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Increasing Obesity Prevalence in the United States End-Stage Renal Disease Population

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Abstract

Background: Among ESRD patients, obesity may improve dialysis-survival but decreases likelihood of transplantation, and as such, obesity prevalence may directly affect growth of the dialysis population. **Objective:** The objective of this study was to assess BMI trends in the ESRD population as compared to the general population. **Materials and Methods:** Incident adult ESRD patients were identified from the United States Renal Data System from 01/01/1995-12/31/2010 (n=1,458,350). Data from the Behavioral Risk Factor Surveillance System (n=4,303,471) represented the US population. Trends in BMI, obesity classes I (BMI of 30-34.9), II (BMI of 35-39.9), and III (BMI ≥ 40), were examined by year of dialysis initiation. Trends in BMI slope were compared between the ESRD and US populations using linear regression. **Results:** Mean BMI of ESRD patients in 1995 was 25.2 as compared to 29.4 in 2010, a 16.7% increase, while the US population's mean BMI increased from 25.3 to 27.2, a 7.5% increase. BMI increase among the ESRD population was significantly more rapid than among the US population (β: 0.16, 95% CI: 0.14-0.18, $p<0.001$). **Conclusions and Recommendations:** Mean BMI among the ESRD population is increasing more rapidly than the US population. Given decreased access to kidney transplantation among ESRD patients with obesity, future research should be directed at controlling healthcare expenditures by identifying strategies to address the obesity epidemic among the US ESRD population.

Keywords: Obesity; Dialysis; End-stage renal disease

Abbreviations:

BRFSS: Behavioral Risk Factor Surveillance System; BMI: Body Mass Index; CMS: Centers for Medicare and Medicaid Services; CKD: Chronic Kidney Disease; CI: Confidence Interval; ESRD: End-Stage Renal Disease; US: United States; USRDS: United States Renal Data System

Introduction

Obesity has become a national epidemic in the United States (US) [1,2]. Driven by a shift in diet over the last century and a more sedentary lifestyle, trends over time show that obesity prevalence is continuing to increase, not only in the US, but globally as well [3-8]. If current trends continue, projections show that by 2030, 20% of the world's adult population will have obesity, and 38% will be overweight [9]. This trend is even more pronounced among the US population with 42-51% percent of the US population estimated to have obesity and 9-11% estimated to have severe obesity by 2030 [10].

Obesity is associated with an increased risk for developing multiple comorbidities, consequently increasing the disease burden overall [11]. Specifically, obesity is a risk factor for developing hypertension and diabetes, both of which are causes of end-stage renal disease (ESRD) [12,13].

Moreover, obesity itself may confer risk for development of chronic kidney disease (CKD) and ESRD [14-16].

Given obesity's association with comorbid disease development, Kramer et al. [14] examined the prevalence of obesity and changes in body mass index (BMI) among the ESRD population, revealing both have increased from 1995 to 2002. However, access to transplantation is restricted to those meeting center-specific BMI cutoffs, typically a BMI below 35 kg/m^2 [17-22]. Thus, while obesity provides a survival advantage among dialysis patients, patients with a BMI in excess of 35 kg/m^2 may not qualify for kidney transplantation until they lose weight [17,23-28]. Importantly, kidney transplantation provides a significant survival benefit among the general ESRD population and among the ESRD population with obesity, though it takes them longer to obtain that survival benefit due to higher risk of mortality early post-transplant [17,28-30]. When ESRD patients with obesity are offered transplant, they experience longer hospitalization, increased risk of surgical site infections, and higher rates of graft loss compared to their counterparts without obesity [31-33].

In spite of these increased risks, kidney transplantation is cost-effective and thus, a preferential treatment option to dialysis [34,35]. However, Gill et al. [20] demonstrated in a 2014 study that women with a BMI of 25 kg/m^2 or higher experienced lower likelihood of receiving a transplant as did men with a BMI of 35 kg/m^2 or higher; Segev et al. [21] similarly reported an independent association between increasing BMI and lower likelihood of transplantation in an earlier study [20,21,36]. Given the increased likelihood of survival on dialysis and decreased likelihood of transplantation, it is likely the prevalent ESRD population with obesity will experience growth. With the high cost of dialysis, understanding the impact of the obesity epidemic upon the ESRD population is critical to understanding both kidney transplant access and healthcare expenditures [14].

