Chapter 1:
CKD in the General Population

- In light of the 2017 blood pressure guidelines from the American College of Cardiology/American Heart Association (ACC/AHA), this year we examine hypertension control at both 130/80 mm Hg and 140/90 mm Hg. In a comparison of four cohorts of NHANES participants (2001-2004, 2005-2008, 2009-2012, and 2013-2016), little change was seen among individuals without chronic kidney disease (CKD), but among individuals with CKD, the percentage within the ACC/AHA guidelines has improved from 40.4% to 48.8% for BP <130/80 and from 61.5% to 68.4% for BP <140/90 (Figures 1.10.b and 1.10.a).
- Also new to the chapter is a deeper look into kidney disease awareness by comorbid health status and age. Comparing these same four NHANES cohorts, we continue to see little improvement in the percentage of individuals with CKD who were aware of their disease in the early stages, but among individuals in Stage 4 CKD awareness increased from 36% to 57%. For individuals with hypertension (HTN) and diabetes mellitus (DM), only 15% were aware of their kidney disease. Awareness improved slightly with older age, but among those 60+ years old with CKD, only 10% reported they had the condition (Figures 1.13.a–1.13.d).
    - Dietary intake was also examined for the first time among individuals with and without CKD. Among individuals with CKD, overall calorie intake increased slightly, while sodium and total sugar intake were very high in all years. Potassium intake appears below the recommended guidelines and did not change over the four cohorts (Table 1.4).
    - Overall prevalence of CKD (Stages 1-5) in the United States adult general population was 14.8% in 2013-2016. CKD Stage 3 (6.4%) was the most prevalent (Figure 1.1). Overall, CKD prevalence has remained relatively stable during the last 2 decades.
- In the general U.S. population during the years 2013-2016, the prevalence of a urinary albumin-to-creatinine ratio (ACR) of >10mg/g of creatinine was 33%, including 8.5% with ACR 30–300 mg/g and 1.6% with ACR >300 mg/g (Figure 1.3). Overall, prevalence of albuminuria does not appear to have changed much since 2001, although in the subgroup with stage 4 CKD, it appears to have increased (Figure 1.4).
- The prevalence of CKD among diabetics has decreased over time among the four cohorts of NHANES participants, from 43.6% (2001-2004) to 36.0% in (2013-2016). A similar decrease was not seen among individuals with hypertension, whose CKD prevalence remains about 31% (Table 1.2).
- Age had the highest correlation with low estimated glomerular filtration rate (eGFR; <60 ml/min/1.73 m^2), with an odds ratio (OR) of 70 in the 2013-2016 cohort, while HTN was the greatest predictor of albuminuria, with an OR of 4.5 in this cohort (Figures 1.7 and 1.8).
- Over time, among those with CKD, only minimal changes in self-reported physical activity have occurred, with around 60% reporting either moderate or vigorous activity (Figure 1.9).
- Among those with CKD, following an initial increase in the percentage of individuals with DM having glycosylated hemoglobin (HbA1c) <7%, the proportion of individuals with this degree of glycemic control declined from 48% to 42% over time (Figure 1.12 and Table 1.5).
    - Among those with CKD, the percentage of individuals with HTN who were unaware of their HTN condition decreased to 20%, while the percentage with treated/controlled HTN increased from 17% to 27% (Table 1.5).
- Among those with CKD, the percentage of individuals with normal cholesterol levels (Figure 1.11) increased over time from under 50% to over 60%.

- The prevalence of self-reported CKD was very low in the U.S. general population, as indicated in a large representative telephone-based survey. For 2016, reports ranged from 1.8% in Wyoming to 4.0% in Mississippi. Given the overall prevalence of CKD in the U.S. population of about 14%, these numbers are consistent with limited awareness of CKD among those who have the condition (Figure 1.14).

Introduction

This chapter presents representative cross-sectional estimates of CKD prevalence in the United States, through analysis of data from the National Health and Nutrition Examination Survey (NHANES; CDC, 2018) and from the Behavioral Risk Factors Surveillance System (BRFSS; CDC, 2018), a large representative telephone-based survey, both administered by the Centers for Disease Control and Prevention (CDC). Both surveys use a stratified probability sampling design to select participants, rather than a simple random sample.

The NHANES program of studies combines interviews and physical examinations, creating a valuable source of information for assessing disease prevalence overall and in at-risk groups. This sample is representative of the civilian, non-institutionalized U.S. population, with oversampling of certain population subgroups to increase the reliability and precision of health status indicator estimates for these groups.

The NHANES data are collected and released biennially; therefore, we primarily report trends based on four, four-year periods within the last 16 years—2001-2004, 2005-2008, 2009-2012, and 2013-2016. These years include the most recent years of the "continuous" NHANES data collection. Data from NHANES III (1988-1994) and the first two years of continuous NHANES data (1999-2001) can be found in previous Annual Data Reports (ADRs). New data available for the 2018 ADR is limited to the 2015-2016 information on CKD, which became available in February of 2018.

The Behavioral Risk Factors Surveillance System (BRFSS; CDC, 2018) is a system of health-related telephone surveys that collect state-level data of U.S. residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services. Similar to the NHANES survey methodology, the data is weighted to allow generation of estimates considered representative of the U.S. population. In the survey, each participant is asked, "(Ever told) you have kidney disease?" In contrast to the NHANES, this data source contains participants' residence information and allows an assessment of the geographic distribution of self-reported kidney disease. As BRFSS conducts annual data collection, we present analyses of data from the past four years, including the newest data gathered in 2016.

Defining Chronic Kidney Disease

While the definition of CKD as initially proposed by K/DOQI (NKF, 2002) and subsequently by KDIGO (KDIGO, 2012) has well served the renal community, it is pertinent to discuss its application to public health surveillance of kidney disease, as opposed to clinical practice. The definition requires that a measured eGFR abnormality or evidence of kidney damage (e.g., albuminuria), or both, be present for a minimum of three months. In examining survey data from random samples of the general population (e.g., NHANES) or available data within health systems (e.g., the national Veterans Affairs Health System, or others), repeat laboratory values are either not available, or repeat testing is conducted based on clinical indication, and thus being subject to bias-by-indication. In future years the NHANES survey may begin to include repeat measurements of serum creatinine and urine albumin in a significant proportion of its participants. Recently published evidence suggest that that estimates of CKD prevalence, based on single laboratory values may be biased upward, especially in those with stage 3A CKD (De Broe, 2017). Future studies may need to consider repeat testing for both albuminuria and serum creatinine (more than simply checking it twice) in large

numbers of individuals in the general population, followed over long periods of time, to clarify existing gaps in the literature in this contentious area. Proposals for an age-based definition of CKD remain the subject of debate (Glassock, 2015; Levey, 2015). Currently, therefore, we must contend with the practical reality of relying on single-point-in-time measurements of serum creatinine (to estimate eGFR) and urine albumin-to-creatinine ratios for public health surveillance, using the KDIGO definition in principle, but without application of its 'persistence' criterion.

Kidney function was evaluated by eGFR as calculated using the CKD-EPI creatinine equation (Levey et al., 2009). Individuals with eGFR <60 ml/min/1.73 m² were considered to have reduced kidney function. In addition, we used the ACR to assess urinary albumin excretion, and considered four categories: <10 mg/g, 10-<30 mg/g, 30-300 mg/g, and >300 mg/g. We then created a composite measure of both eGFR and ACR, classifying individuals as CKD if they had either an eGFR <60 ml/min/1.73 m² or ACR ≥30 mg/g. Staging of kidney disease follows the Kidney Disease Outcomes and Quality Improvement (KDOQI) CKD guidelines (Table A; NKF, 2002).

Estimates presented in this chapter may differ from those published by the Centers for Disease Control Chronic Kidney Disease (CDC CKD) Surveillance project. This is because the CDC CKD Surveillance project has historically employed the Modification of Diet in Renal Disease (MDRD) formula (Levey et al., 1999) to calculate eGFR. Currently, though, the project is actively transitioning to use of the CKD-EPI creatinine equation.

Table A. Kidney Disease Outcomes and Quality Improvement (KDOQI) CKD Staging Guidelines

CKD Stage	Description	GFR (ml/min/1.73 m²)
1	Kidney damage with normal or ↑ GFR	>90
2	Kidney damage with mild ↓ in GFR	60-89
3	Moderate ↓ in GFR	30-59
4	Severe ↓ in GFR	15-29
5	Kidney failure	<15 (or dialysis)

In contrast, all other chapters in this ADR volume identify the presence of CKD and its related stages based on ICD-9-CM and ICD-10-CM (International Classification of Diseases, Ninth and Tenth revisions, clinical modification) diagnosis codes. These classification systems are more likely to underreport the initial stages of CKD, as care providers often do not document formal diagnoses of CKD early in the disease process, or may have not yet clinically identified CKD. In addition, because of the asymptomatic nature of much of CKD, many individuals with early stage CKD will not have sought medical care. NHANES data allows us to distinguish individuals within Stage 1 (eGFR >90 with ACR >30) and Stage 2 (eGFR 60-89 with ACR >30).

By examining level of kidney function and the related comorbidities of DM, HTN, and CVD in the general population, this chapter sets the stage for Volume 1, Chapter 2: *Identification and Care of Patients with CKD*. There we discuss CKD as recognized in the health care system via analysis of Medicare claims, data from OPTUM Clinformatics™, and data from the U.S. Department of Veterans Affairs (VA), providing information on morbidity, interventions, and costs.

Methods

Two nationally representative data sources are included in the analyses for this chapter: NHANES (2001-2016) and BRFSS (2013-2016).

The National Health and Nutrition Examination Survey (NHANES) is a sample of about 5,000 individuals per year drawn from the U.S. civilian, noninstitutionalized population. Respondents answer survey questions, receive a medical examination, and provide blood and urine samples that are tested for various biochemical markers, including serum creatinine and urine albumin. Except for Figure 1.14, all tables and figures in this chapter are based on NHANES data.

