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Prevalence and trends of chronic kidney disease and its risk factors among US adults: An analysis of NHANES 2003-18

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ABSTRACT

Chronic kidney disease (CKD) is a leading cause of mortalities, morbidities, and health-care costs in the United States; however, limited number of recent studies estimated the burden of CKD and its risk factors together. This cross-sectional study estimated the age-adjusted prevalence and trends of CKD and its risk factors, and the prevalence and trends of CKD according to presence of risk factors.

We analyzed National Health and Nutrition Examination Survey 2003–18 data. Individuals aged ≥20 years with albumin-creatinine ratio ≥30 mg/g or glomerular filtration rate < 60 ml/min/1.73 m^2 were considered to have CKD. Following variables were considered as risk factors: hypertension, diabetes, high total cholesterol, high triglyceride, low high-density lipoprotein (HDL), obesity, abdominal obesity, insufficient aerobic physical activity (PA), and current tobacco smoking. Trends were compared by chi-square tests.

The age-adjusted prevalence (95% confidence interval) for CKD was 14.1% (13.1%–15.0%), 13.0% (12.3%–13.8%), 14.0% (13.0%–15.1%), and 13.3% (12.3%–14.4%) in 2003–06, 2007–10, 2011–14, and 2015–18, respectively (p[trend] = 0.24, N = 39569). This prevalence change was also minimal for most CKD stages. Non-Hispanic blacks and low-income people had a higher prevalence than all other races/ethnicities and income groups in most periods. Among risk factors, the prevalence of diabetes, high triglyceride, high total cholesterol, low HDL, obesity, abdominal obesity, and metabolic syndrome increased (p[trend] < 0.05). The prevalence of hypertension remained static. The prevalence of current tobacco smoking and insufficient aerobic PA declined.

The age-adjusted prevalence of CKD has plateaued; however, the prevalence of some risk factors is increasing. Reducing the burden of these risk factors is also essential to reduce the prevalence of CKD.

1. Introduction

Chronic kidney disease (CKD) is the damage of kidney function or glomerular filtration rate (GFR) lower than 60 ml/min/1.73 m^2, irrespective of cause for three or more months (Levey et al., 2005). Because of its asymptomatic nature during the initial stages, most individuals suffering from CKD remain undiagnosed (Chen et al., 2019; Romagnani et al., 2017). The estimated prevalence of CKD among adults in the United States (US) is 15% (Murphy et al., 2016). It is a leading cause of death among US adults and a leading risk factor for cardiovascular disease, including stroke (Chen et al., 2019; Romagnani et al., 2017). In 2017, the estimated Medicare costs for CKD were more than $84 billion (Centers for Disease Control and Prevention, 2019). Due to its significant public health burden, Healthy People (HP) 2020 has set a target to reduce the age-adjusted prevalence to 13.3% by 2020 (Centers for Disease Control and Prevention, 2020). Although recent estimates suggest that CKD prevalence has plateaued (Afkarian et al., 2016; Murphy et al., 2016; Wu et al., 2016), some studies project an increase in prevalence in upcoming decades (Chen et al., 2019; Hoerger et al., 2015).

CKD has many risk factors, including diabetes, hypertension, obesity, and metabolic syndrome (Chen et al., 2019; Romagnani et al., 2017). These diseases are related and share many common risk factors. Similar to CKD, the public health burden, including mortality, morbidity, and costs resulting from these conditions, is high in the US (Centers for Disease Control and Prevention, 2020a; Horowitz et al., 2015; Muntner et al., 2017). Take diabetes as an example: in 2017, the total cost of diagnosed diabetes was estimated at $327 billion (American Diabetes Association, 2018). HP2020 has targets to reduce some of these conditions among patients with CKD. For instance, it targets to reduce the proportion of people with CKD and hypertension to 17.6% from its estimated prevalence of 22.6% (Centers for Disease

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Control and Prevention, 2020b). Since reducing the burden of these risk factors is important to reduce the burden of CKD, regularly monitoring the prevalence and trends of CKD and its risk factors is essential for health care policy and planning (Chen et al., 2019; Murphy et al., 2016; Odutayo et al., 2017). Furthermore, it is essential to estimate the CKD burden among people with these risk factors. However, there have been a limited number of recent studies that estimate these together. In this study, we aimed to identify and fill these existing literature gaps and estimated the age-adjusted prevalence and trends of CKD and its risk factors among US adults using nationally representative data. In addition, we obtained the prevalence and trends of CKD according to the presence of these risk factors.