The largest spike in obesity has occurred within the last decade, and while obesity is preventable by public health measures, efforts have not been effective in reducing the rates of obesity in the US [37]. Despite this rapid increase, no study has examined national trends in obesity within the incident ESRD population since Kramer's et al. [14] analysis in 2006. We hypothesized that the prevalence of obesity has increased among the ESRD population and at a more rapid rate than the general population given obesity's association with ESRD development. Moreover, we hypothesized racial and ethnic groups would be differentially impacted. As BMI $\geq$ 35 kg/m^2 is a relative contraindication to kidney transplantation [38], understanding the impact of the obesity epidemic upon the ESRD population is critical to understanding both kidney transplant access and Medicare expenditures. To this end, we aimed to characterize the prevalence of obesity in the ESRD population over time and compare this trend to the general US population.

Materials and Methods

Study population

This retrospective study used data from the United States Renal Data System (USRDS) and the Behavioral Risk Factor Surveillance System (BRFSS). The clinical and research activities being reported are consistent with the Principles of the Declaration of Istanbul as outlined in the Declaration of Istanbul on Organ Trafficking and Transplant Tourism [39]. The study was approved under an exemption by the University of Alabama at Birmingham Institutional Review Board.

Information on BMI in the ESRD population was provided by USRDS. The USRDS is a national data system that collects, analyzes, and distributes information about ESRD in the US and is funded by the National Institute of Diabetes and Digestive and Kidney Diseases in conjunction with the Centers for Medicare and Medicaid Services [40]. This study was limited to adults 18 years of age and older, who initiated dialysis between the years 1995 and 2010, and had complete information on height and weight. We identified 1,458,350 incident, adult dialysis patients meeting those criteria, excluding patients missing dates, aged <18 at ESRD diagnosis, diagnosed outside of the study period, missing BMI, BMI<13 or >65 given the likely data entry error, or transplanted pre-emptively (Figure 1). BMI was calculated using the height and weight collected by the Centers for Medicare and Medicaid Services End-Stage Renal Disease Medical Evidence Form (CMS 2728), completed by the dialysis health care team within 30 days of initiation of maintenance dialysis. Other demographic and clinical characteristics of interest were patient age, sex, race, ESRD etiology, and diagnoses of diabetes or hypertension.

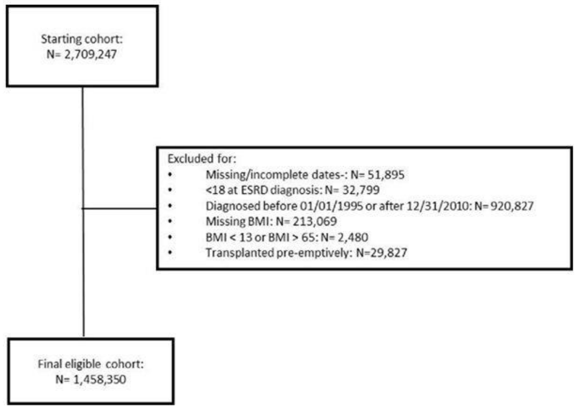

Figure 1: Cohort construction diagram.

BMI trends in the general population were obtained from the Behavioral Risk Factor Surveillance System (BRFSS) of the Centers for Disease Control and Prevention (Atlanta, GA). BRFSS is the largest continuously conducted telephone health survey system in the world, established in 1984 and completing more than 400,000 adult interviews in the US every year [41,42]. The survey captures data on behavioral health-related risk factors, self-reported physical and mental health, and health care utilization. Survey participants were included if aged 18 or older. If BMI was missing or BMI<13 or BMI>65, the participant was excluded, leaving 4,303,471 survey participants who represented the US population when weighted.

Statistical analyses

BMI and prevalence of obesity, diabetes, and hypertension were aggregated within each population at the year-level. Trends in mean BMI and prevalence of obesity classes I (BMI of 30-34.9), II (BMI of 35-39.9), and III (BMI $\geq$ 40) were then examined among incident ESRD patients by year of dialysis initiation [43]. ESRD etiology, prevalence of diabetes, and prevalence of hypertension were similarly examined among ESRD patients by year of dialysis initiation. Percent change over the study period was calculated for both the ESRD and the general populations.

