ORIGINAL ARTICLE

The Prevalence of Renal Failure

Results From the German Health Interview and Examination Survey for Adults, 2008–2011 (DEGS1)

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SUMMARY

Background: The prevalence of non–end stage renal failure among adults in Germany is unknown. Accurate figures would enable us to estimate the overall need for kidney replacement therapies and the unexploited potential for disease prevention. Renal failure is also an important cardiovascular risk factor. Until now, American prevalence figures have often been applied to Germany despite dissimilarities between the two populations.

Methods: We analyzed data on renal function from the nationwide German Health Interview and Examination Survey for Adults, 2008–2011 (DEGS1), which was carried out by the Robert Koch Institute. The glomerular filtration rate was estimated (eGFR) from the serum creatinine and cystatin C levels (CKD-EPI formula) and a semiquantitative measure of albuminuria. Relationships between renal failure and its possible determinants were quantified with adjusted prevalence ratios (PR) and 95% confidence intervals (95% CI).

Results: Roughly 2.3% (95% CI: [1.9; 2.6]) of persons aged 18–79 had an eGFR below 60 mL/min/1.73 m^2. The prevalence rose with age. We extrapolated these figures conservatively to persons aged 80 and above, who were not included in the DEGS1, and arrived at a figure of at least 2 million persons in Germany with renal failure. 11.5% of the population have albuminuria of at least 30 mg/L. Diabetes mellitus (PR = 2.25, 95% CI: [1.59; 3.16]) and arterial hypertension (PR = 3.46, 95% CI: [1.95; 6.12]) are important determinants.

Conclusion: This study provides the first representative estimate of the prevalence of renal failure in Germany. The condition is highly dependent on age but less prevalent than previously assumed on the basis of American prevalence figures.

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Approximately 80 000 patients with end stage renal disease (ESRD) are treated in Germany with hemodialysis or peritoneal dialysis (1). Additionally, about 23 000 people are in follow-up after a successful kidney transplant. Medical care for both patient groups is extremely costly. The vast majority of patients who require long-term dialysis treatment were previously afflicted with progressive chronic kidney disease (CKD). However, permanently requiring renal replacement therapy is just one of the serious consequences of CKD. For instance, non–dialysis-dependent patients with a reduced glomerular filtration rate (GFR) have a stage-dependent, 1.4-fold to 18.6-fold increase of overall mortality (2). Indeed, patients with a GFR <60 mL/min/1.73m^2 are more at risk for death—with a more than two-fold increase (45.7% in 5 years)—than for requiring renal replacement therapy due to disease progression (19.9%) (3).

There are currently no population-based estimates for Germany about the prevalence of chronic renal dysfunction in the non–dialysis-dependent stage. Such studies are particularly necessary for effectively planning and carrying out preventive measures, as well as for providing a continuation of medical care for ESRD. Whether epidemiological data from the United States population—such as that of the National Health and Nutrition Examination Survey (NHANES), which found a population-wide prevalence of 8% for reduced eGFR (4)—can be transferred to the German population is questionable, not the least because of differences in ethnic composition. Worldwide, data are very heterogeneous and difficult to compare, mainly due to differences in measurement methods (5).

The population-representative "German Health Interview and Examination Survey for Adults" (DEGS1) (6) is part of nationwide continuous health monitoring, carried out by the Robert Koch Institute (RKI) on behalf of the German Federal Ministry of Health. The most recent data collection in DEGS (DEGS1), conducted from 11/2008 to 12/2011, included 7115 women and men aged 18 to 79 years. Within the DEGS1 framework, renal function parameters were determined, and participants answered questions about renal dysfunction and any treatment for it. Based on data analyses, we were able to establish a population-representative estimate for the prevalence of renal dysfunction in adults in Germany, as well as determine any correlations between renal dysfunction and age, sex, and

TABLE 1

Demographic data of participants (n = 7115)

	Total		Men		Women	
Age (years): mean, (SD)	47.4	(20.0)	46.8	(19.7)	48.0	(20.1)
BMI (kg/m^2): mean, (SD)	26.9	(7.8)	27.2	(6.4)	26.5	(7.6)
Blood pressure: mean, (SD)*1						
Systolic (mm Hg)	124.1	(22.9)	127.4	(19.5)	120.8	(21.1)
Diastolic (mm Hg)	73.2	(15.1)	75.3	(14.0)	71.2	(12.4)
Sex: n, %	7115	100	3410	49.7	3705	50.3
Anamnestic indications: n, %						
Arterial hypertension*2	2635	31.7	1 366	33.4	1269	30.0
Diagnosed diabetes mellitus*3 (verified by physician, self-declared)	549	6.6	309	7.0	240	6.2
Smoking status: n, %						
Current	1882	29.9	991	32.6	891	27.1
Former	2118	28.2	1221	33.4	897	23.0
Never	3073	42.0	1178	34.0	1895	49.9
SES: N, %						
Low	1133	19.7	526	19.0	607	20.3
Medium	4253	60.4	1955	58.9	2298	61.9
High	1681	20.0	905	22.2	776	17.8