2. Methods

2.1. Study population

We analyzed National Health and Nutrition Examination Survey (NHANES) data from 2003 to 18 survey years (Centers for Disease Control and Prevention, 2020c). This is a cross-sectional survey that aims to obtain nationally representative samples of the non-institutionalized US population to estimate prevalence of common diseases, risk factors, and nutritional status of US children and adults (National Center for Health Statistics, 2020). These publicly available datasets were downloaded from the Centers for Disease Control and Prevention's website and merged using unique identification numbers (Centers for Disease Control and Prevention, 2020c). The National Center for Health Statistics' ethics review board approved the survey protocols (National Center for Health Statistics, 2017). The examination and sample collection take place at mobile examination centers. Persons of black race and Hispanic ethnicity were oversampled. Additional survey details are available elsewhere (Centers for Disease Control and Prevention, 2020c; National Center for Health Statistics, 2020).

3. Chronic kidney disease

The CKD-Epidemiology (CKD-EPI) equation was used to calculate the glomerular filtration rate (GFR) (Levey et al., 2009). A person with a GFR of < 60 ml/min per 1.73 m^2 or urinary albumin-creatinine ratio (UACR) $\geq$ 30 mg/g was categorized as having CKD (Levey et al., 2009). In addition, to report the stages of kidney disease, the Kidney Disease Improving Global Outcomes (KDIGO) classification was used; among persons with CKD, a person was considered as stage 1, stage 2, stage 3A, stage 3B, stage 4, and stage 5 when the GFR was > 90, 60–89, 45–59, 30–44, 15–29, and < 15 ml/min per 1.73 m^2, respectively. According to KDIGO classification, the UACR was $\geq$30 mg/g for individuals with stages 1 and 2 (Levey et al., 2005; Wu et al., 2016). Serum creatinine was calibrated by using provided calibration equations; it was required only for 2005–06 survey period. The calibration process, equations, and laboratory measurements in NHANES are available elsewhere (Centers for Disease Control and Prevention, 2015; Murphy et al., 2016).

4. Risk factors

The prevalence and trends of the following risk factors for CKD were reported: hypertension, diabetes, high total cholesterol, low high-density lipoprotein (HDL), obesity, abdominal obesity, metabolic syndrome, insufficient aerobic physical activity (PA), and current tobacco smoking.

To calculate hypertension, both the 2017 American College of Cardiology/American Heart Association (ACC/AHA) and Seventh Joint National Committee (JNC7) guidelines' cutoffs were used (Chobanian et al., 2003; Whelton et al., 2018). Per 2017 ACC/AHA and JNC7 guidelines, hypertension was defined as a systolic/diastolic blood pressure (SBP/DBP) $\geq$130/80 and $\geq$140/90 mm Hg, respectively (Chobanian et al., 2003; Whelton et al., 2018). Per both guidelines, a person was also considered hypertensive if s/he reported taking any antihypertensive medication (Whelton et al., 2018). As the ACC/AHA hypertension guideline was released in late 2017, both 2017 ACC/AHA and JNC7 cutoffs were used to compare the prevalence by the recommended cutoff for the survey periods (Chobanian et al., 2003; Whelton et al., 2018). Diabetes was defined as glycohemoglobin $\geq$6.5%, previous diagnosis by a doctor of having diabetes, or self-report of taking antidiabetic drugs (Odutayo et al., 2017). Borderline elevated and high total cholesterol levels were defined as 200–239 and $\geq$240 mg/dl total cholesterol levels, respectively; persons taking antilipid drugs were also considered to have high total cholesterol level (Lee and Siddiqui, 2020).

Metabolic syndrome was defined as having at least three of the five following conditions: abdominal obesity (i.e., $\geq$102 cm for men and $\geq$88 cm for women); high serum triglycerides (i.e., $\geq$150 mg/dL); low HDL concentration (i.e., < 40 mg/dL for men and < 50 mg/dL for women); raised SBP/DBP (i.e., $\geq$135/85 mmHg); and raised fasting glucose level (i.e., $\geq$100 mg/dL). People who reported currently taking antihypertensive, antiplipid, and antidiabetic drugs were also considered to have raised BP, high triglyceride/low HDL, and raised blood glucose, respectively (Alberti et al., 2009; Moore et al., 2017).

To obtain body mass index (BMI), 'weight in kilograms' was divided by 'height in meters squared' and BMIs of 25–29 and $\geq$30 kg/m^2 were defined as cutoffs for overweight and obesity, respectively (Khosla and Lowe, 1967). Aerobic PA was obtained from participants' reports of the usual amount of time spent doing moderate, vigorous, and transportation PA in a week. The number of minutes spent performing vigorous PA was multiplied by two and added to the number of minutes performing moderate and transportation PA (Du et al., 2019). Insufficient aerobic PA was defined as having less than 150 minutes of PA in a week (Ostchega et al., 2018; U.S. Department of Health and Human Services, 2008). Study participants also reported current tobacco smoking status (Ostchega et al., 2018). Data for PA were available for survey years 2007–18 (Centers for Disease Control and Prevention, 2020c).