A chi-square test was used to determine significant trends in obesity prevalence among incident patients with ESRD. The mean BMI slope of incident ESRD and US populations were then compared using linear regression. Each model contained a covariate for the time trend, an indicator for the study population, and an interaction between time and study population. The time trend captured the rate of BMI increase among the general population, the study population indicator captured the effect of ESRD on BMI, and the interaction between the time trend and study population indicator captured the ESRD-specific rate of BMI increase as compared to the secular trend. A significant interaction term indicated a significant difference in rate of BMI change between the ESRD and general populations. Thus, we can calculate the total rate of BMI increase among the ESRD population by summing the betas from the time trend indicator and the interaction term (Supplemental Materials). Similarly, linear regression was used to compare increases in diabetes prevalence between the ESRD and US populations. The distribution of diabetes prevalence was assessed to ensure the assumptions of linear regression were met. To assess the robustness of our inferences, analyses were replicated using the median BMI as the outcome of interest. Inferences were confirmed.

Results

The mean age of the ESRD population at dialysis initiation increased from 59.9 in 1995 to 63.4 in 2010. The number of men increased from 52% in 1995 to 57% in 2010. More strikingly, the prevalence of comorbid diabetes increased from 43% in 1995 to 55% in 2010, an increase of 27.9%, and the prevalence of comorbid hypertension increased from 69% to 86%. Mean BMI increased from 25.2 in 1995 to 29.4 in 2010, a 16.7% increase (Table 1).

Year	Incident ESRD Patients	Mean Age (SD)	% Male	% Diabetes	% Hypertension	Mean BMI (SD)
1995	48,092	59.9 (15.8)	52	43	69	25.2 (6.6)
1996	65,841	60.9 (15.6)	53	45	72	25.5 (6.6)
1997	70,602	61.6 (15.5)	53	46	74	25.7 (6.7)
1998	76,105	61.8 (15.5)	53	46	75	26.1 (6.9)
1999	82,331	62.1 (15.5)	53	47	76	26.6 (7.0)
2000	89,957	62.4 (15.4)	54	49	77	27.1 (7.0)
2001	94,163	62.7 (15.4)	54	50	79	27.3 (7.1)
2002	96,757	63.0 (15.4)	54	51	80	27.5 (7.2)
2003	98,652	63.0 (15.3)	54	52	81	27.7 (7.2)
2004	100,060	63.1 (15.3)	55	53	82	27.9 (7.3)
2005	101,541	63.1 (15.3)	56	52	83	28.3 (7.5)
2006	105,012	63.1 (15.3)	56	52	84	28.6 (7.7)
2007	104,656	63.2 (15.2)	56	53	84	28.8 (7.7)
2008	105,874	63.2 (15.2)	57	53	85	29.1 (7.9)
2009	109,158	63.2 (15.2)	57	54	86	29.3 (7.9)
2010	109,549	63.4 (15.0)	57	55	86	29.4 (7.9)
SD: Standard Deviation; BMI: Body Mass Index						

Table 1: Characteristics of the end-stage renal disease population by year of dialysis initiation.

ESRD disease etiology similarly evolved over the study period. The increase in ESRD attributed to diabetes from 1995 to 2010 was 7.5%, a substantially lower increase than was seen among comorbid diabetes. Similarly, hypertension reported as the etiology of ESRD increased in prevalence by 11.5% across the study period. In contrast, there was a 40.9% decrease in the proportion of patients whose disease was attributable to glomerulonephritis and a 24.0% decrease in ESRD attributable to cystic kidney disease (Table 2).

In comparison to the ESRD population, mean BMI in the general population increased from 25.3 to 27.2 over the study period, a 7.5% increase. This trend was more pronounced when examined by obesity class with a 65.6%, 128.2%, and 222.6% increase among the ESRD population as compared to 54.9%, 106.3%, and 184.6% among the general population for obesity classes I, II, and III respectively (Table 3).

When assessing time trends with regression, the mean BMI of the general population was 25.19 in 1995 as compared to 25.07 among the ESRD population, a non-significant difference ($\beta0$: 25.19, 95% CI: 25.06, 25.31, $p<0.001$; $\beta2$: -0.12, 95% CI: -0.29, 0.05, $p=0.17$). Each year of the study period was associated with a significant 0.13 increase in BMI in both cohorts ($\beta1$: 0.13, 95% CI: 0.11, 0.14, $p<0.001$).