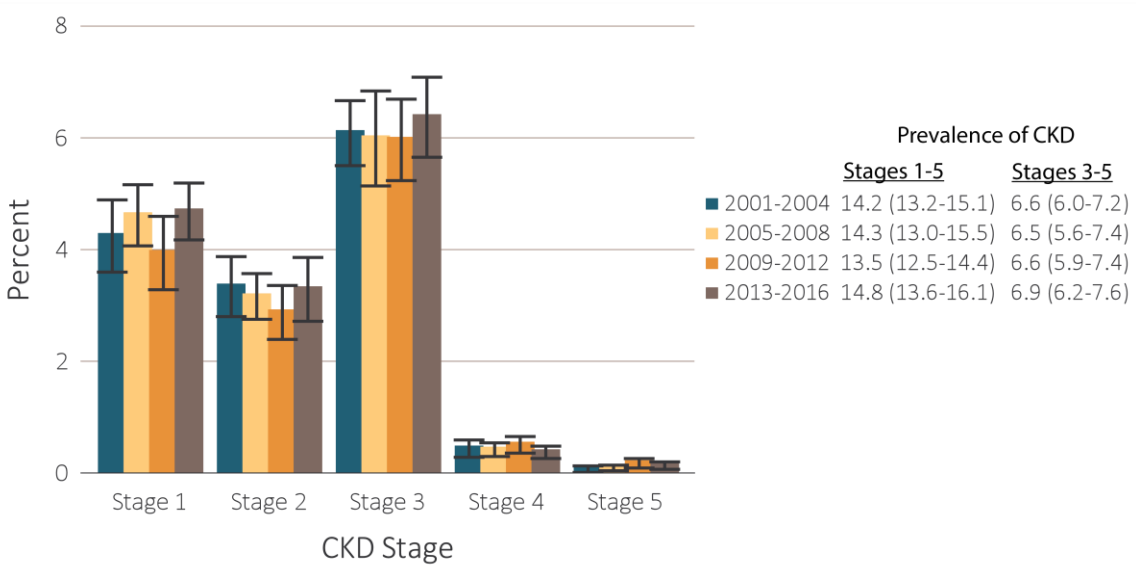
Figure 1.14 employs data from the Behavioral Risk Factor Surveillance System (BRFSS) to illustrate the geographic distribution by state of self-reported (SR) kidney disease. These data are also a sample of the U.S. general population, but respondents answer survey questions during a phone interview, and there is no medical examination. However, the sample size is large and data includes residence information, allowing precise estimation for U.S. states.

A full explanation of these data is included in the *Data Sources* section of the CKD Analytical Methods chapter. See the section on *Chapter 1*, in the *CKD Analytical Methods* chapter for an explanation of the analytical methods used to generate the study cohorts, figures, and tables in this chapter. Downloadable Microsoft Excel and PowerPoint files containing the data and graphics for these figures and tables are available from the *USRDS website*. Downloadable Microsoft Excel and PowerPoint files containing the data and graphics for these figures and tables are available from the *USRDS website*.

Prevalence of CKD

Figure 1.1 presents the U.S. prevalence of CKD, over four periods from 2001 to 2016. A small increase occurred in Stage 3 CKD, which rose from 6.1% to 6.4% over the four periods. The percent of individuals in Stages 1-2 decreased from 2001 to 2012, but reverted to initial levels in the most recent period. The trend in increasing prevalence for Stages 3-5 (non-ESRD) was statistically significant in past ADRs due to the inclusion of the 1999-2000 data, however, from 2001 to 2016 the change in prevalence was positive, but not significant (OR=1.02, p=0.50 per 1 more recent NHANES cohort).

vol 1 Figure 1.1 Prevalence of CKD by stage among NHANES participants, 2001-2016



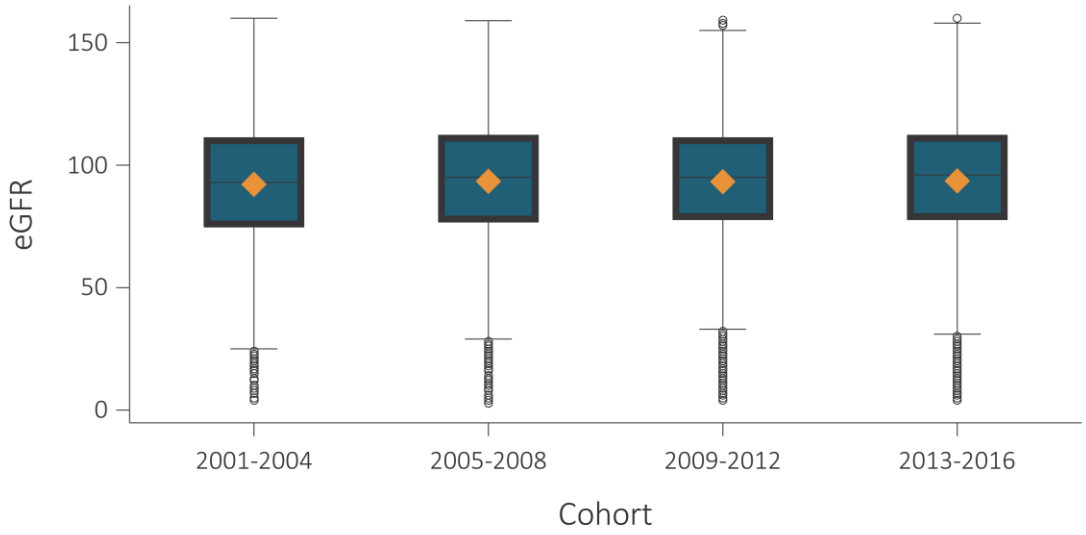
Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 & older. Whisker lines indicate 95% confidence intervals. Abbreviation: CKD, chronic kidney disease.

Figure 1.2 provides the density distributions of eGFR in NHANES during 2001-2004, 2005-2008, 2009-2012, and 2013-2016. Overall, minimal population changes have been observed over the entire period. We also examined these densities among individuals over the age of 60 years, as this group experiences the highest prevalence of CKD. The average eGFR for individuals over 60 years was approximately 20 ml/min/1.73 m^2, lower than for the complete sample (Figure 1.2.b).

vol 1 Figure 1.2 eGFR distribution among NHANES participants, 2001-2016

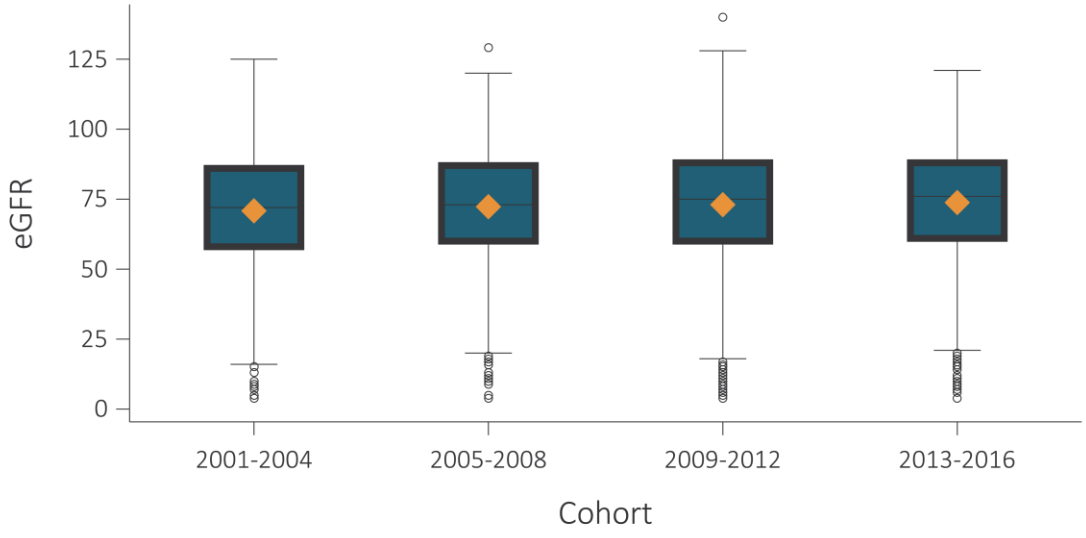
(a) All individuals

Cohort	Mean	SE
2001-2004	94.4	0.54
2005-2008	94.6	0.68
2009-2012	94.6	0.50
2013-2016	94.3	0.52



(b) Individuals 60+ years

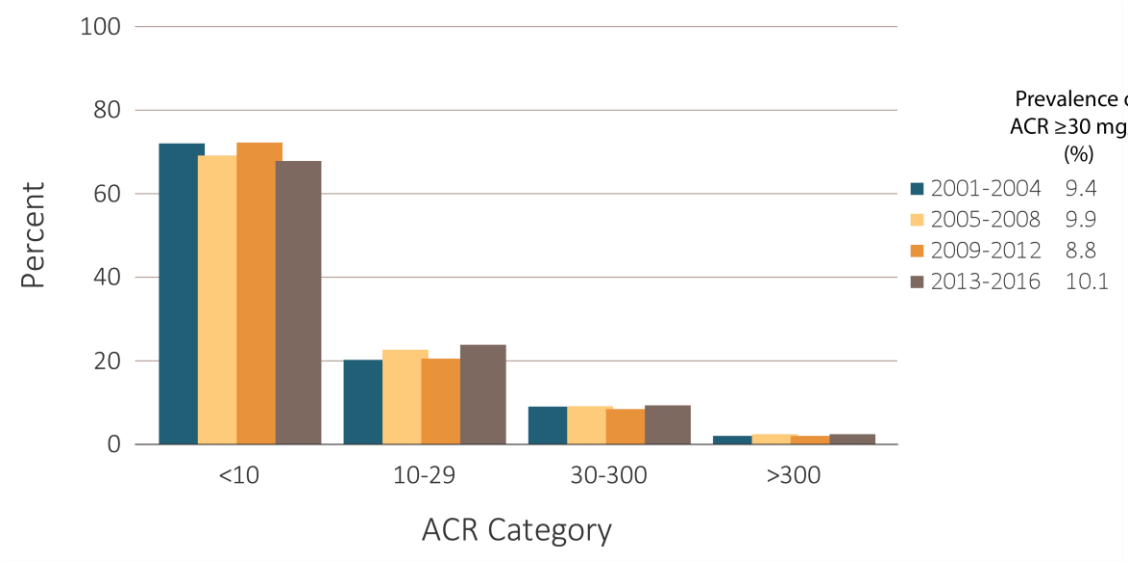
Cohort	Mean	SE
2001-2004	70.7	0.52
2005-2008	72.2	0.49
2009-2012	73.3	0.39
2013-2016	74.0	0.55



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2016 participants aged 20 & older. Single-sample estimates of eGFR; eGFR calculated using the CKD-EPI equation. Abbreviations: eGFR, estimated glomerular filtration rate; SE, standard error. Accounts for change in serum creatinine assays.

Figure 1.3, with corresponding findings for ACR, shows little change over time in the distribution patterns of individuals with ACR >300 mg/g. However, comparison of the groups with ACR 10-29 mg/g and 30-300 shows a slight increase, with a corresponding decrease in the proportions of individuals with ACR <10 mg/g, over the four periods. This has important mortality implications, as increased rates of all-cause mortality have occurred with ACR values as low as 10 mg/g (Matsushita, 2010).