*1 Details for blood pressure measurement given in Neuhauser et al. (10)
*2 Diagnosed based on self-reported anamnestic history, current treatment with an antihypertensive medication, or blood pressure values >140/90 mm Hg in the study
*3 Only diagnosed based on self-reported anamnestic history.
SD, standard deviation; SES, socioeconomic status

known risk factors. Furthermore, we were able to assess the levels of awareness about renal dysfunction and the medical treatment received for it.

Methods

Participants and survey methodology

The complex design of the DEGS survey wave 2008–2011 (DEGS1) has been described in detail (6, 7). The study population was selected to be representative of the total adult resident population, aged 18 to 79 years, in Germany. Overall, 7115 participants were examined in one of the 180 study centers. To determine socio-demographic variables, information was collected about education levels, vocational training, employment status, and net household income. Participants were categorized as having a low, medium, or high socioeconomic status (SES) (8).

Information on diabetes, hypertension, and smoking status

The survey methodology for diabetes mellitus (9), arterial hypertension (10), and smoking status (11) have been published (see details in the *eSupplement*). Deviating from the above-mentioned definition (9), cases of gestational diabetes were not included for prevalence estimation.

Evaluation of kidney function

To determine kidney function, measurements were taken from participant blood samples for standardized serum creatinine concentration (Architect, Abbott Diagnostics, Wiesbaden; IDMS traceable creatinine assay) and for cystatin C (Prospec, Siemens Healthcare, Eschborn). The estimated GFR (eGFR) was calculated using the CKD-EPI equation for creatinine and cystatin C (12). Following recommendations of the Kidney Disease Improving Global Outcomes Initiative (KDIGO) (13), eGFR values were categorized as reduced at <60 mL/min/1.73 m^2. Urinary albumin was determined from a random urine sample by semi-quantitative test strips (Micral, Roche Diagnostics, Grenzach-Wyhlen). However, results from the Micral test strips have limited diagnostic accuracy and are categorized in ranges (negative, 20 mg/L, 50 mg/L, and 100 mg/L) that are not congruent with albumin/creatinine ratio measurements or with the KDIGO-recommended albuminuria categories (A1, <30 mg/g; A2, 30 to 300 mg/g; A3, >300 mg/g) (13). For this reason, participant results were reclassified according to Parikh (14), taking into account the Micral test false- and true-positive rates of determining albuminuria as compared to the KDIGO categories. Moreover, a diagnosis of increased albumin excretion usually requires repeated albuminuria measurements (4, 13), which was not carried out in the DEGS1 framework. Therefore, to estimate the prevalence of persistent albuminuria, an eGRF-independent correction was made similar to that described by Coresh (4); for correction details, see the *eSupplement*.

Statistical methods

All analyses were statistically weighted to correct for deviations in the sample from the German population (as of 31 December 2010) with respect to age, sex, region, nationality, community type, and education levels. For the DEGS1 subgroup who had already participated in the German Federal Health Survey 1998, calculation of the individual weighting factor also considered the re-participation probability (6). To account for the association between impaired kidney function and the risk factors of smoking, diabetes mellitus, and arterial hypertension, adjusted prevalence ratios (PR) and 95% confidence intervals (95% CI) were estimated using log-binomial regression models (15). Adjustment variables were determined using directed acyclic graphs (16). All analyses were performed with SAS version 9.3 (Cary, NC). To take into account both the weighting and the correlation of the participants within a community, all confidence intervals were calculated using the survey procedures of SAS.

Results

The prevalence of eGFR <60 mL/min/1.73m^2 for adults aged 18 to 79 years is 2.3% (95% CI: [1.9; 2.6]). This

estimate is based on the survey of 7115 participants, whose demographics are shown in *Table 1*. Renal dysfunction was associated primarily with increasing age (see *Figure*). The estimate was based on an eGFR calculated with the CKD-EPI equation using creatinine and cystatin C. This can be considered reliable especially for values around GFR 60 mL/min/1.73m^2. However, the more widely used Modification of Diet in Renal Disease (MDRD) Study formula (17) estimated a higher prevalence of renal dysfunction, of 3.5% (95% CI, 3.1 to 3.9).

Increased urinary albumin excretion is also a sign of renal injury. Albuminuria can be seen together with a reduced GFR, but it also occurs by itself and as an early sign of renal microvascular damage. The prevalence of albuminuria ≥ 30 mg/L was determined with respect to age and sex (*eTable 1*) as well as for renal impairment (*Table 2*).