Moreover, the rate of BMI increase among the ESRD population was significantly more rapid than among the general population ($\beta3$: 0.16, 95% CI: 0.14, 0.18, $p<0.001$) such that the mean BMI of the ESRD population increased by 0.29 units each year as compared to the 0.13 unit increase among the general population (Table 4 and Figure 2).

Should this trend continue mean BMI among the ESRD population in 2020 is projected to be 32.32 as compared to 28.44 among the general population.

When the model was stratified by age, race, ethnicity, gender, and diabetes status, a similar trend to the general population was observed. There was consistently an increase in BMI over time, and the rate of increase was consistently faster among the ESRD population as compared to the general population. The most dramatic divergence between the ESRD and general population was observed among those aged 25-44 ($\beta3$: 0.22, 95% CI: 0.20, 0.23, $p<0.001$).

The general population had a mean BMI of 24.63 in 1995, and the ESRD population had a significantly higher mean BMI of 25.13 ($\beta0$: 24.63, 95% CI: 24.52, 24.74, $p<0.001$; $\beta2$: 0.50, 95% CI: 0.35, 0.66, $p<0.001$).

Year	% Diabetes	% Hypertension	% GN	% Cystic Kidney
1995	42.6	26.1	13.2	2.5
1996	44.1	26.2	12.5	2.3
1997	44.6	26.7	11.9	2.3
1998	45.0	26.7	11.5	2.3
1999	45.1	27.1	11.1	2.3
2000	45.5	27.0	10.6	2.1
2001	45.9	27.3	10.1	2.1
2002	45.4	27.8	10.1	2.0
2003	45.5	28.4	9.5	2.0
2004	45.6	28.0	9.5	2.0
2005	45.3	27.8	9.2	2.1
2006	45.6	27.6	8.8	2.1
2007	45.4	28.5	8.4	2.0
2008	45.4	28.8	8.2	2.0
2009	45.3	29.1	8.1	2.0
2010	45.8	29.1	7.8	1.9
% change	7.5	11.5	-40.9	-24.0
GN: Glomerulonephritis				

Table 2: End-stage renal disease etiology by year of dialysis initiation.

	ESRD Population				US Population			
Year	Mean BMI	% Obesity Class I	% Obesity Class II	% Obesity Class III	Mean BMI	% Obesity Class I	% Obesity Class II	% Obesity Class III
1995	25.2	11.4	4.6	3.1	25.3	11.3	3.2	1.3
1996	25.5	11.9	4.7	3.4	25.4	11.6	3.2	1.5
1997	25.7	12.2	5.0	3.7	25.6	12.3	3.2	1.4
1998	26.1	12.9	5.6	4.2	25.7	12.7	3.8	1.9
1999	26.6	13.6	6.0	4.9	25.8	13.5	4.1	1.9
2000	27.1	14.9	6.6	5.5	25.9	14.0	4.3	2.2
2001	27.3	15.1	7.0	5.7	26.1	14.7	4.6	2.3
2002	27.5	15.5	7.3	6.2	26.2	14.7	4.8	2.4
2003	27.7	16.2	7.6	6.5	26.3	15.1	5.0	2.7
2004	27.9	16.4	7.9	6.8	26.5	15.5	5.2	2.7
2005	28.3	16.9	8.5	7.6	26.6	16.0	5.5	3.1
2006	28.6	17.4	9.0	8.5	26.7	16.3	5.6	3.2
2007	28.8	17.9	9.2	8.8	26.8	16.8	6.0	3.5
2008	29.1	18.2	9.7	9.3	27.0	17.1	6.2	3.4
2009	29.3	18.3	10.2	9.9	27.1	17.3	6.4	3.7
2010	29.4	18.9	10.5	10.0	27.2	17.5	6.6	3.7
% increase	16.7	65.6	128.2	222.6	7.5	54.9	106.3	184.6
ESRD: End-Stage Renal Disease; US: United States; BMI: Body Mass Index								

Table 3: Obesity and mean body mass index by year of dialysis initiation.