Participants' age, gender, race/ethnicity, and family income-to-poverty ratio were also used to describe sample characteristics. Race/ethnicity was grouped as non-Hispanic whites, non-Hispanic blacks, Hispanics, and other races/ethnicities. NHANES reports the family income-to-poverty ratio as a ratio of the family's income to poverty threshold. The poverty threshold is defined by the US Department of Health and Human Services and is measured according to the number of members in each family. A higher ratio indicates a higher level of income (Ostchega et al., 2018; U.S. Department of Health & Human Services, 2019). The total number of participants was equally stratified into three income groups: low-, middle-, and high-income. Supplemental Table 1 reports the study variables.

4.1. Statistical analysis

First, the study sample with CKD for each group of survey years was described. Continuous variables were reported as mean and standard deviation (SD) and categorical variables were reported as weighted percentages (%) and unweighted frequencies (n). To compare the continuous and categorical variables, analysis of variance and chi-square tests were used, respectively. Then, the age-adjusted prevalence and trends of kidney disease stages were reported. The age-adjusted prevalence and trends for the risk factors were also reported. Lastly, the age-adjusted prevalence and trends of CKD (any stage) by the risk factors were reported. All prevalence was reported with 95% confidence intervals (CI) and the trends were calculated using chi-square tests. We also examined the factors associated with CKD by logistic regression and reported odds ratio (OR) with 95% CI (Supplemental Table 2). In the multivariable model, we studied metabolic syndrome, aerobic PA, and smoking as potential risk factors in addition to sociodemographic factors and survey periods.

The 2000 Population Census age distributions were used to obtain

Table 1
Age-adjusted characteristics of adult study participants by survey years and chronic kidney disease status, NHANES 2003–18.

Variables	Total sample (N = 39569)	Participants with chronic kidney disease, % (N)					
		Total (n = 7161)	2003–06 (n = 1635)	2007–10 (n = 1926)	2011–14 (n = 1786)	2015–18 (n = 1814)	p-value
Age, Mean (SD), y	47 (16.8)	61 (17.3)	61 (17.8)	61 (18.6)	60 (17.1)	61 (16.0)	0.45
Female	51.6	58.2	57.7	58.3	59.7	57.2	0.78
Race/Ethnicity							
NH Whites	67.4	60.8	61.5	64.7	60.8	57.0	0.55
NH Blacks	10.8	13.9	14.1	12.9	14.2	14.1	
Hispanics	14.2	17.1	15.9	17.1	17.3	17.8	
Other	7.5	8.2	8.5	5.3	7.6	11.2	
Education level							
Below high school	16.2	21.0	21.9	24.5	21.2	17.4	0.10
High School	55.1	57.9	61.4	54.7	55.7	59.8	
College/Above	28.7	21.0	16.7	20.9	23.1	22.7	
Family income							
Low	22.5	29.9	26.3	29.1	35.8	27.3	0.048
Middle	31.1	33.7	34.8	31.9	31.3	37.0	
High	46.4	36.4	38.9	39.0	32.9	35.8	
Hypertension 2017 ACC/AHA	44.9	59.6	58.3	59.0	59.7	61.4	0.66
Hypertension JNC7	30.5	47.0	47.8	45.9	45.4	49.1	0.36
Diabetes	11.2	24.8	23.2	23.9	23.9	27.7	0.18
High cholesterol	38.3	43.2	43.2	40.3	45.9	42.6	0.58
High triglyceride	35.7	43.5	39.6	45.0	43.2	45.9	0.26
Low HDL	29.5	36.3	32.0	40.8	36.3	36.4	0.07
Obesity	36.5	46.4	42.9	43.7	44.7	53.5	0.029
Abdominal obesity	55.6	64.4	63.8	61.5	63.7	68.4	0.20
Metabolic syndrome	33.6	47.5	45.4	47.0	47.2	54.5	0.20
Insufficient aerobic PA	34.4	43.0	—	46.2	44.2	39.1	0.11
Current tobacco smoker	21.2	22.0	23.7	24.1	21.9	19.0	0.21