Known factors that influence the occurrence of chronic renal dysfunction are diabetes mellitus (adjusted PR = 2.25) and arterial hypertension (adjusted PR = 3.46). Moreover, former smokers had slightly increased prevalence ratios for renal dysfunction (*Table 3*).

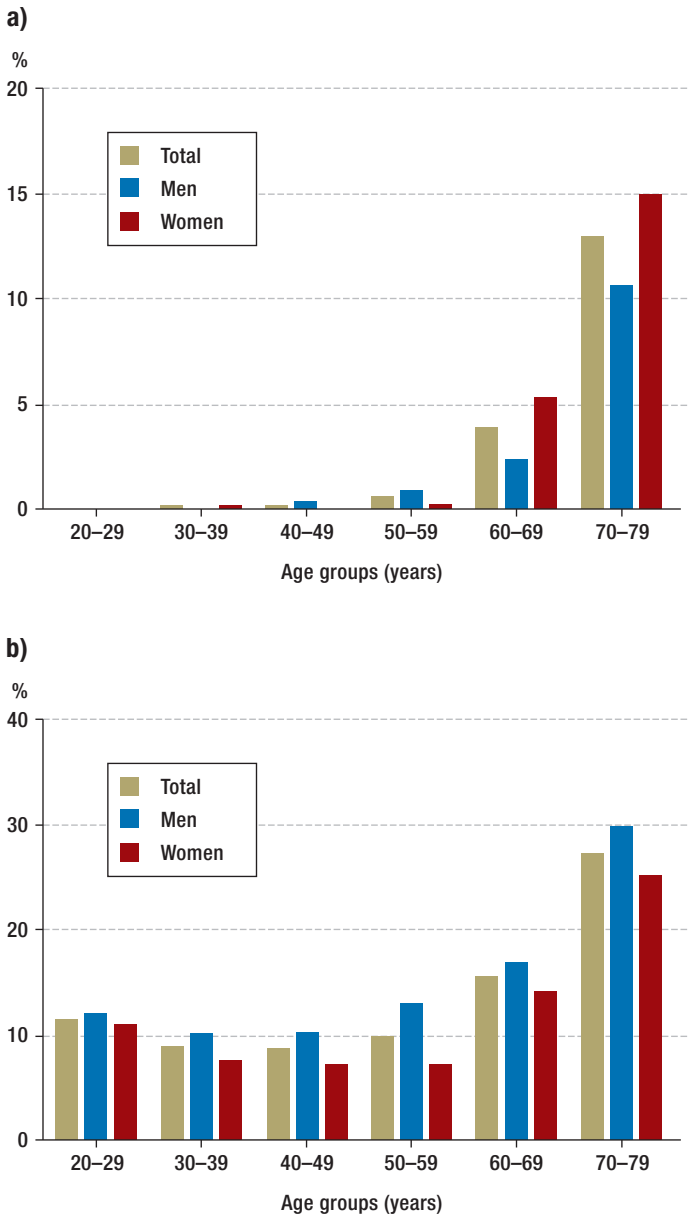
Only about 28% of participants with an eGRF of <60 mL/min/1.73m^2 were aware of their impaired kidney function (*Table 4*). Of those who were aware, only about two-thirds reported that they receive medical treatment for kidney disease. Thus, compared to the limitations of the measurement-based eGFR, self-reports of chronic renal dysfunction are highly specific but less sensitive. Self-awareness of renal dysfunction was not associated with socioeconomic status or sex (*Table 3*).

Discussion

Approximately 2.3% of the adult German population, aged 18 to 79 years, has an eGFR of <60 mL/min/1.73m^2. In the same group, the estimated overall prevalence for elevated urinary albumin excretion is 11.5%, while that for having either a reduced eGFR or albuminuria is 12.7%. Based on these data, we are able for the first time to quantitatively estimate the prevalence of kidney damage in Germany. While the medical care requirements for patients with end-stage kidney failure who require renal replacement therapy is known, due to the established quality assurance systems (1), the percentage of people in non–dialysis-dependent stages could previously only be roughly estimated based US surveys (4). Data was available for Germany only for people aged 70 years or older from the Berlin Initiative study (BIS) (18), which determined that 30.1% of this age group have an eGFR of <60mL/min/1.73 m^2.

The prevalence estimates mean that, in Germany in 2011, about 1.53 million adults in the age group 18 to 79 years had a reduced eGFR. Further, the data show a strong association with age. Thus, while kidney damage is very rare in people younger than 50 years of age, every eighth person aged 70 to 79 years is affected.