	Intercept [A] **β_0 (95% CI)**	**Year [A]** **β_1 (95% CI)**	**ESRD population [A]** **β_2 (95% CI)**	**Year*ERSD [A, B]** **β_3 (95% CI)**
Parameter				
Overall	25.19 (25.06, 25.31)	0.13 (0.11, 0.14)	-0.12 (-0.29, 0.05)	0.16 (0.14, 0.18)
Age (years)				
<25	23.29 (23.13, 23.46)	0.11 (0.09, 0.13)	1.05 (0.81, 1.28)	0.06 (0.04, 0.09)
25-44	24.63 (24.52, 24.74)	0.14 (0.12, 0.15)	0.50 (0.35, 0.66)	0.22 (0.20, 0.23)
45-64	26.30 (26.09, 26.50)	0.11 (0.08, 0.13)	0.12 (-0.17, 0.41)	0.19 (0.16, 022)
65-74	25.65 (25.49, 25.81)	0.12 (0.10, 0.14)	-0.89 (-1.12, -0.66)	0.20 (0.17, 0.22)
75+	24.43 (24.33, 24.52)	0.09 (0.08, 0.10)	-1.34 (-1.47, -1.20)	0.16 (0.14, 0.17)
Race				
Black	26.57 (26.38, 26.76)	0.15 (0.13, 0.17)	-0.82 (-1.09, -0.55)	0.13 (0.10, 0.16)
Non-black	25.04 (24.93, 25.15)	0.12 (0.11, 0.13)	-0.27 (-0.42, -0.11)	0.17 (0.15, 0.19)
Ethnicity				
Hispanic	25.68 (25.55, 25.82)	0.12 (0.11, 0.14)	-0.81 (-1.00, -0.62)	0.14 (0.12, 0.16)
Non-Hispanic	25.13 (25.00, 25.26)	0.12 (0.11, 0.14)	-0.04 (-0.22, 0.14)	0.17 (0.15, 0.19)
Sex				
Male	25.77 (25.67, 25.88)	0.11 (0.10, 0.12)	-1.13 (-0.98, -1.28)	0.16 (0.14, 0.17)
Female	24.62 (24.48, 24.77)	0.14 (0.12, 0.15)	0.88 (0.68, 1.09)	0.18 (0.15, 0.20)
Diabetes Status				
Diabetes	28.31 (28.09, 28.54)	0.19 (0.17, 0.21)	-2.27 (-2.58, -1.95)	0.14 (0.10, 0.17)
No Diabetes	25.21 (24.82, 25.60)	0.07 (0.03, 0.11)	-0.87 (-0.32, -1.42)	0.14 (0.09, 0.20)

CI: confidence interval; ESRD: end-stage renal disease
[A]Bold indicates significance at p<0.05
[B]Interaction term between year and data which when significant suggests a difference in BMI slopes between the ESRD and general population. The beta for 'year' captured the slope of BMI increase among the general population, the 'ESRD population' indicator captured the effect of ESRD on BMI, and the 'Year*ESRD' indicator captured the ESRD-specific slope of BMI increase. A significant interaction term indicated a difference in rate of BMI change between the ESRD and general populations.

Table 4: Change in body mass index over time between the end-stage renal disease and general United States population, 1995-2010.

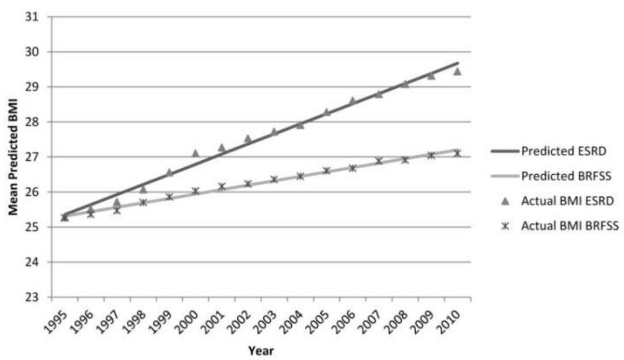

Figure 2: Temporal trends in mean body mass index among the incident end-stage renal disease population and the United States population.

Additionally the ESRD population in this age group experienced a 0.36 unit change in mean BMI each year as compared to the general population which only experienced a 0.14 unit increase in mean BMI annually (β1: 0.14, 95% CI: 0.12, 0.15, p<0.001; β3: 0.22, 95% CI: 0.20, 0.23, p<0.001) (Table 4). Given this increased rate of change, if the current trend remains consistent, the mean BMI of the ESRD population aged 25-44 years would be 34.13 in 2020 as compared to 28.13 among the general population aged 25-44 years.