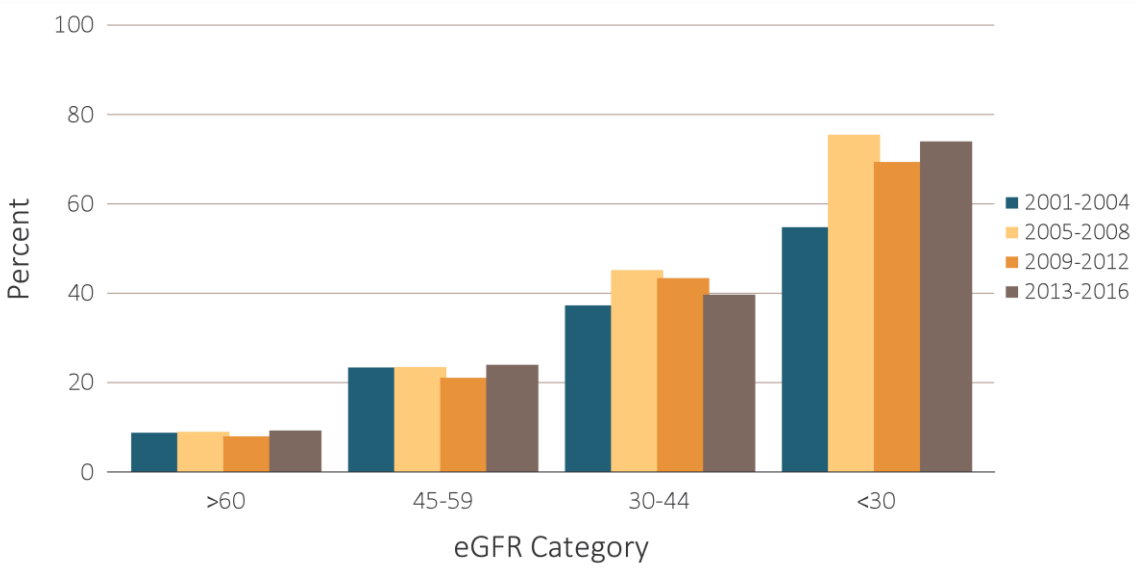
vol 1 Figure 1.3 Urine albumin/creatinine ratio (ACR) distribution among NHANES participants, 2001-2016



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2016 participants aged 20 & older. Single-sample estimates of ACR. Abbreviation: ACR, urine albumin (mg)/creatinine (g) ratio.

Figure 1.4 displays the prevalence of albuminuria (ACR >30mg/g) by eGFR category over time. Albuminuria is more prevalent at lower levels of kidney function and has increased the most among individuals with eGFR <30 ml/min/1.73 m². In the 2013-2016 NHANES sample, 8.6% of persons with eGFR >60 ml/min/1.73 m² had some evidence of albuminuria. This rose to 23.3% among individuals with an eGFR of 45-59 and 39.0% for those with an eGFR of 30-44. Of individuals with Stage 4 CKD (eGFR <30 ml/min/1.73 m²), the majority had evidence of albuminuria (73.3%).

vol 1 Figure 1.4 Percentage of NHANES (2001-2016) participants with ACR >30 mg/g, by eGFR category



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2016 participants aged 20 & older. Single-sample estimates of eGFR. Abbreviations: ACR, urine albumin (mg)/creatinine (g) ratio; eGFR, estimated glomerular filtration rate.

When assessing the joint distribution of eGFR and ACR, using the KDIGO 2012 framework (Table 1.1), which was developed based on the prognostic value of these measures, we see in the most recent cohort (2013-2016) that 14.8% are classified as high risk (10.7% at moderately high risk, 2.7% at high risk, and 1.4% at very high risk). Since 2001 the prevalence of individuals within the high risk categories has increased slightly (14.2-14.8%), with a dip in the 2009-2012 cohort (Table 1.1.b).

vol 1 Table 1.1 Percentage of NHANES 2013-2016 participants, in the various CKD (eGFR and albuminuria) risk categories (KDIGO 2012)

(a) Percentage in each category (2013-2016)

GFR categories (ml/min/1.73 m²)				Albuminuria categories			Total
				A1	A2	A3	
				Normal to mildly increased	Moderately increased	Severely increased	
				<30 mg/g <3 mg/mmol	30-300 mg/g 3-30 mg/mmol	>300 mg/g >30 mg/mmol	
	G1	Normal to high	≥90	54.9	4.2	0.5	59.6
	G2	Mildly decreased	60-89	30.2	2.9	0.3	33.5
	G3a	Mildly to moderately decreased	45-59	3.6	0.8	0.3	4.7
	G3b	Moderately to severely decreased	30-44	1.0	0.4	0.2	1.7
	G4	Severely decreased	15-29	0.13	0.10	0.15	0.37
	G5	Kidney failure	<15	0.01	0.04	0.09	0.13
			Total	89.9	8.5	1.6	100

(b) Summary of prevalence in each risk category, by cohort (2001-2016)

	2001-2004	2005-2008	2009-2012	2013-2016
Low risk	85.8	85.6	86.5	85.1
Moderately high risk	14.2 = 10.6	14.4 = 10.3	13.5 = 9.7	14.8 = 10.7
High risk	2.4	2.7	2.4	2.7
Very high risk	1.2	1.4	1.4	1.4

Data source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 and older. Single-sample estimates of eGFR and ACR; eGFR calculated using the CKD-EPI equation. Low risk: eGFR ≥60 ml/min/1.73 m² and ACR <30 mg/g; moderately high risk: eGFR 45-59 ml/min/1.73 m² or eGFR ≥60 ml/min/1.73 m² and ACR 30-300 mg/g; high risk: eGFR 30-44 ml/min/1.73 m² or eGFR 45-59 ml/min/1.73 m² and ACR 30-300 mg/g or eGFR ≥60 ml/min/1.73 m² and ACR >300 mg/g; very high risk: eGFR <30 ml/min/1.73 m² or eGFR 30-44 ml/min/1.73 m² and ACR 30-300 mg/g or eGFR ≥60 ml/min/1.73 m² and ACR >300 mg/g. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; GFR, glomerular filtration rate; KDIGO, Kidney Disease: Improving Global Outcomes CKD Work Group.

Demographic Characteristics and Risk Factors for CKD

Many studies have shown that older age, diabetes mellitus (DM), hypertension (HTN), cardiovascular disease (CVD), and higher body mass index (≥30 kg/m²; BMI) are associated with CKD. Data showing the percentage of adult NHANES participants with either eGFR <60 ml/min/1.73 m² or an ACR ≥30 mg/g confirmed a higher estimated prevalence in the presence of each of these risk factors, although with a smaller increase in relation to BMI ≥30 kg/m² (Table 1.2). Other observations of interest include that CKD was more prevalent in women and those over 60 years of age, and that DM was the most common comorbid risk factor for CKD. Ethnic and racial comparisons showed that non-Hispanic Blacks had a higher prevalence of ACR ≥30 but lower prevalence of eGFR <60, as compared to non-Hispanic Whites.

Table 1.2 shows that CKD defined by an eGFR <60 was much more prevalent in individuals aged 60 and older. Low eGFR was present in this age group for over 21.0% of the 2013-2016 participant cohort, compared to 0.4% of individuals aged 20 to 39 years and 2.8% of those aged 40 to 59 years.

Examining trends over time within these risk factor categories shows that CKD prevalence has decreased markedly among individuals with diabetes (from 43.6% to 36.0%). This is in contrast to other comorbid conditions such as hypertension, where little change has been seen (32.7% to 31.2%) or obesity (16.5% to 16.8%). When examining eGFR <60 ml/min/1.73 m² and ACR ≥30 mg/g independently, the decrease in prevalence appears to be due to ACR ≥30 mg/g, which decreased from 33.2% to 25.8% among patients with diabetes during these time periods. Also of interest is that prevalence of all three measures of CKD have decreased among the individuals aged 60+ years, while prevalence increased among individuals <60 years of age.

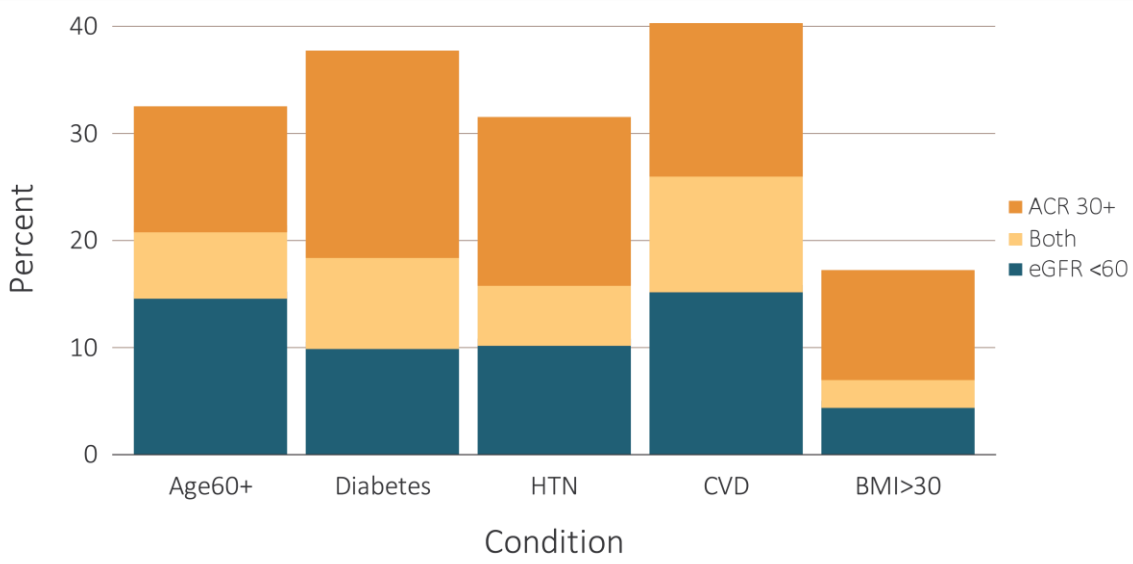
vol 1 Table 1.2 Prevalence (%) of CKD in NHANES population within age, sex, race/ethnicity, & risk factor categories, 2001-2016

	All CKD				eGFR <60 ml/min/1.73 m^2				ACR ≥30 mg/g			
	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016
Age												
20-39	5.4	6.1	5.5	6.3	0.2	0.2	0.2	0.4	5.3	6.0	5.4	6.1
40-59	9.7	10.1	8.3	10.4	2.1	2.5	2.2	2.8	8.2	8.2	6.8	8.6
60+	38.8	34.5	33.1	32.2	26.7	23.5	23.0	21.1	19.4	19.1	17.0	17.3
Sex												
Male	12.7	12.1	12.3	12.9	5.4	5.4	5.7	6.1	9.1	8.5	8.5	8.9
Female	15.5	16.3	14.6	16.7	7.7	7.5	7.5	7.6	9.7	9.1	9.1	11.2
Race/Ethnicity												
Non-Hispanic White	14.3	14.4	13.6	15.6	7.7	7.7	7.7	8.2	8.5	9.0	7.9	9.6
Non-Hispanic Black/African American	14.7	16.3	16.1	15.9	4.7	5.7	6.5	5.8	12.4	13.3	12.2	12.6
Mexican American	11.4	11.8	11.9	12.6	1.5	1.9	2.1	3.3	10.5	10.9	10.9	11.2
Other Hispanic	13.0	14.9	11.5	11.4	3.9	2.7	4.3	3.0	11.4	13.1	9.3	9.1
Other Non-Hispanic	15.9	11.4	11.7	12.6	5.2	2.1	4.1	4.7	12.8	10.2	9.8	9.8
Risk Factor												
Diabetes	43.6	40.1	38.6	36.0	18.2	17.4	21.0	18.7	33.2	31.6	26.9	25.8
Self-reported diabetes	43.8	41.8	39.5	37.1	19.2	18.7	22.4	19.3	32.4	33.1	27.1	27.3
Hypertension	32.7	31.6	30.9	31.2	17.7	16.8	17.4	16.1	20.4	20.8	19.3	20.7
Self-reported hypertension	27.2	26.6	26.1	26.6	15.8	14.8	15.7	14.7	16.4	17.3	15.8	16.9
Self-reported cardiovascular disease	42.2	40.6	40.8	40.3	29.4	27.3	28.2	26.3	22.8	25.6	23.2	24.8
Obesity (BMI ≥30)	16.5	17.2	16.5	16.8	6.6	7.0	7.8	7.2	11.9	12.6	10.8	12.1
All	14.2	14.3	13.5	14.8	6.6	6.5	6.6	6.9	9.4	9.9	8.8	10.1