FIGURE



Age- and sex-specific prevalence (%) a) eGFR <60 mL/min/1.73m^2. b) eGFR <60 mL/min/1.73m^2 or urinary albumin excretion ≥ 30 mg/L.
eGFR, estimated glomerular filtration rate

While it can be assumed that this prevalence is even higher in the over-80s age group, the present survey can not draw any conclusions about this. A very conservative estimate would assume that the prevalence of reduced eGFR observed for the 70- to 79-year-olds remains the same for the over-80s. Based on this assumption, at least 2 million people in Germany have an

TABLE 2

Weighted prevalence (%) of albuminuria ≥ 30 mg/L in relation to calculated eGFR (mL/min/1.73 m²) and sex

	eGFR ≥ 90	60 ≤ eGFR < 90	eGFR< 60	Total
Men	10.6	24.5	57.2	13.4
Women	7.7	13.3	35.2	9.6
Total	9.2	18.1	43.2	11.5

eGFR, estimated glomerular filtration rate

TABLE 3

Weighted multivariate analysis of factors influencing kidney damage and awareness of kidney damage

Endpoint	Causal risk factor	PR	95% CI
Reduced eGFR <60 mL/min/1.73m²	**Smoking status*1**		
	– Current	0.96	(0.54–1.73)
	– Former	1.24	(0.86–1.78)
	– Never	1.0	
	Diabetes mellitus*1		
	– Yes	2.25	(1.59–3.16)
	– No	1.0	
	Arterial hypertension*2		
	– Yes	3.46	(1.95–6.12)
	– No	1.0	
Awareness of kidney damage	**Socioeconomic status*3**		
	– High	1.07	(0.83–1.38)
	– Low	1.09	(0.93–1.27)
	– Medium	1.0	
	Sex*4		
	– Female	1.00	(0.76–1.31)
	– Male	1.0	

For the endpoint of reduced eGFR <60 mL/min/1.73 m², N = 6896 participants (smoking status), N = 6871 participants (diabetes mellitus), or N = 6848 participants (hypertension) were analyzed; for the endpoint of awareness of kidney damage, N = 187 participants with kidney damage were analyzed.
*1 Adjusted for age, sex, body mass index, and socioeconomic status (SES)
*2 Adjusted for age, body mass index, diabetes mellitus, and smoking status
*3 Adjusted for age, sex, smoking status, hypertension, and diabetes
*4 Adjusted for age, SES, smoking status, hypertension, and diabetes mellitus
95% CI, 95% confidence interval; PR, prevalence ratio; eGFR, estimated glomerular filtration rate

eGFR of <60 mL/min/1.73m². However, depending on the actual prevalence in the over-80s group, the overall prevalence could reach up to 2.5 million. The Berlin Initiative Study reported that 20.7% of the 70- to 79-year-old participants, and 46.6% of the ≥ 80-year-old participants, had a reduced eGFR (18). These figures were calculated using the CKD-EPI$_{Krea}$ equation, which classifies fewer participants as having renal insufficiency (12).

Nevertheless, our prevalence estimates are lower than those estimated based on the US NHANES results. In contrast to DEGS1, the survey population in NHANES also included individuals older than 79 years (7.4% of the total) and was heterogeneous in terms of ethnic composition. The high diversity of populations represented in NHANES is particularly striking (weighted percentage: 72.6% non-Hispanic white, 10.5% non-Hispanic blacks, 7.3% Hispanic, and 1.2% other). In particular, non-Hispanic blacks, but also other non-white populations, are much more frequently affected with diabetes mellitus (19). Additionally, when diabetes or arterial hypertension is present, these groups often have higher cardiovascular and renal risks (20), and they often have impaired kidney function (4). DEGS1 defined the representative population to be those reported at the local resident registries during the survey period, of people whose primary residence was in Germany and who were 18 to 79 years old, irrespective of origin or nationality (7). As adults without German nationality were oversampled by a factor of 1.5 (6), the proportion of people with an immigrant background after weighting was around 20%, which is not negligible (21). However, population-representative statements for this group as a whole, or even for different subgroup ethnicities, can not be made due to the survey design.

As directly measuring GFR is complicated, the empirical estimation, eGFR, is routinely used instead in epidemiological surveys as well as in everyday clinical practice. Here, we have used the CKD-EPI equation (12) to estimate the parameters for serum creatinine, serum cystatin C, age, sex, and ethnicity. The MDRD equation used in NHANES (17) has been criticized for its inaccuracy in eGFR values of >60 mL/min/1.73m² (22). The CKD-EPI equation is more reliable, and particularly so within this range (23, 24).