Abbreviations: ACC/AHA: American College of Cardiology/American Heart Association, HDL: High-density lipoprotein, JNC7: Seventh Joint National Committee, PA: Physical activity, NH: Non-Hispanic, SD: Standard deviation, NHANES: National Health and Nutrition Examination Survey.
Hypertension according to the 2017 American College of Cardiology/American Heart Association guideline was defined as a systolic/diastolic blood pressure ≥130/80 mmHg or self-report of any taking antihypertensive drugs.
Hypertension according to the Seventh Joint National Committee guideline was defined as a systolic/diastolic blood pressure ≥140/90 mmHg or self-report of taking any antihypertensive drugs.
The high total cholesterol level was defined as ≥240 mg/dl total cholesterol level. High serum triglycerides was defined as ≥150 mg/dL. Low high-density lipoprotein concentration was defined as < 40 mg/dL for men and < 50 mg/dL for women. Any person reported taking antilipid drugs was also defined as having high total cholesterol, high serum triglyceride, or low high-density lipoprotein.
Obesity was defined as body mass index of ≥30 kg/m^2.
Abdominal obesity was defined as ≥102 cm for men and ≥ 88 cm for women.
Metabolic syndrome was defined as having at least 3 of the 5 following conditions: abdominal obesity (defined above); high serum triglycerides (defined above); low HDL concentration (defined above); raised SBP/DBP (i.e., ≥135/85 mmHg); and raised fasting glucose level (i.e., ≥100 mg/dL). People who reported that they were taking antihypertensive, antiplipid, and antidiabetic drugs were also defined as having raised BP, high triglyceride/low HDL, and raised blood glucose, respectively.
Diabetes was defined as the glycohemoglobin of ≥6.5%, previous diagnosis by a doctor of having diabetes, or taking of any antidiabetic drugs.
Insufficient aerobic physical activity was defined as < 150 min of moderate, vigorous, or transportation activity in a regular week. The physical activity data was available from 2007 to 08 survey year.
p-values were obtained by analysis of variance (for continuous variables) or chi-square tests (for categorical variables).

Table 2
Age-Adjusted prevalence (with 95% confidence interval) and trends by chronic kidney disease (CKD) stages, NHANES 2003–18.

Stages	2003–06	2007–10	2011–14	2015–18	p-value
No CKD	85.9 (85.0–86.9)	87.0 (86.2–87.7)	86.0 (84.9–87.0)	86.7 (85.6–87.7)	0.24
Stage 1 (GFR ≥ 90 & ACR ≥ 30)	4.0 (3.5–4.7)	3.9 (3.5–4.4)	4.7 (4.1–5.5)	5.0 (4.5–5.3)	0.037
Stage 2 (GFR 60–89 & UACR ≥ 30)	3.2 (2.8–3.6)	3.0 (2.6–3.5)	2.7 (2.3–3.2)	2.7 (2.3–3.3)	0.88
Stage 3A (GFR 45–59)	4.7 (4.3–5.2)	4.1 (3.6–4.6)	4.5 (4.1–5.0)	4.0 (3.4–4.6)	0.51
Stage 3B (GFR 30–44)	1.6 (1.3–1.9)	1.4 (1.3–1.6)	1.5 (1.3–1.8)	1.1 (1.0–1.4)	0.58
Stage 4 (GFR 15–29)	0.4 (0.3–0.6)	0.5 (0.4–0.6)	0.4 (0.3–0.6)	0.3 (0.2–0.5)	0.76
Stage 5 End Stage (GFR < 15)	0.1 (0.0–0.2)	0.1 (0.1–0.2)	0.2 (0.1–0.3)	0.1 (0.1–0.2)	0.22
Any stage (GFR < 60 or ACR ≥ 30)	14.1 (13.1–15.0)	13.0 (12.3–13.8)	14.0 (13.0–15.1)	13.3 (12.3–14.4)	0.24

GFR: Glomerular filtration rate, UACR: Urinary albumin-creatinine ratio.
p-values obtained by chi-square tests.

age-adjusted estimates. The multistage cluster sampling design of the survey and mobile examination center's weights were accounted to report all the estimates. Pairwise deletion (i.e., available case analysis) approach was used to handle missing data. Since most of the variables had < 10% missing data, this approach is not expected to adversely affect our estimates. Stata 14.0 (College Station, TX, USA) was used to analyze data.