Data source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Diabetes defined as HbA1c >7%, self-reported (SR), or currently taking glucose-lowering medications. Hypertension defined as BP ≥130/≥80 for those with diabetes or CKD, otherwise BP ≥140/≥90, or taking medication for hypertension. Values in Figure 1.12 cannot be directly compared to those in Table 1.3 due to different survey cohorts. The table represents NHANES participants who are classified as hypertensive (measured/treated) but some of those are at target blood pressure. Abbreviations: ACR, urine albumin/creatinine ratio; BMI, body mass index; BP, blood pressure, CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

Figure 1.5 displays the prevalence of CKD markers (eGFR <60 ml/min/1.73 m² and ACR ≥30 mg/g) among adult NHANES 2013–2016 participants—specifically those aged 60 years and older, and those of all ages who had the comorbid conditions of DM, HTN, SR CVD, and higher BMI. The prevalence of eGFR <60 was highest among those aged 60+ years (21.1%) and those with SR CVD (26.3%), followed by those with DM (18.7%), HTN (16.1%), and higher BMI (7.3%). An ACR ≥30 was most common in those with DM (27.2%), followed by those with HTN (20.7%), aged+ 60years (17.3%), with SR CVD (14.8%), and of higher BMI (12.2%). The presence of both eGFR <60 and ACR ≥30 was most common with SR CVD, at 10.8%, followed by DM at 8.5%, those aged 60+ years (6.2%), with HTN (5.6%), and with higher BMI (2.6%).

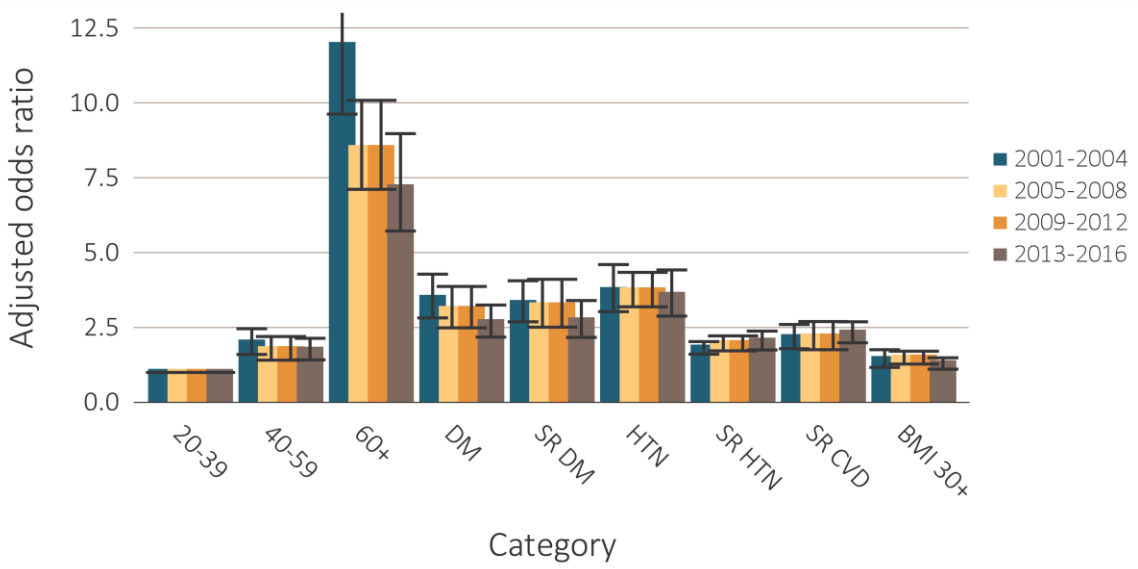
vol 1 Figure 1.5 Distribution of markers of CKD in NHANES participants with diabetes, hypertension, self-reported cardiovascular disease, & obesity, 2013–2016



Data Source: National Health and Nutrition Examination Survey (NHANES), 2013-2016 participants age 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Abbreviations: ACR, urine albumin/creatinine ratio; BMI, body mass index; CKD, chronic kidney disease; SR CVD, self-reported cardiovascular disease; eGFR, estimated glomerular filtration rate; HTN, hypertension.

Figures 1.6-1.8 illustrate the odds ratios for presence of CKD for each of the common comorbid conditions. Analyses were adjusted for age, sex, and race. As consistent with the remainder of this chapter, presence of CKD was indicated by either eGFR <60 ml/min/1.73 m² or ACR ≥30 mg/g.

vol 1 Figure 1.6 Adjusted odds ratios of CKD in NHANES participants, by risk factor, 2001-2016



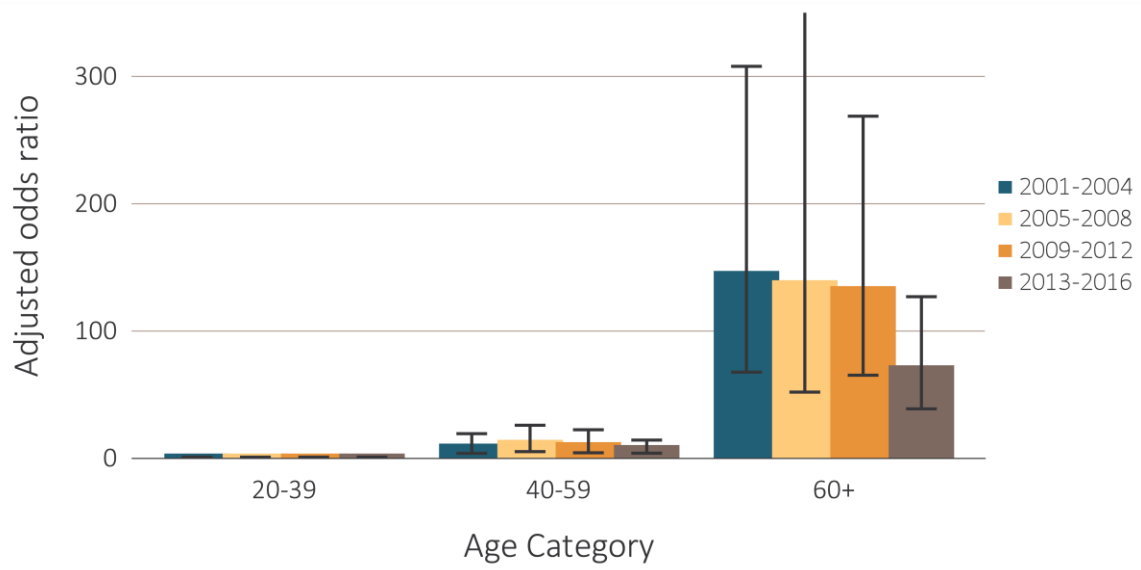
Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older; single-sample estimates of eGFR & ACR. Adjusted for age, sex, & race; eGFR calculated using the CKD-EPI equation. Whisker lines indicate 95% confidence intervals. Abbreviations: ACR, urine albumin/creatinine ratio; BMI, body mass index; CKD, chronic kidney disease; CVD, cardiovascular disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension; SR, self-reported.

Adjusted odds ratios for presence of CKD (Figure 1.6) were generally lower in NHANES 2005-2008, 2009-2012, and 2013-2016 participants than during 2001-2004. This was true for each risk factor except SR HTN and SR CVD, where adjusted odds ratios rose from 1.81 to 2.04 and 2.16 to 2.31 over these periods. Age had the strongest association with CKD, followed by HTN, DM, and CVD; these comorbidities contributed about one-third of the effect size as did age.

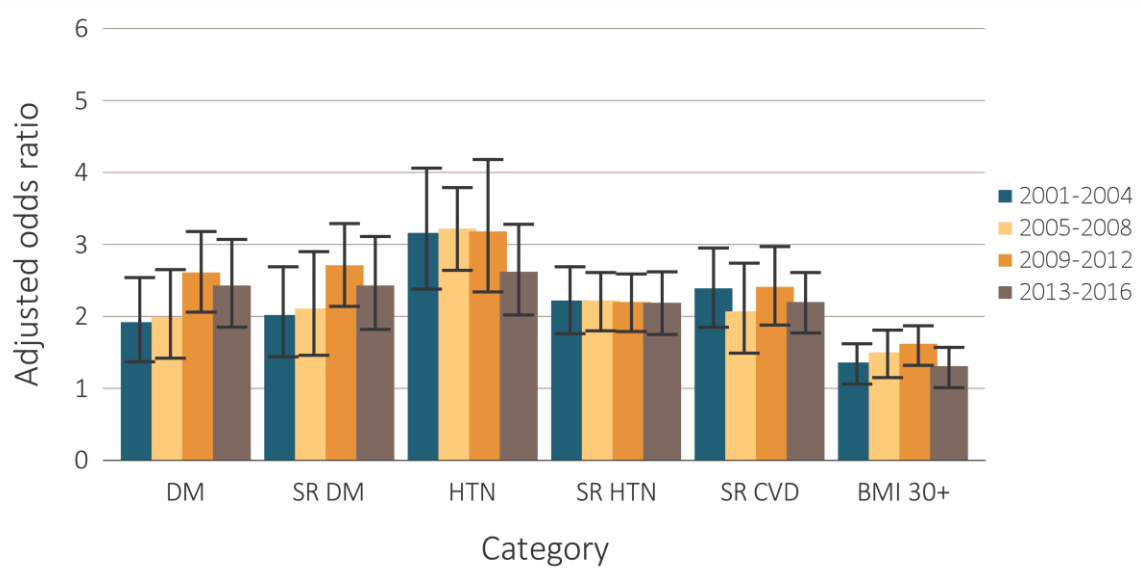
For eGFR <60 alone (Figure 1.7), adjusted odds ratios followed a similar pattern, except for DM and SR DM, where the odds increased from 1.9 to approximately 2.4 in both groups. Also, eGFR <60 showed a very strong association with age, with adjusted odds ratios in the 100 range. For ACR ≥30 alone (Figure 1.8), a substantial decline in the adjusted odds ratio was seen among both those with DM (from 4.16 to 3.03) and aged 60 or older (from 4.94 to 3.40), while a substantial increase in the adjusted odds ratio was seen for those with SR CVD (from 1.80 to 2.30).

vol 1 Figure 1.7 Adjusted odds ratios of eGFR <60 ml/min/1.73 m^2 in NHANES participants, by age & risk factor, 2001-2016