Calculating the DEGS1 prevalence with the MDRD equation gives a higher overall prevalence. Modeling calculations on other populations show that 17% to 22% of the participants would be reclassified to the healthier GFR category (e.g., eGFR <60 to eGFR ≥ 60 mL/min/1.73m²) if the CKD-EPI equation, rather than the MDRD equation, is used. In contrast, there were few reclassifications in individuals with severely impaired renal function (25–27). Participants who were classified by the MDRD equation to have renal insufficiency, and by the CKD-EPI equation to have an eGFR >60 mL/min/1.73m², would have a significantly better renal and cardiovascular prognosis than the non-reclassified participants (27). This suggests that classification based on the CKD-EPI equation avoids a falsely high prevalence estimate of renal insufficiency. Calculating the eGFR by the CKD-EPI equation, which takes into account creatinine and cystatin C, is also the method of choice according to the KDIGO guidelines (13).

The nature of the cross-sectional design of DEGS1 does not allow conclusions to be drawn about the permanency of a dysfunction. According to the definition of chronic kidney disease (13), detection of a structural or functional disruption over a period of at least three months is required to be termed chronic. For this reason, we discuss here "impaired kidney function" rather than chronic kidney disease (CKD); however, the probability is low that people with acute renal failure were included as DEGS1 participants.

Increased urinary albumin excretion (30–300 mg/g creatinine; formerly termed "microalbuminuria") is also a symptom of renal damage and can be found as an early sign of diabetic or hypertensive damage. The presence of albuminuria with impaired kidney function is associated with a faster progression of renal damage (28). Albuminuria is additionally associated with an increased risk of cardiovascular events (29).

The ability to estimate the albuminuria prevalence was hindered in both NHANES and DEGS1 by the fact that the surveys were conducted with only limited validity, due to practical restraints. Specifically, the KDIGO definition of albuminuria (13) requires elevated urinary albumin excretion from at least two independent samplings. However, both surveys were conducted only once. This leads to an overestimation of persistent albuminuria, an effect that can be mathematically corrected (30). Albumin excretion was measured by quantifying the albumin/creatinine ratio in NHANES, but only by semi-quantitative (test strips) in DEGS1. The predictive value of this test strip for the actual presence of albuminuria is known (14), so that this can also be mathematically corrected. The 12.7% prevalence of renal damage symptoms (reduced eGFR and/or albuminuria) in the surveyed age range allows us to assume that more than 10 million adults (including those aged 80 years and over) are affected in the population residing in Germany.

People with renal insufficiency not only are in danger of renal function deterioration and long-term dialysis dependency, but also from an increased risk of death. In large population-based surveys, the age-standardized mortality steadily increases with decreasing GFR. For instance, 0.76 deaths/100 person-years is observed in populations with GFR ≥ 60 mL/min/1.73m^2, but this increases to 11.36 deaths/100 person-years once the GFR has reached 15–30 mL/min/1.73m^2, and 14.14 deaths/100 person-years at GFR < 15 mL/min/1.73m^2 (2). Similarly, the risk of cardiovascular events increases significantly with decreased GFR. Albuminuria provides a comparable index with additive importance—doubling of the urinary albumin concentration is associated with a 35% increased risk of death (31). Even the urinary albumin levels that fall within what has been considered as a "normal" range of excretion (<30 mg/g creatinine) are clearly associated with overall and cardiovascular mortality (32).

Diabetes mellitus and arterial hypertension are important predictors of kidney function impairment. As might be expected, these two diseases numerically represent the most important causes of long-term dialysis treatment (1). Based on the DEGS1 data, we are now able to provide a quantitative estimate of the relationship between these factors and the prevalence of kidney function impairment for the general population in Germany. In patient collectives with renal insufficiency, nicotine is known to increase the risk of progression for diabetic (33) and non-diabetic (34) kidney damage. The DEGS1 cross-sectional study did not reveal an association between nicotine use and prevalence of a reduced eGFR.

Critically, this study reveals that people with impaired kidney function are often unaware of their status. Approximately three-fourths of the participants with eGFR <60 mL/min/1.73m^2 claimed to have no knowledge of any kidney damage. Among those who were aware of their renal dysfunction, only two-thirds reported that they received medical treatment. Taken together, these results reveal that only about 16% of those affected receive appropriate medical care. From the perspective of medical care providers, these figures are highly relevant. For instance, taking adequate preemptive measures for health disorders such as chronic renal insufficiency requires the highest possible level of information about those affected. Preventive measures—such as cause identification, treatment of inflammatory kidney diseases, reduction of blood pressure, optimization of metabolic control, drug-induced angiotensin blockade, and avoidance of nephrotoxic effects—are strongly dependent on the cooperation of patients.

In summary, evaluation of DEGS1 data has provided the first estimates of a representative prevalence for renal impairment and/or albuminuria for the resident adult population (18 to 79 years old) in Germany.