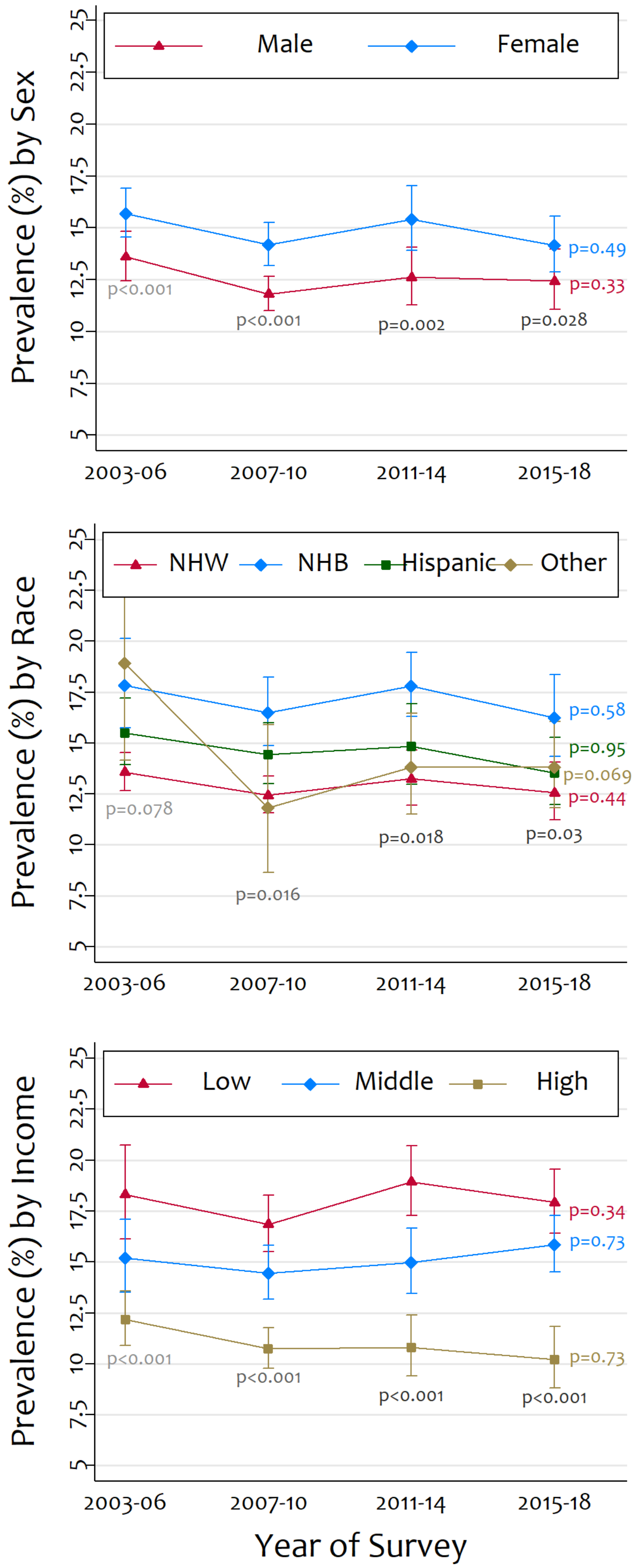

Fig. 1. Age-adjusted Prevalence and Trends of Chronic Kidney Disease by Gender, Race/Ethnicity, and Family Income-to-Poverty Ratio, 2003–18″.

5. Results

A total of 39,569 participants were included in the analysis, about half of the participants were females and the mean age of the participants was 47 (SD: 16.8) years (Table 1). More than two-thirds of the participants were non-Hispanic whites (67.4%; n = 17210). The number of participants with CKD from survey years 2003–06, 2007–10, 2011–14, and 2015–18 was 1635, 1926, 1786, and 1814, respectively. Among participants with CKD, most of the characteristics were similar across the survey years. The overall number of participants along with the number of participants with CKD are reported in Supplemental Table 3.

Table 2 shows the age-adjusted prevalence and trends of CKD by its stages. Overall, the prevalence of CKD changed from 14.1% (95% CI: 13.1 to 15.0%) in 2003–06 to 13.3% (95% CI: 12.3 to 14.4%) in 2015–18; however, this change was not substantial (p[trend] = 0.24). In addition, the prevalence for stages 2 to 5 did not change significantly ($p > 0.05$). Among participants with CKD, a majority of them had stage 1 to stage 3A CKD.

Fig. 1 compares the age-adjusted prevalence and trends of CKD based on gender, race/ethnicity, and income. The prevalence differed according to these three characteristics in all survey years. Females had a higher prevalence of CKD than their male counterparts in all survey years. Among males, the prevalence of CKD changed from 13.1% (95% CI: 11.9 to 14.3%) in 2003–06 to 12.4% (95% CI: 11.1 to 13.9%) in 2015–18 (p[trend] = 0.46). Similarly, the prevalence among females changed from 15.0% (95% CI: 13.9 to 16.2%) in 2003–06 to 14.2% (95% CI: 12.9 to 15.5%) in 2015–18 (p[trend] = 0.33). Among races/ethnicities, the overall prevalence was higher among non-Hispanic blacks compared to other races/ethnicities; the prevalence and trends changed substantially across the survey years for none of the races/ethnicities. Lastly, the prevalence of CKD was the highest among low-income people while it was the lowest among high incomes in all survey years.