(a) Age category

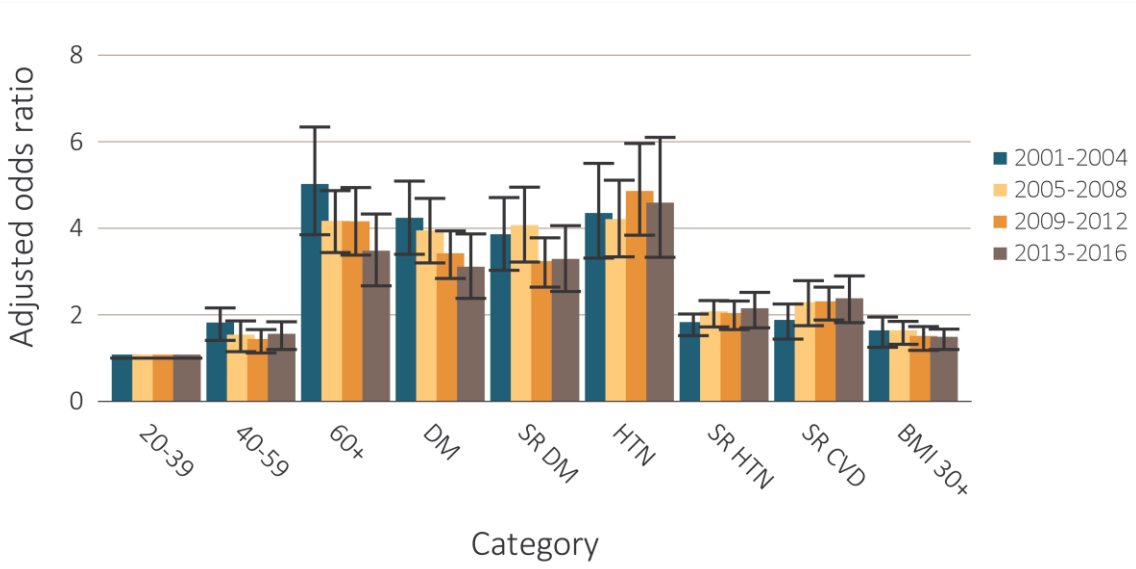


(b) CKD risk factor



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older; single-sample estimates of eGFR & ACR. Adjusted for age, sex, & race; eGFR calculated using the CKD-EPI equation. Whisker lines indicate 95% confidence intervals. Abbreviations: ACR, urine albumin/creatinine ratio; BMI, body mass index; CKD, chronic kidney disease; CVD, cardiovascular disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension; SR, self-reported.

vol 1 Figure 1.8 Adjusted odds ratios of urine albumin/creatinine ratio ≥30 mg/g in NHANES participants, by age & risk factor, 2001-2016



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older; single-sample estimates of eGFR & ACR. Adjusted for age, sex, & race; eGFR calculated using the CKD-EPI equation. Whisker lines indicate 95% confidence intervals. Abbreviations: ACR, urine albumin/creatinine ratio; BMI, body mass index; CKD, chronic kidney disease; CVD, cardiovascular disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension; SR, self-reported.

Time Trends in Characteristics of Individuals with and without CKD

In this section, we will examine changes over the four time periods in characteristics for both individuals with and without CKD in the U.S. general population. Specifically we examine socio-economic factors, including health insurance status, household income, and education. We also examine health behaviors of individuals focusing on activity level, smoking status, sleep, and nutritional intake.

Socioeconomic Factors

Table 1.3 examines the socioeconomic factors of health insurance status, income, and education level among individuals with and without CKD over time. The overall proportion with health care coverage remained steady between approximately 87%-91%. The highest coverage was seem among individuals with eGFR <60, who were typically older in age. The highest percentage of individuals had a combination of government provided health insurance (mainly Medicare) and private insurance coverage. The proportion of individuals without CKD who had insurance coverage also remained quite stable during this time period, but in contrast to individuals with CKD, they had a lower prevalence of insurance coverage (79%-84%) with the majority of those insured reporting private insurance. This observation is likely due to the fact that individuals with CKD tend to be older and a higher proportion are eligible for Medicare coverage.

Income levels for these cohorts appear to have risen over time; approximately 25% of individuals with CKD reported an income of $75,000 or more in 2013-2016. Comparatively, the U.S. median income fluctuated across the same period, decreasing from $57,909 in 1999 to $56,716 in 2015, with the lowest income of $52,666 reported in 2012 (U.S. Census Bureau). Overall, individuals without CKD had higher proportions in the upper income levels, which is also consistent with their younger age and ability to work.

Education levels also rose over time, especially among those with eGFR <60. The percentage of individuals with less than high school education decreased from 31.5% in 2001-2004 to 17.4% from 2013-2016, while the group with at least some college increased from 42.4% to 57.3% over the same period. These trends are similar to those of the general U.S. population. The National Center for Education Statistics reports that adjusted high school graduation rates increased from 79% 2010-2011 to 83% percent in 2014-2015. Rates were highest overall among those of White and Asian race, and lowest for Blacks and American Indians. In addition, college enrollment rose from 35% in 2000 to 40% in 2015. Overall college enrollment rates were higher for females compared to males.

Health Risk Behaviors

Historically, health risk behaviors for CKD have received less emphasis than have the contributing biological risk factors. Table 1.4 examines self-reported activity level, smoking status, amount of sleep, and new to the chapter this year, nutrient intake for individuals with and without CKD. An increase in in activity level across the cohorts was seen among individuals with both eGFR <60 and ACR ≥30. The percent of individuals with CKD reporting a sedentary life-style decreased from 44.9% to 38.2%. This trend is similar to individuals who do not have CKD, who have reported an increase in physical activity (69.0% to 75.4%, Figure 1.9). Overall, individuals without CKD reported more activity.

A moderate decrease in the percentage of individuals reporting current smoking was seen across the cohorts, primarily in individuals with ACR ≥30 mg/g. The percentage of current smokers increased among those with eGFR <60 ml/min/1.73 m^2. Reported amount of sleep was lowest for those with albuminuria, while a higher percentage of those with eGFR <60 reported more than nine hours of sleep per night. The percent of individuals getting less than 6 hours of sleep has decreased in all populations, except eGFR <60.

Nutrient intake was examined in terms of total energy (kcals), fat, carbohydrates, protein, total sugars, sodium, and potassium estimated as daily intake. In patients with CKD, calorie intake increased slightly, but remained under 2,000 kcals. Individuals without CKD reported higher calorie intake, ranging from 2,200-2,300 kcal/day. Daily intake of sugar and protein was very high across all years studied. Most striking is sodium intake, which is high and has increased from 2,965 mg to 3,192 mg among those with CKD, from 2,617 mg to 2,950 mg among those with eGFR <60, and from 3,142 mg to 3,303 mg among those with ACR ≥30 g/mg. Most striking, though, is the reported sodium intake for individuals without CKD, which averages >3,500 mg over the entire time period. Contrary to this, potassium intake is below the recommended guidelines and has not changed substantially over the time periods.

vol 1 Table 1.3 Time trends in socioeconomic factors among individuals with and without CKD, percent of NHANES participants, 2001-2016

	No CKD				All CKD				eGFR <60 ml/min/1.73 m^2				ACR ≥30 mg/g			
	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016
Health insurance status																
Not insured	18.8	20.0	21.5	16.4	9.4	12.1	13.5	11.6	2.8	4.8	3.2	4.7	12.7	15.1	18.9	14.9
Insured	81.2	80.0	78.5	83.6	90.6	87.9	86.5	88.4	97.2	95.2	96.8	95.3	87.3	84.9	81.1	85.1
Private only	61.1	59.5	56.0	54.9	32.7	31.2	28.0	29.9	19.8	18.1	19.7	19.4	39.0	36.1	31.3	33.6
Medicare only	4.6	3.8	3.8	4.7	19.7	14.1	16.6	14.4	28.1	18.5	23.5	20.9	16.6	12.6	13.6	11.6
Other government only	6.7	5.0	6.0	7.6	5.8	5.1	5.8	8.1	2.0	2.7	3.9	5.3	8.0	6.0	7.2	10.8
Private and any government	6.0	6.7	7.1	8.0	23.8	27.8	26.1	24.2	36.1	44.6	39.2	36.3	16.1	21.3	18.6	17.0
Other/Unknown	2.8	5.0	5.6	8.4	8.6	9.7	10	11.8	11.2	11.3	10.5	13.4	7.6	8.9	10.4	12.1
Income																
Less than $10,000	7.4	4.9	6.0	5.0	10.6	6.6	7.8	7.6	10.2	5.2	5.3	6.6	12.7	7.0	9.6	8.7
$10,000 – $24,999	20.5	16.8	16.1	14.3	29.2	25.7	23.8	22.4	30.7	29.2	24.5	24.0	29.1	26.4	25.0	22.2
$25,000 – $44,999	20.4	19.9	19.1	17.5	20.9	23.7	21.6	20.3	23.6	24.2	25.2	18.6	18.1	22.9	19.1	21.7
$45,000 – $74,999	22.0	22.3	19.5	20.4	18.9	19.5	18.5	17.9	17.5	19.0	20.0	18.5	19.1	19.0	16.6	17.3
$75,000 or more	24.2	31.2	32.7	35.8	12.6	17.7	19.8	24.6	10.7	13.9	17.0	24.8	12.7	18.4	20.7	22.6
Missing	5.5	4.9	6.6	7.1	7.8	6.8	8.4	7.3	7.3	8.4	8.0	7.6	8.3	6.3	9.0	7.4
Education																
<High School	16.8	17.3	16.2	13.9	28.8	27.0	25.8	19.2	31.5	27.3	26.1	17.4	29.2	28.1	27.2	21.2
High School Graduate/GED	25.9	24.2	21.1	20.5	26.3	28.0	23.1	24.5	26.2	31.6	23.7	25.3	25.9	26.6	23.1	24.3
At least some College	57.3	58.5	62.7	65.6	44.9	45.0	51.1	56.3	42.4	41.1	50.2	57.3	44.9	45.3	49.7	54.5