TABLE 4

Prevalence (%) of self-awareness of kidney damage by participants (weighted responses)

	eGFR <60 (n = 187)		eGFR ≥ 60 (Nn = 6701)	
	n	%	n	%
No known kidney damage	139	71.7	6622	98.9
Known kidney damage	48	28.3	79*	1.1
Receiving medical treatment (known damage)	30	63.7	23	26.5
Not receiving medical treatment (known damage)	18	36.3	55	73.5

*including one case with missing data about medical treatment

Kidney damage is inherently progressive, but deterioration can often be delayed therapeutically. Further, kidney impairment is a significant risk for cardiovascular disease. Knowing this prevalence rate is important for planning and organizing medical care for those affected, which goes far beyond planning for cost-intensive renal replacement therapy.

KEY MESSAGES

- This is the first population-based estimate of the prevalence of chronic renal dysfunction based on survey data from Germany.
- This prevalence rate was estimated based on data from 7115 men and women from the DEGS1 survey—a nationwide, population-representative study on the health of adults (aged 18 to 79 years) in Germany.
- Approximately 2.3% of the study population have impaired kidney function, defined as an estimated glomerular filtration rate (eGFR) below 60 mL/min /1.73m^2, and 12.7% have a reduced eGFR or albuminuria.
- The prevalence of impaired kidney function was 2.25-fold higher for participants with diabetes mellitus, and 3.46-fold higher for participants with arterial hypertension.
- Only 28% of participants with impaired kidney function were aware of it; of these, only two-thirds were receiving medical treatment for it.

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Conflict of interest statement
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The remaining authors declare that no conflict of interest exists.

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REFERENCES

1. Medical Netcare GmbH: Jahresbericht Datenanalyse Dialyse für den Gemeinsamen Bundesausschuss, Berichtsjahr 2013. www.medical-netcare.de/qsd.php (last accessed on 6 November 2014).
2. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY: Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med 2004; 351: 1296–305.
3. Keith DS, Nichols GA, Gullion CM, Brown JB, Smith DH: Longitudinal follow-up and outcomes among a population with chronic kidney disease in a large managed care organization. Arch Intern Med 2004; 164: 659–63.
4. Coresh J, Selvin E, Stevens LA, et al.: Prevalence of chronic kidney disease in the United States. JAMA 2007; 298: 2038–47.
5. McCullough K, Sharma P, Ali T, et al.: Measuring the population burden of chronic kidney disease: a systematic literature review of the estimated prevalence of impaired kidney function. Nephrol Dial Transplant 2012; 27: 1812–21.
6. Scheidt-Nave C, Kamtsiuris P, Gosswald A et al.: German health interview and examination survey for adults (DEGS) – design, objectives and implementation of the first data collection wave. BMC Public Health 2012; 12: 730.
7. Kamtsiuris P, Lange M, Hoffmann R, et al.: Die erste Welle der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1): Stichprobendesign, Response, Gewichtung und Repräsentativität. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2013; 56: 620–30.
8. Lampert T, Kroll LE, Müters S, Stolzenberg H: Messung des sozioökonomischen Status in der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1). Bundesgesundheitsblatt 2013; 56: 631–6.
9. Heidemann C, Du Y, Schubert I, Rathmann W, Scheidt-Nave C: Prävalenz und zeitliche Entwicklung des bekannten Diabetes mellitus – Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2013; 56: 668–77.
10. Neuhauser H, Thamm M, Ellert U: Blutdruck in Deutschland 2008–2011. Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2013; 56: 795–801.
11. Lampert T, von der LE, Muters S: Verbreitung des Rauchens in der Erwachsenenbevölkerung in Deutschland – Ergebnisse der Studie zur Gesundheit Erwachsener in Deutschland (DEGS1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2013; 56: 802–8.
12. Inker LA, Schmid CH, Tighiouart H, et al.: Estimating glomerular filtration rate from serum creatinine and cystatin C. N Engl J Med 2012; 367: 20–9.
13. KDIGO Clinical Practice Guideline for the Evaluation and Management of Chronic Kidney Disease. Kidney Int Suppl 3: 1, 2013.
14. Parikh CR, Fischer MJ, Estacio R, Schrier RW: Rapid microalbuminuria screening in type 2 diabetes mellitus: simplified approach with micral test strips and specific gravity. Nephrol Dial Transplant 2004; 19: 1881–5.
15. Greenland S: Introduction to Regression Models. In Rothman KJ, Greenland S, Lash TL: Modern epidemiology. 3rd ed., Philadelphia, Wolters Kluwer, Lippincott Williams & Wilkins, 2008; 381–417.
16. Greenland S, Pearl J, Robins JM: Causal diagrams for epidemiologic research. Epidemiology 1999; 10: 37–48.
17. Levey AS, Coresh J, Greene T, et al.: Expressing the modification of diet in renal disease study equation for estimating glomerular filtration rate with standardized serum creatinine values. Clin Chem 2007; 53: 766–72.
18. Schaeffner ES, Ebert N, Delanaye P, et al.: Two novel equations to estimate kidney function in persons aged 70 years or older. Ann Intern Med 2012; 157: 471–81.
19. Centers for Disease Control and Prevention. 2014 National Diabetes Statistics Report. www.cdc.gov/diabetes/data/statistics/2014StatisticsReport.html. (last accessed on 23 October 2015).