The mean BMI among the black general population was higher than most subgroups at 26.57 (β0: 26.57, 95% CI: 26.38, 26.76, p<0.001), though black ESRD patients had a significantly lower mean BMI as compared to the general black population (β2: -0.82, 95% CI: -1.09, -0.55, p<0.001). Mirroring every other subgroup of ESRD patients, the rate of BMI increase was significantly more rapid among black ESRD patients (β: 0.28) as compared to the general population (β1: 0.15, 95% CI: 0.13, 0.17<0.001; β3: 0.13, 95% CI: 0.10, 0.16, p<0.001) (Table 4). If this increase in BMI persists, mean BMI among the black ESRD population will be 32.75 as compared to 30.32 among the general black population in 2020.

Lastly, the mean BMI of the Hispanic general population was 25.68 as compared to 24.87 among the Hispanic ESRD population (β0: 25.68, 95% CI: 25.55, 25.82, p<0.001; β2: -0.81, 95% CI: -1.00, -0.62, p<0.001). The mean BMI of the Hispanic general population increased by 0.12 units each year whereas the mean BMI of the Hispanic ESRD population increased by 0.26 units each year (β1: 0.12, 95% CI: 0.11, 0.14, p<0.001; β3: 0.14, 95% CI: 0.12, 0.16, p<0.001). In 2020, should these trends continue, the mean BMI of the Hispanic ESRD population will be 31.37 in contrast to 28.68 among the general Hispanic population.

While the prevalence of diabetes as a comorbid condition increased in the ESRD population by 12.4 percentage points and the general population by 4.7 percentage points, the percent increase was lower among the ESRD population (27.9%) as compared to the general population (93.6%). This was mirrored with hypertension prevalence, though to a much lesser extent (ESRD: 24.6%; US: 27.9%) (Supplemental Table 1). When linear regression was used to assess trends in diabetes prevalence, there was a significant increase in diabetes prevalence associated with both increasing year (β: 0.31, 95% CI: 0.24, 0.38, p<0.001) and with ESRD prevalence (β: 39.8, 95% CI: 38.8, 40.8, p<0.001). As seen with BMI, the increase in diabetes prevalence among the ESRD population occurred at a more rapid pace than among the general population (β: 0.40, 95% CI: 0.29, 0.50, p<0.001) (Supplemental Table 2).

Discussion

We found that obesity prevalence in both the ESRD population and in the US general population increased over time. BMI increased by almost 17% in the ESRD population, while the BMI in general population only increased 8%. Perhaps more strikingly, there was a 128.2% and 222.6% increase in obesity classes II and III respectively among the ESRD population as compared to 106.3% and 184.6% increases among the general population. Thus, our findings extend previous work demonstrating a more rapid increase in BMI and in obesity prevalence among the ESRD population as compared to the general population while also demonstrating a striking increase in the prevalence of obesity class III.

Our findings support those originally discussed by Kramer et al. [14] in 2006, in that we found that the number of individuals with obesity in both the general and ESRD populations continues to grow. Kramer et al. [14] noted increases of 32% in the obesity class I prevalence and of 63% in the obesity class II prevalence from 1995 to 2002. In projections of total obesity and obesity stage ≥ 2, they predicted prevalence of 44.6% and 22.7% in 2007 respectively. These estimates exceeded the prevalence we found in 2007 of 35.9% total obesity overall and 18% of obesity stage ≥ 2. Despite earlier awareness of the obesity epidemic permeating the ESRD population, little progress was made in mitigating its growth.

We also found that this rapid increase in BMI was consistent across patient characteristics including age, race, ethnicity, sex, and diabetes status. Mimicking the general population, there has been a rapid increase in the prevalence of obesity class III among the ESRD population [44]. As a BMI in excess of 35 kg/m^2 is a relative contraindication to kidney transplantation at many centers, this increase in prevalence of individuals with obesity class III may have profound implications for the growth of the prevalent ESRD population [20,21,23-25,36]. Moreover, the increase in ESRD attributable to diabetes and/or hypertension was not large enough to fully explain the increase in BMI and obesity, suggesting that simply controlling the growth of diabetes and hypertension many not stem the growth of obesity prevalence among ESRD patients.