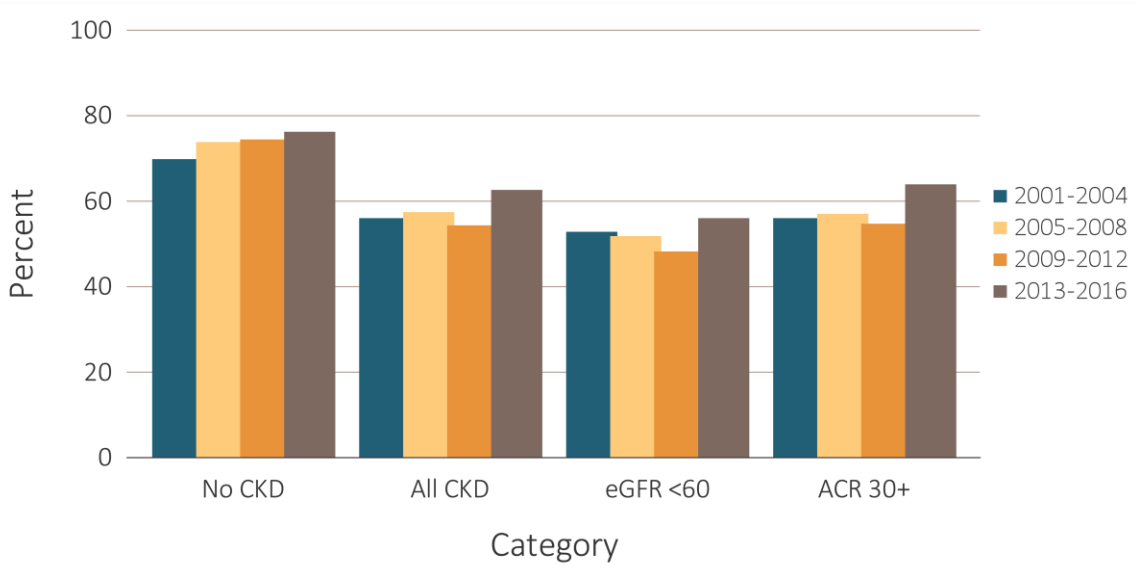
Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

vol 1 Table 1.4 Time Trends in Health Risk Behaviors among individuals with and without CKD, percent of NHANES participants, 2001-2016

	No CKD				All CKD				eGFR <60 ml/min/1.73 m^2				ACR ≥30 mg/g			
	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016	2001-2004	2005-2008	2009-2012	2013-2016
Physical Activity (%)																
Vigorous	37.4	40.9	41.0	44.2	18.6	23.3	20.9	26.7	13.8	16.0	13.6	19.4	20.0	25.1	23.9	28.5
Moderate	30.9	31.8	32.6	31.1	36.6	33.3	32.6	35.1	38.2	35.0	33.8	35.8	35.2	31.1	30.0	34.6
Sedentary	31.7	27.3	26.4	24.7	44.9	43.4	46.5	38.2	48.0	49.0	52.6	44.8	44.8	43.8	46.1	36.9
Smoking (%)																
Current	21.5	20.3	17.2	15.0	20.0	17.8	16.1	16.8	9.0	9.7	9.7	10.1	25.9	21.4	19.2	21.0
Former	23.5	23.9	23.1	23.0	32.4	28.7	31.4	30.3	39.6	36.6	38.8	36.3	28.1	26.4	28.1	27.9
Never	55.0	55.8	59.6	62.0	47.6	53.4	52.5	52.8	51.4	53.7	51.4	53.6	46.0	52.2	52.7	51.1
Amount of Sleep (%)																
Less than 6 hours	-	13.9	13.1	12.3	-	14.7	14.8	14.0	-	9.2	12.9	14.1	-	18.0	16.5	14.1
6 hours	-	23.4	24.2	22.5	-	22.2	19.7	21.8	-	22.1	15.6	20.5	-	22.9	22.6	22.8
7-8 hours	-	57.2	57.1	58.3	-	53.9	55.5	53.2	-	57.5	57.3	48.6	-	51.2	53.2	54.9
9 hours or more	-	5.5	5.6	6.9	-	9.2	10.0	11.0	-	11.1	14.2	16.8	-	7.9	7.8	8.2
Macronutrient Intake*																
Energy (kcal)	2,307	2,254	2,238	2,212	1,862	1,885	1,883	1,916	1,637	1,712	1,712	1,800	1,973	1,943	1,958	1,963
Fat (grams)	87	86	84	86	70	73	72	73	62	67	66	71	74	75	74	74
Carbohydrates (grams)	282	269	271	260	230	226	229	228	205	208	209	216	241	232	238	232
Protein (grams)	86	86	85	86	70	75	73	74	63	69	66	70	74	76	76	76
Total Sugars (grams)	135	123	121	114	107	102	102	101	95	95	93	99	112	103	105	100
Sodium (mg)	3,576	3,622	3,685	3,632	2,965	3,082	3,175	3,192	2,617	2,825	2,913	2,950	3,142	3,162	3,297	3,303
Potassium (mg)	2,806	2,743	2,829	2,721	2,468	2,510	2,529	2,450	2,376	2,434	2,376	2,466	2,488	2,505	2,572	2,407

Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. – Data not available. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.
**Dietary intake data not yet available for 2015/2016.*

vol 1 Figure 1.9 NHANES participants physically active, 2001-2016



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

Time Trends in Treatment and Control of Patients with CKD

Table 1.5 presents reported awareness of HTN, treatment of CKD-contributing conditions, and control of HTN, hyperlipidemia, and DM in the NHANES adult participants with eGFR <60 ml/min/1.73 m^2 or ACR ≥30 mg/g. While the 73%-74% prevalence of HTN among CKD patients was similar in the four periods, the proportion of participants unaware of their HTN fell from 28.5% to 20.0% in those years. The proportion of hypertensive individuals who were aware, treated, and disease-controlled rose steadily from approximately 17% in the early cohorts to 27% in 2013-2016. In the subgroup with DM, glycemic control initially improved, but then dropped in the most recent cohort, with 58.3% remaining uncontrolled in 2013-2016.

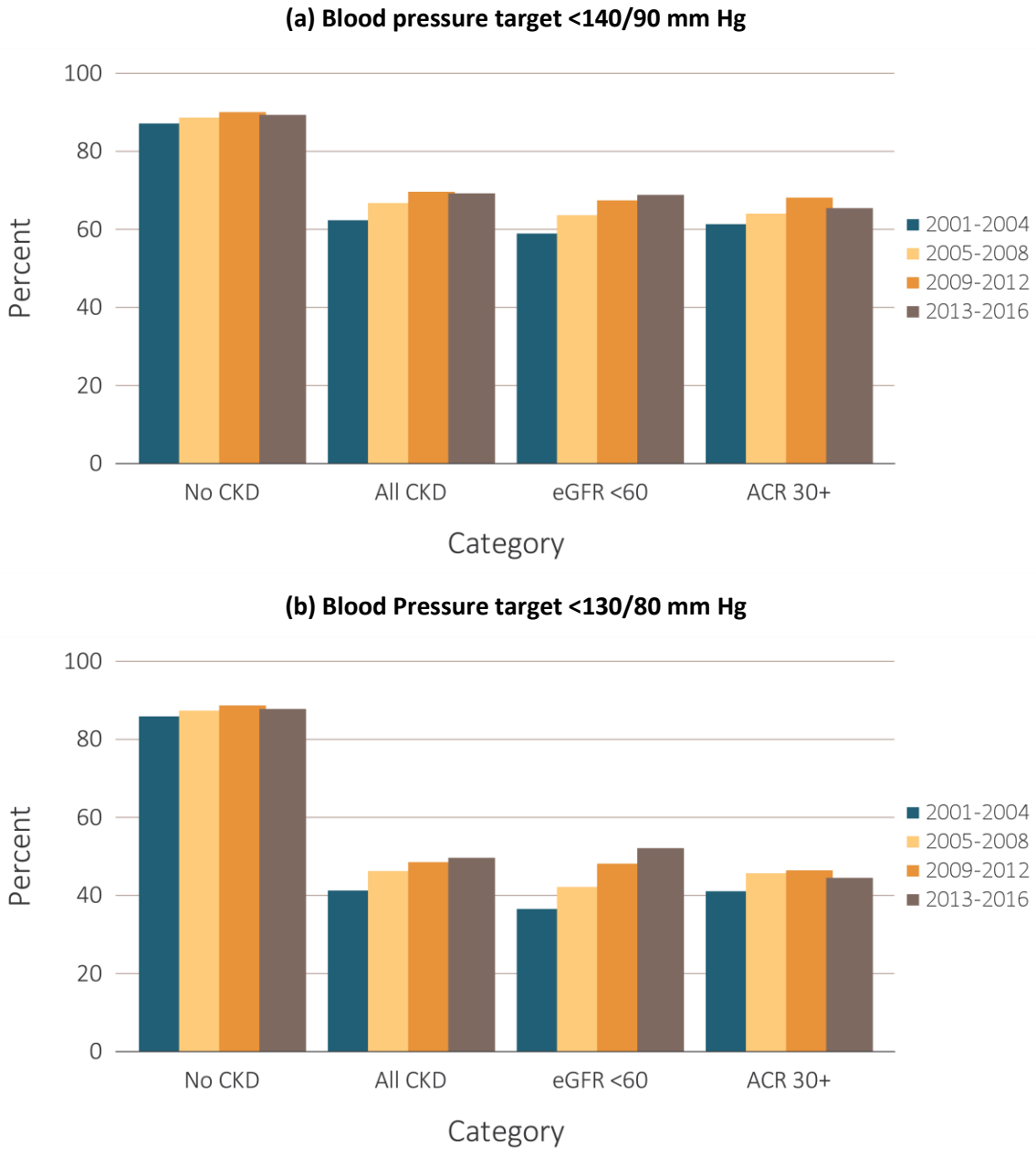
vol 1 Table 1.5 Treatment, and measures of control of CKD risk factors, among NHANES participants with CKD, 2001-2016

	All CKD					eGFR <60 ml/min/1.73 m^2					ACR ≥30 mg/g				
	2001-2004	2005-2008	2009-2012	2013-2016	Trend p-value	2001-2004	2005-2008	2009-2012	2013-2016	Trend p-value	2001-2004	2005-2008	2009-2012	2013-2016	Trend p-value
Hypertension, by current hypertensive status [a]															
Non-hypertensive status	25.6	26.9	25.0	27.7	0.50	15.4	16.1	15.7	19.7	0.05	29.4	30.1	27.9	29.4	0.82
Hypertensive (measured/treated)	74.4	73.1	75.0	72.3		84.6	83.9	84.3	80.3		70.6	69.9	72.1	70.6	
Control of hypertension among hypertensive patients [b]															
Unaware	28.5	24.5	21.9	20.0	<0.01	21.9	19.0	16.0	13.3	<0.01	31.3	26.3	24.9	23.5	<0.01
Aware, not treated	9.2	8.0	6.2	12.1		5.8	4.1	2.4	5.1		10.7	10.6	8.4	15.9	
Aware, treated, uncontrolled	45.6	44.6	43.4	40.5		51.0	48.8	46.3	44.1		45.8	44.9	43.9	42.0	
Aware, treated, controlled	16.7	22.8	28.4	27.4		21.3	28.0	35.3	37.3		12.2	18.2	22.8	18.6	
Total cholesterol [c]															
<200 (desirable)	48.7	54.6	60.2	62.2	<0.01	49.0	58.2	64.5	66.6	<0.01	49.0	54.8	58.9	60.7	<0.01
200–239 (borderline high)	31.0	27.2	26.0	23.3		31.7	24.2	22.7	20.7		30.8	27.6	27.3	23.9	
240+ (high)	20.3	18.2	13.9	14.5		19.2	17.7	12.7	12.6		20.3	17.6	13.7	15.4	
Control of diabetes among patients with diabetes [d]															
HbA1c <7% (controlled)	43.8	47.8	46.3	41.7	0.42	54.8	59.6	56.3	48.0	0.11	37.0	43.4	37.1	36.3	0.45
HbA1c 7% - 7.9% (borderline)	21.1	25.3	25.3	22.7		24.4	24.1	26.4	27.0		22.3	25.6	26.8	21.9	
HbA1c 8% + (uncontrolled)	35.1	27.0	28.4	35.6		20.8	16.3	17.3	25.0		40.7	31.0	36.1	41.8	

Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants age 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. [a] Hypertension defined as blood pressure ≥130/≥80 for those with CKD and diabetes; otherwise, ≥140/≥90, or self- reported treatment for hypertension. [b] Awareness and treatment are self-reported. Control defined as <130/<80 for those with CKD and diabetes; otherwise <140/<90. [c] Total cholesterol classified according to Adult Treatment Panel III blood cholesterol guidelines (ATP III). [d] Glycosylated hemoglobin (HbA1c) classified according to American Diabetes Association guidelines. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; HbA1c, glycosylated hemoglobin.

