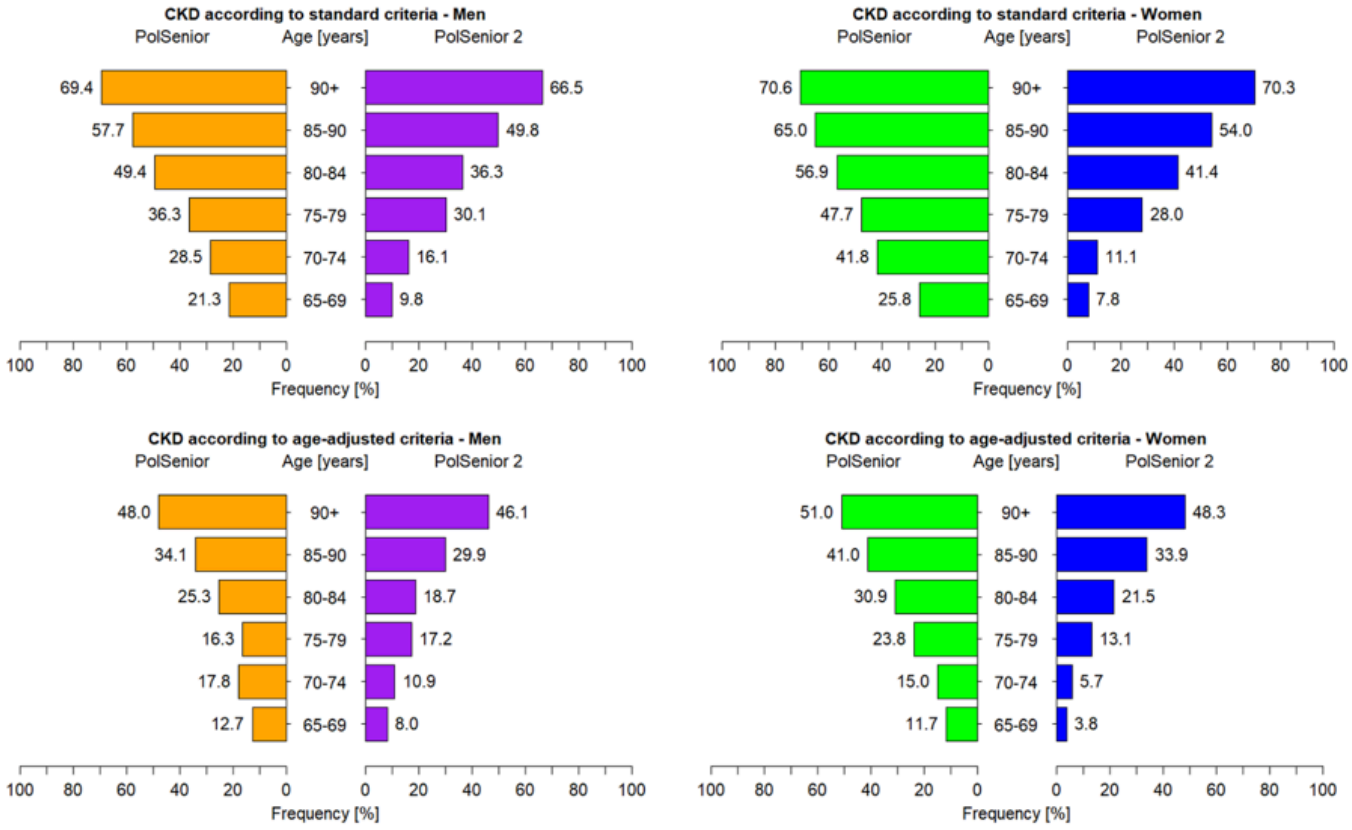


Figure 2

Frequency of chronic kidney disease (eGFR < 60 ml/min/1.73 m^2 and/or ACR ≥ 30 mg/g creatinine) in women and men, in the consecutive age groups from the two cohorts: Polsenior (2007-2010) and PolSenior 2 (2017-2019). The eGFR was cslculated using $MDRD_{full}$ formula for PolSenior and the CKD-EPI formula for PolSenior 2.