20. Bergman S, Key BO, Kirk KA, Warnock DG, Rostant SG: Kidney disease in the first-degree relatives of African-Americans with hypertensive end-stage renal disease. Am J Kidney Dis 1996; 27: 341–6.
21. Sass AC, Grune B, Brettschneider AK, Rommel A, Razum O, Ellert U: [Participation of people with migration background in health surveys of the Robert Koch Institute]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2015; 58: 533–42.
22. Froissart M, Rossert J, Jacquot C, Paillard M, Houillier P: Predictive performance of the modification of diet in renal disease and Cockcroft-Gault equations for estimating renal function. J Am Soc Nephrol 2005; 16: 763–73.
23. Earley A, Miskulin D, Lamb EJ, Levey AS, Uhlig K: Estimating equations for glomerular filtration rate in the era of creatinine standardization: a systematic review. Ann Intern Med 2012; 156: 785–95 .
24. Van PG, Vaes B, Adriaensen W, et al.: The glomerular filtration rate estimated by new and old equations as a predictor of important outcomes in elderly patients. BMC Med 2014; 12: 27.
25. Skali H, Uno H, Levey AS, Inker LA, Pfeffer MA, Solomon SD: Prognostic assessment of estimated glomerular filtration rate by the new chronic kidney disease epidemiology collaboration equation in comparison with the modification of diet in renal disease study equation. Am Heart J 2011; 162: 548–54.
26. Stevens LA, Li S, Kurella TM et al.: Comparison of the CKD Epidemiology Collaboration (CKD-EPI) and Modification of Diet in Renal Disease (MDRD) study equations: risk factors for and complications of CKD and mortality in the Kidney Early Evaluation Program (KEEP). Am J Kidney Dis 2011; 57: 9–16.
27. Matsushita K, Tonelli M, Lloyd A, Levey AS, Coresh J, Hemmelgarn BR: Clinical risk implications of the CKD Epidemiology Collaboration (CKD-EPI) equation compared with the Modification of Diet in Renal Disease (MDRD) Study equation for estimated GFR. Am J Kidney Dis 2012; 60: 241–9.
28. Gansevoort RT, Matsushita K, Van d V et al.: Lower estimated GFR and higher albuminuria are associated with adverse kidney outcomes. A collaborative meta-analysis of general and high-risk population cohorts. Kidney Int 2011; 80: 93–104.
29. Matsushita K, Van d V, Astor BC, et al.: Association of estimated glomerular filtration rate and albuminuria with all-cause and cardiovascular mortality in general population cohorts: a collaborative meta-analysis. Lancet 2010; 375: 2073–81.
30. Coresh J, Astor BC, Greene T, Eknoyan G, Levey AS: Prevalence of chronic kidney disease and decreased kidney function in the adult US population: Third national health and nutrition examination survey. Am J Kidney Dis 2003; 41: 1–12.
31. Hillege HL, Fidler V, Diercks GF, et al.: Urinary albumin excretion predicts cardiovascular and noncardiovascular mortality in general population. Circulation 2002; 106: 1777–82.
32. Roest M, Banga JD, Janssen WM, et al.: Excessive urinary albumin levels are associated with future cardiovascular mortality in postmenopausal women. Circulation 2001; 103: 3057–61.
33. Phisitkul K, Hegazy K, Chuahirun T, et al.: Continued smoking exacerbates but cessation ameliorates progression of early type 2 diabetic nephropathy. Am J Med Sci 2008; 335: 284–91.
34. Schiffl H, Lang SM, Fischer R: Stopping smoking slows accelerated progression of renal failure in primary renal disease. J Nephrol 2002; 15: 270–4.