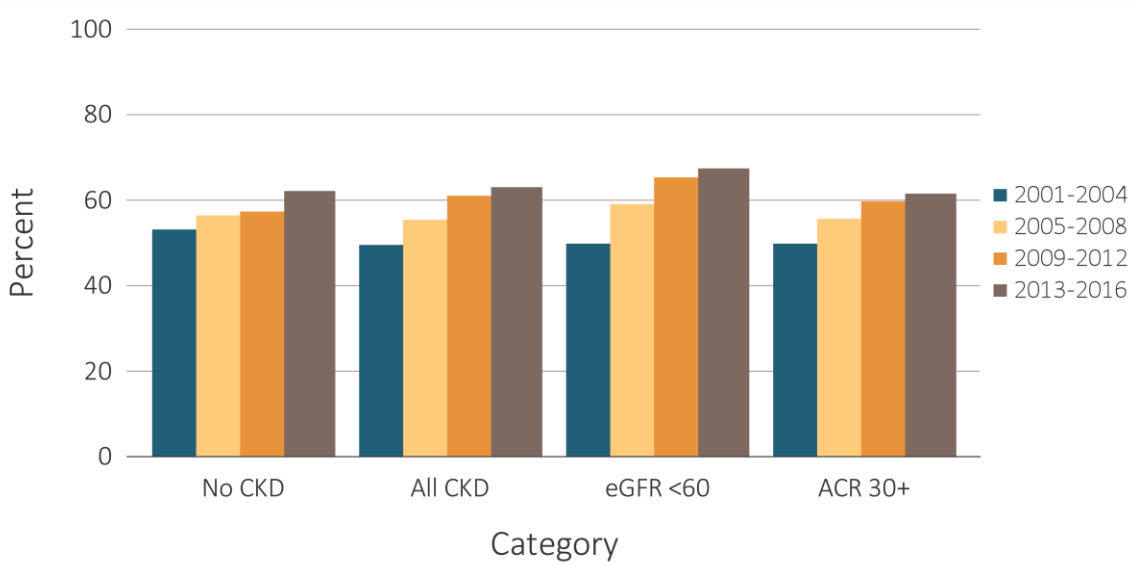
As illustrated by Figures 1.10-1.12, over the periods of 2001-2004, 2005-2008, 2009-2012, & 2013–2016, improvements in the management of HTN and cholesterol were observed, regardless of whether the criterion was eGFR or ACR level. For comparison, these figures include estimates for individuals without CKD.

vol 1 Figure 1.10 Time Trends of NHANES participants with and without CKD at target blood pressure, 2001-2016



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Figure represents all hypertensive participants including those who were at target blood pressure, probably due to medication. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

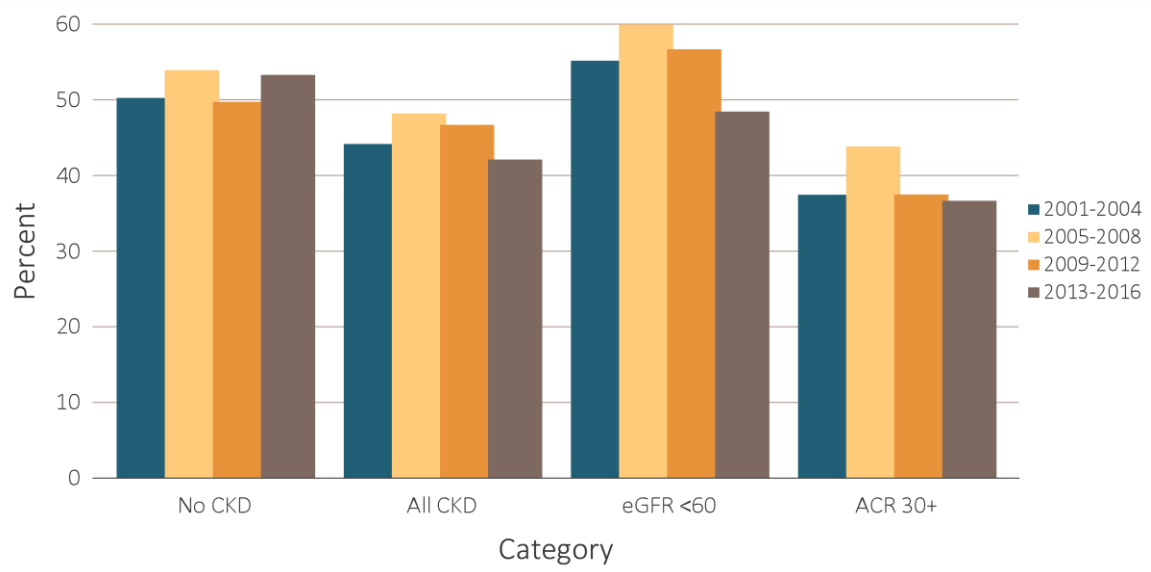
vol 1 Figure 1.11 Time Trends of NHANES participants with and without CKD with respect to cholesterol in the normal range, 2001-2016



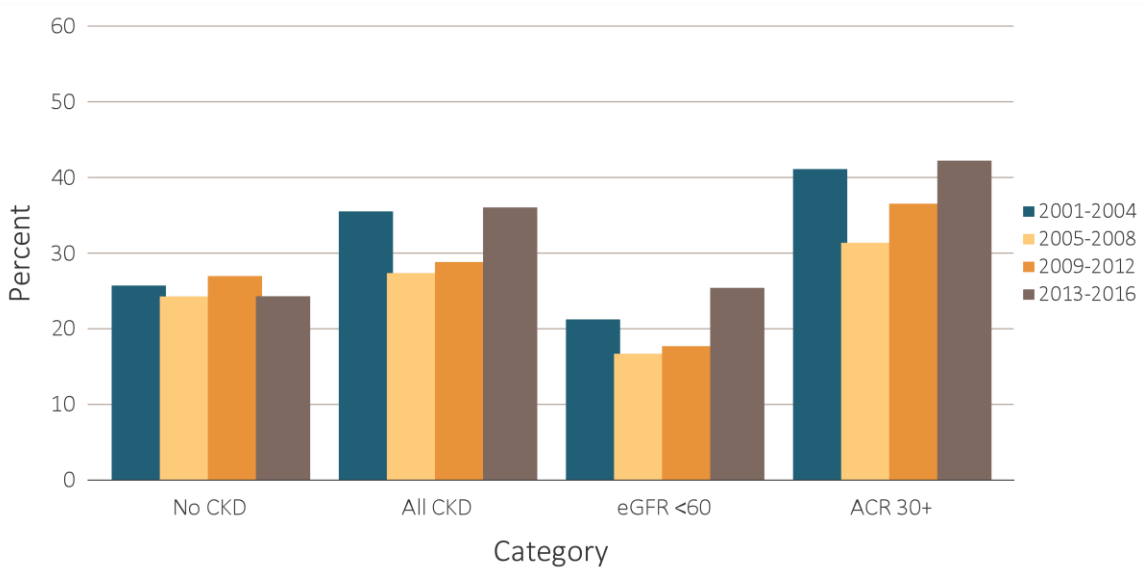
Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

vol 1 Figure 1.12 Time trends of diabetic NHANES participants with and without CKD with respect to glycemic control, 2001-2016

(a) Glycosylated hemoglobin <7%



(b) Glycosylated hemoglobin >8%



Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2004, 2005-2008, 2009-2012 & 2013-2016 participants aged 20 & older. Single-sample estimates of eGFR & ACR; eGFR calculated using the CKD-EPI equation. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

CKD Awareness

Among the individuals who were classified by laboratory measurements as having CKD, the percentage who were aware of their kidney disease remained low from 2001-2016 (Figure 1.13). There is a suggestion of an improvement among individuals with Stage 4 CKD between 2009-2012 and 2013-2016. We do not present awareness data for those in Stage 5 CKD because of a very small sample size. When examined by eGFR <60 vs. ACR >30, awareness was markedly higher for individuals who had both conditions.

When examining awareness by conditions that are known risk factors for CKD (DM and HTN), awareness was still very low. Even among individuals with both conditions, awareness was steady around 15% (Figure 1.13.c). Figure 1.13.d displays awareness by age categories, and while older patients have slightly better awareness, those 60+ years only reached 10% in the most recent cohort (2013-2016).

vol 1 Figure 1.13 Time trends of individuals with CKD aware of their kidney disease, NHANES 2001-2016