Table 3 represents the age-adjusted prevalence and trends for CKD risk factors. The overall prevalence of some factors declined (e.g., current tobacco smoking and insufficient aerobic PA) across the survey years. For instance, the prevalence of current tobacco smoking was 24.7% (95% CI: 22.9 to 26.5%), 21.6% (95% CI: 20.0 to 23.3%), 19.9% (95% CI: 18.2 to 21.7%), and 18.7% (95% CI: 17.2 to 20.3%) in 2003–06, 2007–10, 2011–14, and 2015–18, respectively (p[trend] < 0.001). On the other hand, the prevalence increased for the following risk factors: diabetes, high total cholesterol, high triglyceride, low HDL, obesity, abdominal obesity, and metabolic syndrome (p[trend] < 0.05). For instance, the prevalence of diabetes increased from 9.4% (95% CI: 8.7 to 10.2%) in 2003–06 to 13.1% (95% CI: 12.0 to 14.3%) in 2015–18. The prevalence of hypertension (per both guidelines) remained similar (p[trend] > 0.05).

Per the estimations presented in Table 4, the age-adjusted prevalence of CKD was higher in presence of most studied factors. Among all the studied factors, people with diabetes had the highest prevalence of CKD, 34.2% (95% CI: 29.6 to 39.0%), 30.7% (95% CI: 26.4 to 35.3%), 29.0% (95% CI: 26.0 to 32.2%), and 28.1% (95% CI: 25.1 to 31.3%) in survey years 2003–06, 2007–10, 2011–14, and 2015–18, respectively (p[trend] = 0.25). The overall change in prevalence was not substantial per most other characteristics either. The studied factors in Supplemental Table 2 show similar results.

6. Discussion

In this study, we analyzed a nationally representative survey to study the age-adjusted prevalence and trends of CKD and its risk factors along with the prevalence and trends of CKD according to the presence of these risk factors. Between 2003–06 and 2015–18, the overall prevalence change of CKD, including the prevalence change for most CKD stages, was not significant. These findings indicate that the prevalence has plateaued; however, it remained substantial, affecting roughly one in seven people. Females, non-Hispanic blacks, and low-income people had a higher prevalence of CKD compared to males and their counterparts of other races/ethnicities and income groups. Regarding risk

Table 3
Prevalence and trends of chronic kidney disease risk factors by survey years, NHANES 2003–18.

Variable	2003–06	2007–10	2011–14	2015–18	p-values
Hypertension 2017 ACC/AHA	46.1 (44.3–48.0)	43.9 (42.2–45.5)	44.0 (42.6–45.3)	45.9 (43.9–47.9)	0.062
Hypertension JNC7	30.9 (29.5–32.4)	30.1 (28.9–31.3)	30.3 (29.2–31.5)	31.0 (29.1–33.0)	0.15
Diabetes	9.4 (8.7–10.2)	10.6 (9.7–11.5)	11.2 (10.4–12.0)	13.1 (12.0–14.3)	< 0.001
High total cholesterol	37.5 (36.2–38.9)	35.9 (34.6–37.2)	40.2 (38.9–41.6)	38.9 (37.5–40.4)	< 0.001
High triglyceride	33.3 (31.9–34.6)	37.6 (36.2–39.0)	36.3 (34.3–38.4)	35.6 (33.5–37.8)	0.012
Low HDL	26.6 (25.1–28.2)	33.1 (31.4–34.8)	29.9 (27.9–32.0)	28.5 (26.6–30.4)	< 0.001
Obese	33.1 (31.2–35.0)	34.4 (32.9–36.0)	36.3 (34.6–38.0)	41.4 (38.9–43.9)	< 0.001
Abdominal obesity	53.4 (51.3–55.4)	53.5 (51.7–55.4)	55.9 (54.1–57.6)	59.4 (56.6–62.1)	< 0.001
Metabolic syndrome	31.2 (29.2–33.2)	33.7 (31.5–35.9)	33.6 (31.4–35.9)	38.1 (34.5–41.9)	< 0.001
Insufficient aerobic PA	–	35.8 (34.0–37.6)	35.8 (34.2–37.5)	31.8 (30.4–33.4)	0.003
Current tobacco smoker	24.7 (22.9–26.5)	21.6 (20.0–23.3)	19.9 (18.2–21.7)	18.7 (17.2–20.3)	< 0.001