The 2017 USRDS Annual Data Report 40 states the cost of dialysis to Medicare per patient as $88,000 in contrast to $34,000 for kidney transplant. Thus, dramatic growth in a patient population deemed ineligible for transplantation and increased likelihood of survival on dialysis may have profound implications for healthcare spending in the US. A previous study utilizing administrative claims data found that increasing BMI was associated with increased cost of deceased donor and living donor kidney transplantation [45]. An additional study exploiting a novel linkage between the Scientific Registry of Transplant Recipients and the databases of the University Health System Consortium similarly demonstrated greater direct costs, index admission costs, readmission costs, and combined costs for patients with BMI ≥ 40 kg/m^2 as compared to patients without obesity [46]. Despite higher costs, kidney transplantation among patients with obesity is still likely more cost-effective than remaining on dialysis. However, patients with a higher BMI have issues accessing transplantation due to center specific BMI cutoffs, and thus, those patients that are ineligible for transplantation due to excess BMI will either initiate or remain on dialysis. As a result, healthcare costs will likely increase with the growing number of individuals starting and remaining on dialysis for the duration of their lifetime.

One potential strategy for mitigating dialysis duration among patients with class III obesity is the provision of weight-loss surgery such as laparoscopic sleeve gastrectomy (LSG), which could increase the opportunity for addition to the waitlist. A recent study of kidney transplant recipients who underwent LSG were matched to recipients with similar BMIs who did not undergo LSG, demonstrating those who did undergo LSG experienced lower rates of delayed graft function and renal dysfunction-related readmissions and similar patient and graft survival, suggesting excellent transplant outcomes can be achieved in these patients [47]. Bariatric surgery has also been shown in multiple case series to aid in weight loss that promotes candidacy for kidney transplantation while affording comparable post-transplant mortality and complication rates [48]. While not standard of care, centers might consider offering weight loss surgery to ESRD patients whose BMI is a barrier to wait listing.

As with any observational study, there are limitations to our analysis. BMI in the general population was calculated with self-reported height and weights from BRFSS, introducing the potential for reporting bias as individuals are more likely to underreport weight as weight increases. Thus, it is possible that individual BMIs have actually been underestimated. However, BMI and obesity prevalence were aggregated to the year-level to allow for estimation of temporal trends, which would not be substantially influenced by underreporting of weight. History of diabetes and hypertension among the general population are also self-reported and thus, susceptible to recall bias. As a result, the prevalence of these comorbidities may not be truly representative of the general population. We were restricted to comparison with incident ESRD patients, as height and weight are only reported at time of dialysis initiation and completion of the CMS 2728 Medical Evidence form. As a result, we are unable to estimate BMI trends among patients after dialysis initiation. Moreover, BMI in the ESRD population is measured within the first thirty days of initiation of dialysis, a time when a true dry weight may not have been established. Thus, many patients may have excess volume leading to an overestimation of weight. The amount of weight by which we may have overestimated, however, likely would not yield a meaningful difference in the change in BMI, and the rise in trend of BMI is still informative, as this overestimation at baseline has remained unchanged over the study period. When estimating the prevalence of diabetes and hypertension, we were unable to account for changes in diagnosis criteria for these comorbidities, and thus, some proportion of the increases in prevalence may be attributable to clinicians diagnosing more diabetes and hypertension. Lastly, we were unable to compare incident ESRD patients and the general population after 2010, as BRFSS changed the sampling methodology employed. Thus, we are only able to forecast current trends in BMI and obesity and are unable to make assertions about the current trends. Despite these acknowledged limitations, this study extends previous work on the obesity epidemic in the ESRD and general populations, providing valuable information for policy makers and clinicians.

Conclusion and Recommendation

We have observed that the obesity prevalence in the US ESRD population has increased at a more rapid rate than previously reported. This trend was consistent in multiple patient subgroups. Obesity is known to limit access to kidney transplantation, and as a result, if the trends in obesity among the incident ESRD population continue, the number of ESRD patients who start and remain on dialysis will continue to grow. Given the cost-effectiveness and survival benefit of kidney transplantation over remaining on dialysis, selection criteria for candidates with obesity may need to be reconsidered to offset the negative effects of a growing ESRD population with obesity. Health care expenditures for dialysis will likely increase with the growing ESRD population with obesity, and overall patient quality of life will be affected if the criteria are not re-evaluated to be more inclusive of individuals with moderate obesity. Future studies will be aimed at examining access to transplantation and the impact upon healthcare expenditures in the modern era to ensure appropriate management of the ESRD population and healthcare resources.

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