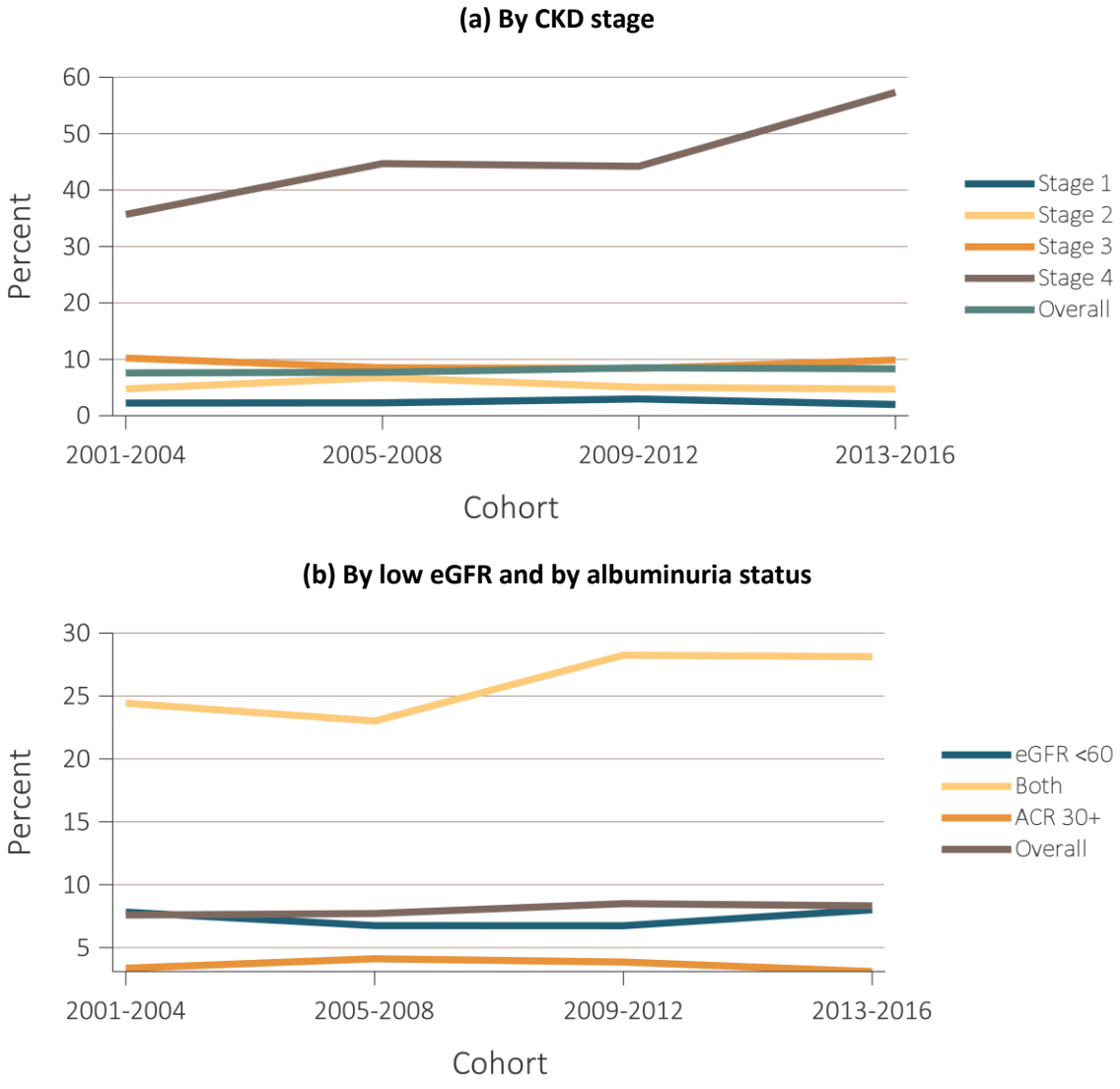
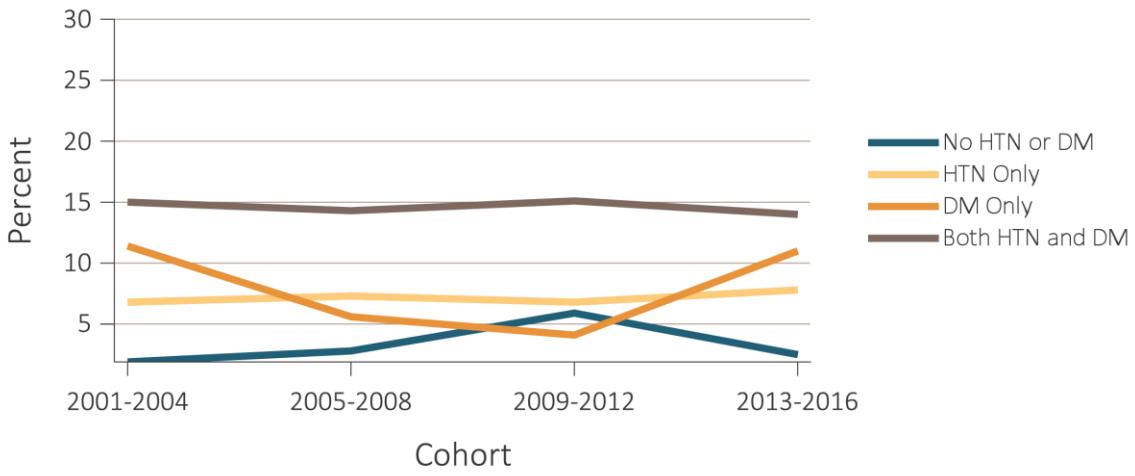


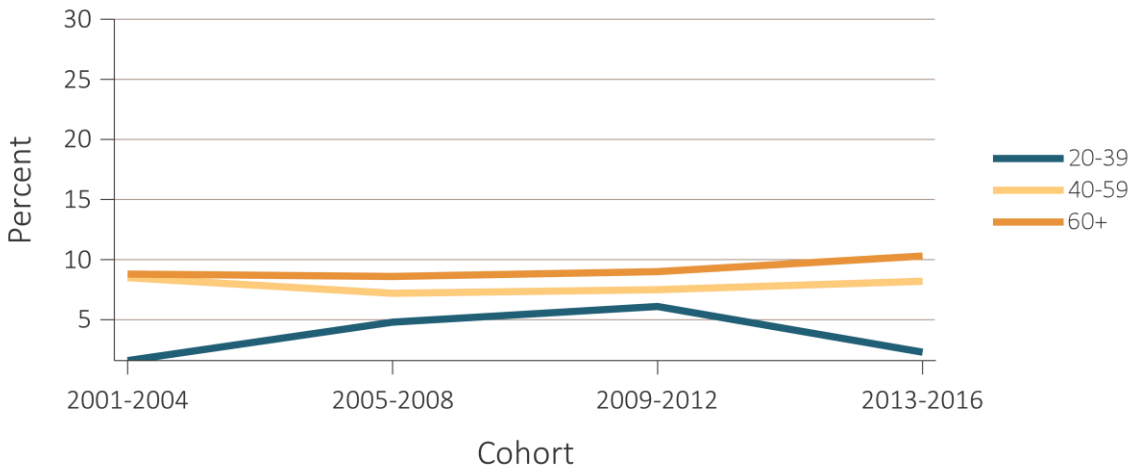
Figure 1.13 continued on next page.

vol 1 Figure 1.13 Time trends of individuals with CKD aware of their kidney disease, NHANES 2001-2016 (continued)

(c) By diabetes and hypertension status



(d) By age categories

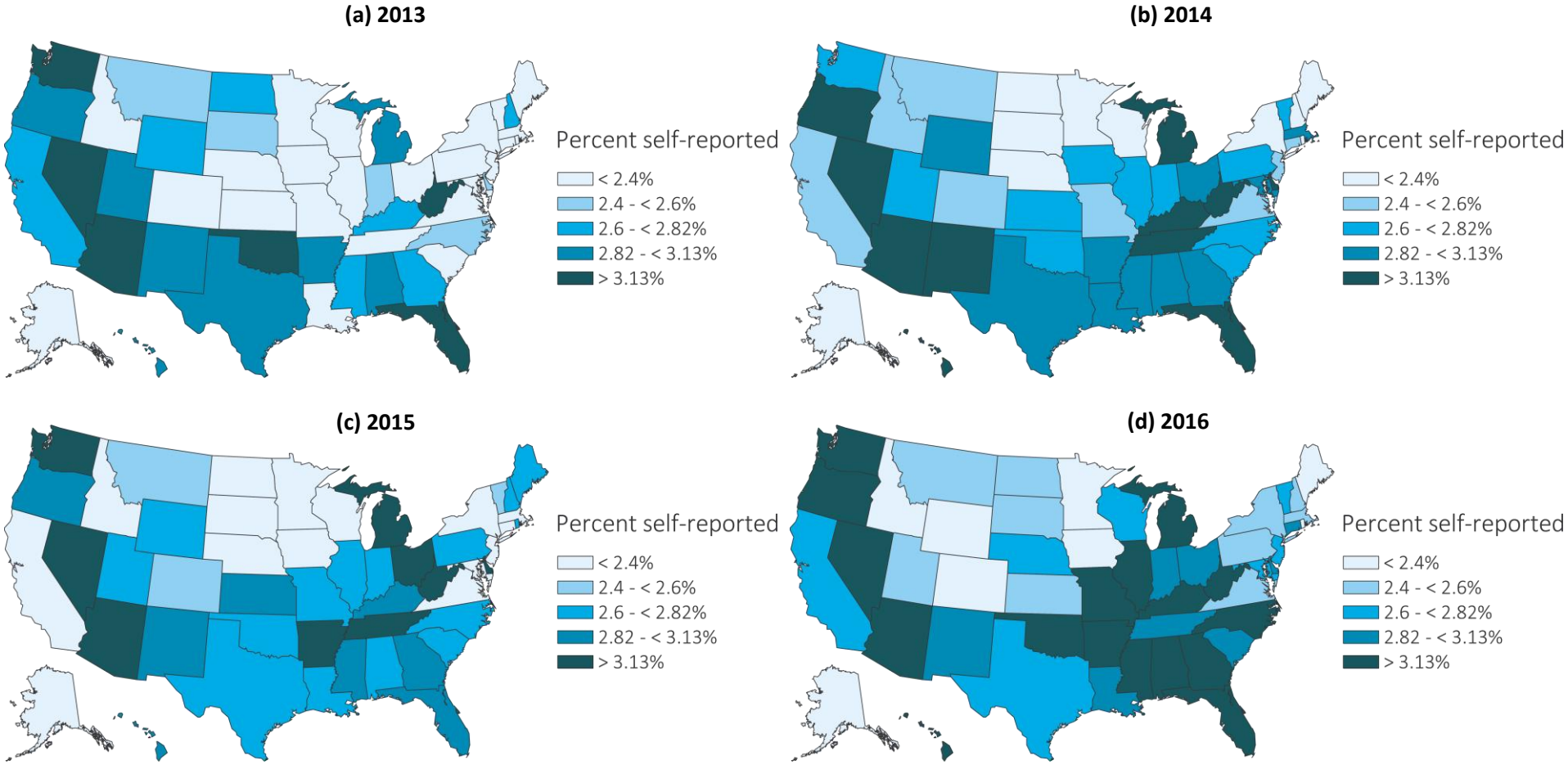


Data Source: National Health and Nutrition Examination Survey (NHANES), 2001-2016 participants aged 20 & older. Abbreviations: ACR, urine albumin/creatinine ratio; CKD, chronic kidney disease; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension.

Figure 1.14 displays the state-specific proportions of individuals who reported being told they had 'kidney disease', based on the 2013 and 2016 BRFSS cohorts. The overall national averages were very low, hovering just under 3% for all years. The NHANES prevalence of self-reported kidney disease ('weak or failing kidneys') of 2.8% matches this national estimate from the BRFSS survey, suggesting poor identification or awareness of kidney disease in the general population.

States with the highest proportion of participants over the years who indicated that they had been informed they had kidney disease included Hawaii, Arizona, Michigan, and West Virginia. Conversely, the states with the lowest proportion of BRFSS participants self-reporting kidney disease included Alaska, Minnesota, Colorado, and New York. These differences could reflect varying prevalence of kidney disease by state, or variations in survey participants' awareness of the condition, if present. The true underlying prevalence of kidney disease by individual state is currently unknown as no state-level NHANES-like surveys are conducted in the United States. Estimates of CKD prevalence and awareness of CKD by state have been computed recently, using prediction modeling (Dharmarajan, 2017).

vol 1 Figure 1.14 Estimated prevalence of self-reported kidney disease by state, BRFSS participants ages 18 and older



Data source: Behavioral Risk Factors Surveillance System (BRFSS), participants aged 18 & older. 2013 (N=491,777), 2014 (N=464,617), 2015 (N=441,460), and 2016 (N=486,303).

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