Abbreviations: ACC/AHA: American College of Cardiology/American Heart Association, HDL: High density lipoprotein, JNC7: Seventh Joint National Committee, PA: Physical activity, NHANES: National Health and Nutrition Examination Survey.
Hypertension according to the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guideline was defined as a systolic/diastolic blood pressure ≥ 130/80 mmHg or self-report of taking any antihypertensive drugs.
Hypertension according to the Seventh Joint National Committee (JNC7) guideline was defined as a systolic/diastolic blood pressure ≥ 140/90 mmHg or self-report of taking any antihypertensive drugs.
High total cholesterol level was defined as having ≥ 240 mg/dl total cholesterol level. High serum triglycerides was considered as ≥ 150 mg/dL. Low high-density lipoprotein concentration was considered as < 40 mg/dL for men and < 50 mg/dL for women. Any person reported taking antilipid drugs was also considered as having high total cholesterol, high serum triglyceride, or low high-density lipoprotein.
Obesity was defined as body mass index of ≥ 30 kg/m^2.
Abdominal obesity was defined as ≥ 102 cm for men and ≥ 88 cm for women.
Metabolic syndrome was defined as having at least 3 of the 5 following conditions: abdominal obesity (defined above); high serum triglycerides (defined above); low HDL concentration (defined above); raised SBP/DBP (i.e., ≥135/85 mmHg); and raised fasting glucose level (i.e., ≥100 mg/dL). People who reported that they were taking antihypertensive, antiplipid, and antidiabetic drugs were also considered as having raised BP, high triglyceride/low HDL, and raised blood glucose, respectively.
Diabetes was defined as the glycohemoglobin of ≥ 6.5%, previous diagnosis by a doctor of having diabetes, or taking of antidiabetic drugs.
Insufficient aerobic physical activity was defined as < 150 min of moderate, vigorous, or transportation activity in a regular week. The physical activity data was available from 2007 to 08 survey year.
p-values obtained by chi-square tests.

Table 4
Prevalence and trends of CKD by presence of risk factors, NHANES 2003–18.

Variable	2003–06	2007–10	2011–14	2015–18	p-value
Hypertension 2017 ACC/AHA	16.8 (15.3–18.5)	16.8 (15.5–18.2)	18.4 (16.6–20.3)	17.3 (15.7–18.9)	0.25
Hypertension JNC7	21.2 (18.6–24.0)	20.1 (18.0–22.4)	21.2 (18.9–23.6)	21.3 (19.3–23.5)	0.84
Diabetes	34.2 (29.6–39.0)	30.7 (26.4–35.3)	29.0 (26.0–32.2)	28.1 (25.1–31.3)	0.25
High total cholesterol	15.2 (13.9–16.6)	14.2 (12.7–15.7)	16.0 (14.8–17.3)	14.1 (12.9–15.5)	0.063
High triglyceride	16.1 (14.3–18.1)	14.7 (13.3–16.1)	16.4 (14.7–18.3)	16.2 (14.7–17.8)	0.35
Low HDL	16.8 (14.8–19.1)	15.7 (14.2–17.3)	17.9 (15.9–20.2)	16.8 (15.2–18.5)	0.23
Obese	16.5 (15.0–18.1)	15.3 (13.8–16.8)	16.6 (14.8–18.5)	15.9 (14.6–17.4)	0.58
Abdominal obesity	15.5 (14.2–16.9)	14.2 (13.2–15.3)	15.1 (13.7–16.7)	14.4 (13.2–15.6)	0.70
Metabolic syndrome	18.5 (15.9–21.4)	17.0 (15.4–18.8)	17.7 (15.5–20.0)	16.0 (13.4–19.0)	0.73
Insufficient aerobic PA		16.4 (15.1–17.8)	17.3 (15.6–19.0)	16.1 (14.6–17.7)	0.60
Current tobacco smoker	13.3 (11.8–14.9)	13.6 (12.2–15.1)	14.9 (13.0–17.0)	12.5 (10.7–14.5)	0.055

Abbreviations: ACC/AHA: American College of Cardiology/American Heart Association, HDL: High density lipoprotein, JNC7: Seventh Joint National Committee, PA: Physical activity, NHANES: National Health and Nutrition Examination Survey.
Hypertension according to the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guideline was defined as a systolic/diastolic blood pressure ≥ 130/80 mmHg or self-report of taking any antihypertensive drugs.
Hypertension according to the Seventh Joint National Committee (JNC7) guideline was defined as a systolic/diastolic blood pressure ≥ 140/90 mmHg or self-report of taking any antihypertensive drugs.
Borderline elevated and high total cholesterol levels were defined as 200–239 and ≥ 240 mg/dl total cholesterol levels, respectively. High serum triglycerides was defined as ≥ 150 mg/dL). Low HDL concentration was defined as < 40 mg/dL for men and < 50 mg/dL for women. Any person reported taking antilipid drugs was also defined as having high total cholesterol, high serum triglyceride, or low HDL.
Overweight and obesity were defined as body mass index of 25–29 and ≥ 30 kg/m^2, respectively.
Abdominal obesity was defined as ≥ 102 cm for men and ≥ 88 cm for women.
Metabolic syndrome was defined as having at least 3 of the 5 following conditions: abdominal obesity (defined above); high serum triglycerides (defined above); low HDL concentration (defined above); raised SBP/DBP (i.e., ≥135/85 mmHg); and raised fasting glucose level (i.e., ≥100 mg/dL). People who reported that they were taking antihypertensive, antiplipid, and antidiabetic drugs were also considered as having raised BP, high triglyceride/low HDL, and raised blood glucose, respectively.
Diabetes was defined as the glycohemoglobin of ≥ 6.5%, previous diagnosis by a doctor of having diabetes, or taking of antidiabetic drugs.
Insufficient aerobic physical activity was defined as < 150 min of moderate, vigorous, or transportation activity in a regular week. The physical activity data was available from 2007 to 08 survey year.
p-values obtained by chi-square tests.

factors, though the prevalence of some risk factors declined (e.g., current tobacco smoking and insufficient aerobic PA) or did not change substantially (e.g., hypertension), it increased for many risk factors, including diabetes, high total cholesterol, high triglyceride, low HDL, obesity, abdominal obesity, and metabolic syndrome. The prevalence of CKD was also substantially higher in presence of most risk factors.