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Supplementary material
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Supplementary material to:

The Prevalence of Renal Failure

Results from the German Health Interview and Examination Survey for Adults, 2008–2011 (DEGS1)

by Matthias Girndt, Pietro Trocchi, Christa Scheidt-Nave, Silke Markau, and Andreas Stang

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eSUPPLEMENT

Formulas to determine eGFR

CKD-EPI equation (creatinine, cystatin C) (12)

$$\text{eGFR [mL/min/1.73m}^2\text{]} = 135 \times \min(\text{creatinine [mg/dL]}/\kappa, 1)^{\alpha} \times \max(\text{creatinine}/\kappa, 1)^{-0.601} \times \min(\text{cystatin [mg/L]}/0.8, 1)^{-0.375} \times \max(\text{cystatin}/0.8, 1)^{-0.711} \times 0.995^{\text{age [years]}} [\times 0.969 \text{ if female}] [\times 1.08 \text{ if black}]$$

Min, minimum of creatinine/κ or 1; max, maximum of creatinine/κ or 1;
κ = 0.7 for women, 0.9 for men;
α = –0.248 for women, –0.207 for men

MDRD equation (17)

$$\text{eGFR [mL/min/1.73m}^2\text{]} = 175 \times \text{creatinine [mg/dL]}^{-1.154} \times \text{age [years]}^{-0.203} \times 0.742 \text{ (if female)} \times 1.21 \text{ (if black)}$$

Survey methodology for diabetes mellitus, hypertension, and smoking status

Diabetes mellitus was assumed if an affirmative answer was given during the medical interview to the question "Has a doctor ever diagnosed you with any type of diabetes?" or if current treatment with antidiabetic medication was documented (9). Arterial hypertension was assumed if the respondent reported hypertension and current treatment with antihypertensive medications or if elevated blood pressure (≥ 140 mm Hg systolic or ≥ 90 mm Hg diastolic) was measured in the survey. Details for the measurement and definition of blood pressure in DEGS are published (10). Smoking status was determined from the self-reports of subjects in the interview categorized into three groups: current (daily or occasional), former, or never (11).

eTABLE 1

Age- and sex-specific prevalence of albuminuria ≥ 30 mg/L (%)

Age (years)	Albuminuria					
	Total		Men		Women	
	n	Prevalence (95% CI[*1,2])	n	Prevalence (95% CI[*1,2])	n	Prevalence (95% CI[*1,2])
18–19	26	12.7 (8.7–16.8)	14	11.6 (6.6–16.5)	12	14.5 (7.8–21.3)
20–29	89	11.4 (9.4–13.3)	44	11.9 (9.0–14.7)	45	11.0 (8.3–13.7)
30–39	73	8.8 (7.0–10.5)	41	10.0 (7.4–12.6)	31	7.5 (4.8–10.2)
40–49	105	8.5 (7.1–9.9)	56	9.9 (7.8–12.1)	49	7.0 (5.2–8.9)
50–59	132	9.6 (8.0–11.2)	81	12.4 (9.8–14.9)	51	6.9 (4.9–8.8)
60–69	183	13.2 (11.1–15.3)	112	15.7 (12.4–18.9)	71	10.8 (8.1–13.6)
70–79	220	20.1 (17.5–22.8)	145	25.8 (21.5–30.1)	75	15.3 (12.1–18.6)
Total	828	11.5 (10.7–12.2)	493	13.4 (12.2–14.5)	335	9.6 (8.6–10.5)

*1 95% confidence interval
*2 The complex sampling design was not considered. Prevalence values were based on reclassified albumin values, which were further corrected for persistent albuminuria
n = number of affected participants in the sample; prevalence = weighted prevalence in the total population

Identification of participants with albuminuria of ≥ 30 mg/L based on the results of the Micral Tests

In a first step, the classification error was computationally corrected, to align the Micral Test results with the measurements of the albumin/creatinine ratio (*eTable 2*). In a second step, the predictive probability was computationally corrected, to allow it to be used as evidence of persistent albuminuria despite using data from a single measurement (*eTable 3*).

eTABLE 2

Accounting for the misclassification of Micral Tests (14) with respect to measurements of the albumin/creatinine ratio in the category A2–3: ≥ 30 mg/g

Albuminuria value (Micral Test)	Category A2–3 True-positive (%)	Category A2–3 False-positive (%)
20 mg/L	49	51
50 mg/L	81	19
100 mg/L	91	9

eTABLE 3

Correction for positive single albumin measurements in relation to a persistently detectable albuminuria ≥ 30 mg/L (4)

eGFR mL/min 1.73 m^2	Persistent albuminuria (%)
≥ 90	50.9
60<90	75.0
<60	100.0

eTABLE 4

Comparison of the raw prevalence with values corrected according to eTables 2 and 3 for albuminuria prevalence, by eGFR categories

eGFR category	Raw prevalence DEGS (%)	After correction for test precision according to Parikh (%)	After correction for persistence according to Coresh (%)
>90	31.8	18.1	9.2
60–90	37.9	24.1	18.1
<60	61.1	43.2	43.2
Total	33.5	19.7	11.5