These study results support the conclusions drawn by Murphy and colleagues, they also analyzed NHANES data from survey years 1988–2012 and concluded that the prevalence of CKD or any of its stages has plateaued. The authors also found a plateauing prevalence for both males and females (Murphy et al., 2016). Hoerger et al. developed a simulation model using NHANES 1990–2010 data and predicted that the prevalence of CKD would increase; however, our results did not corroborate the authors' conclusions (Hoerger et al., 2015). Over the past few decades, the US population has aged, increasing the prevalence of many chronic conditions which are risk factors for CKD (Chen et al., 2019; Murphy et al., 2016). The static or insignificant change of the prevalence observed by this study may be attributable to the improvement of diagnostic and treatment facilities (e.g., dialysis and transplant) as well as the improvement in treatment and control of hypertension (Murphy et al., 2016).

The increment in prevalence for many risk factors indicates that controlling and treating these conditions may reduce the future burden of CKD. Furthermore, the prevention and control strategies of these risk factors are similar, including increasing physical exercise, balanced diet, and smoking cessation (Centers for Disease Control and Prevention Chronic Kidney Disease, 2015; Chen et al., 2019). Due to a large number of complications, the public health burden of conditions like hypertension, diabetes, obesity, and dyslipidemia is also high (Centers for Disease Control and Prevention, 2020a; GBD 2015 DALYs and HALE Collaborators, 2016; Muntner et al., 2017). CKD patients are recommended to manage these complications (Chen et al., 2019; Romagnani et al., 2017). Therefore, preventing and treating these conditions may not only reduce the mortalities, morbidities, or costs resulting from CKD, but also from these conditions themselves. Successful prevention of CKD or its risk factors may have synergistic effects on the health system (Centers for Disease Control and Prevention, 2020a). Reducing the burden of these risk factors would be essential to meet the HP2020 target of CKD (Centers for Disease Control and Prevention, 2020b). Adopting the control measures during the initial stages may also reduce its progression to advanced stages.

We have also found differences in prevalence of CKD by race/ethnicity and income, which have been estimated previously in burden of hypertension, tobacco smoking, obesity, and other risk factors (Afkarian et al., 2016; Murphy et al., 2016). For instance, non-Hispanic blacks have a substantially higher prevalence of hypertension compared to other races/ethnicities (Muntner et al., 2017). It is essential to develop and adopt effective prevention, treatment, and control measures to reduce the burden of CKD risk factors and associated disparities.

This study has several notable strengths. First, we analyzed nationally representative survey data across a period of 16 years. The sample size of NHANES was large, which allowed us to perform adequate subgroup analysis. NHANES used standardized validated protocols. We also obtained the prevalence and trends after applying sample weights and using appropriate statistical procedures.

This study also has multiple limitations. First, we analyzed cross-sectional datasets; due to uncertainty about any temporal association, the observed association may not be causal. Obtaining the estimates based on a single day's measure instead of three or more months may also cause some overestimation. Additionally, self-reported data of antihypertensive or other drug use are subject to recall bias. Lastly, a condition's prevalence may differ based on the used cutoff and sample composition. The NHANES data used for this study comprised a non-institutionalized population, which may underestimate some prevalence.

7. Conclusion

Though the prevalence of CKD has plateaued, it remained disproportionately high among some sociodemographic groups. Moreover, many of the studied risk factors' prevalence is increasing. Effective prevention, treatment, and control strategies are required to reduce the burden of CKD as well as its associated complications and risk factors.

8. Summary

What is already known in this topic?

- The prevalence of chronic kidney disease (CKD) has become static but little is known about its prevalence in recent years.

What is added by this report?

- About 13.3% adults have CKD in 2015-18 and the prevalence has not increased since 2003-06; however, prevalence and trends differ by gender, race/ethnicity, and income. The prevalence of many risk factors is changing.

What are the implications for public health practice?

Regular screening for early diagnosis of CKD and its risk factors, including prevention of these conditions may reduce the burden of CKD.

CRediT authorship contribution statement

Gulam Kibria: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing - original draft. **Reese Crispen:** Investigation, Methodology, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101193.

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