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Subjective and Objective Sleep Quality in Patients on Conventional Thrice-Weekly Hemodialysis: Comparison With Matched Controls From the Sleep Heart Health Study

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Abstract

Background—Studies examining sleep in the hemodialysis (HD) population have largely lacked an adequate comparison group. It therefore remains uncertain if poor sleep quality among the HD population reflects the age, chronic health conditions, or the effects of conventional hemodialysis.

Study Design—Cross-sectional matched-group study

Setting & Participants—Forty-six in-center hemodialysis patients were compared with 137 community subjects participating in the Sleep Heart Health Study matched for age, sex, body mass index (BMI), and race.

Predictor—HD patients compared to community dwelling non-HD subjects.

Outcomes and Measurements—Home unattended polysomnography (PSG) was performed and scored using similar protocols. Sleep habits and sleepiness were assessed using the Sleep Habits Questionnaire and the Epworth Sleepiness Scale.

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Results—The average age of the study samples was 63 years, 72% were white, and the average BMI was 28 ± 5 kg/m². HD patients were significantly more likely than the community participants to have short sleep (odds ratio [OR] 3.27; 95% confidence interval [CI] 1.16–9.25) and decreased sleep efficiency (OR 5.5; CI 1.5–19.6). The HD patients reported more difficulty getting back to sleep (OR 2.25; CI 1.11–4.60) and waking up too early (OR 2.39; CI 1.01–5.66). There was no association between PSG sleep time and self-reported sleep time ($r=0.09$; $p=0.6$) or between the Epworth Sleepiness Scale and the severity of sleep apnea ($r=0.10$; $p=0.5$) in the HD population.

Limitations—The study was limited to participants older than 45 years.

Conclusions—Kidney failure treated with thrice-weekly HD is significantly associated with poor subjective and objective sleep quality.

Keywords

Hemodialysis; sleep; polysomnography; self-report; questionnaire

Studies of patients on maintenance hemodialysis have found that 50–80% of patients undergoing conventional hemodialysis (HD) report some sleep complaint or excessive daytime somnolence.^{1,2} Poor sleep quality is associated with important health outcomes, including disability days, health care utilization, and quality of life.³ The relevance of sleep quality, the subjective integration of sleep disturbances and satisfaction with sleep, to patient values was highlighted in a recent study of preferences for more frequent hemodialysis.⁴ In addition to poor subjective sleep quality, objectively monitored sleep in studies using polysomnography (PSG) have suggested shorter sleep times, fragmented sleep, and disrupted sleep architecture in the HD population.

The combination of older age and chronic health conditions found among the HD population make it important to account for their confounding effects when trying to delineate the underlying relationship between hemodialysis and subjective and objective sleep quality. In the general population, changes in sleep time and sleep architecture have been related to age and sleep apnea.^{5,6} Several large scale studies have shown that many older adults have reported difficulty initiating sleep, feel tired during the day, have difficulty maintaining sleep and wake up too early in the morning.^{7,8} These observations are of considerable relevance for the persons undergoing HD because an increasing number of HD patients cared for in the US are older than 65 years of age.

Additionally, we have previously reported that the prevalence of sleep apnea was four-fold higher among a population of older conventional hemodialysis patients compared to a control sample; engendering a potentially important influence on sleep and sleep quality in these patients.⁹ Since older adults are at higher risk for poor subjective and objective sleep quality, we asked whether HD confers additional risk for poor sleep independent of the risk of sleep apnea. To determine the association of HD with subjective and objective sleep quality, we compared older adults undergoing HD to age, sex, race and BMI matched community-based participants in the multi-center Sleep Heart Health Study. We hypothesized that HD is associated with poor subjective and objective sleep quality independent of the effects of age and chronic health conditions, including sleep apnea.

METHODS

STUDY SETTING, SAMPLES, AND DESIGN

This study sample and methods have been previously described.⁹ Briefly, the HD study sample was composed of patients undergoing thrice-weekly in-center HD at one of 24 centers in Western Pennsylvania. Measurements were performed between May, 2004 and September,

2005. Subjects were excluded for: craniofacial abnormalities, age <45 years or > 90 years of age, use of home oxygen or history of uvulopalatopharyngoplasty, active malignancy, acute infection, active coronary artery, advanced cirrhosis, advanced dementia, active alcohol abuse and refractory psychiatric disease. This study was approved by the University of Pittsburgh Institutional Review Board and all participants provided informed consent. Forty-six HD participants are included in this report. Patient preference determined when nocturnal PSG was conducted relative to the day of HD. Nineteen participants were studied the evening of HD and 27 were studied during a day off of hemodialysis. Of the 45 participants with shift data, 29 were on a morning shift (5:30–8 AM), 14 were on an afternoon shift (10 AM – 330PM), and 2 were on an evening shift (330PM–530PM).

The overall objectives and study design of the SHHS have been reported previously.¹⁰ The SHHS is a prospective cohort study aimed at investigating the relationship between sleep apnea and cardiovascular disease (CVD). From parent cohorts, a sample of participants meeting the inclusion criteria (age ≥ 40 years, no history of treatment of sleep apnea, no tracheostomy, and no current home oxygen therapy) was invited to participate in the baseline examination of the SHHS.¹¹ The control sample consisted of 137 individuals who participated in the SHHS 2001–2002 examination. The goal was to randomly assign up to three SHHS controls individually matched to each HD patient on sex, race and as close as possible on BMI and age. Forty-three HD patients were each assigned three controls within ± 2 kg/m² of BMI and ± 3 years of age while two HD patients had three matches and one patient had two matches each within ± 3 kg/m² of BMI and ± 5 years of age.

DATA COLLECTION

The baseline HD and SHHS data collection session included a brief standardized health interview and questionnaire administration, assessment of current medication use¹², blood pressure and anthropometric measurements, and unattended home PSG.¹⁰ A self-completed sleep habits questionnaire provided information on perceived sleep disturbances and sleep quality.¹⁰ A history of physician-diagnosed medical illnesses, previous surgical treatments, or medical procedures was obtained from the health interview.

POLYSOMNOGRAPHY

In the HD cohort, PSG was performed in the home using the Compumedics Siesta System (Abbottville, AU), overnight between 20:00 and 8:00. PSG sleep recordings included measurement of sleep with bilateral bipolar EEG channels (C₃-P₃, C₄-P₄ and Cz-Pz), right and left eye movements (ROC, LOC), and submental is electromyogram. Respiratory parameters were assessed with finger pulse oximetry (Nonin, Minneapolis, MN), oral thermocouple, and abdominal and thoracic effort by inductance plethysmography. A bipolar ECG and position sensor also were used to measure heart rate and body position, respectively.

In SHHS, PSG was performed using an earlier version of the device used in the HD cohort (PS-2 System), using methods previously detailed.¹³ Data collection included a subset of the physiological channels collected in the HD sample: two central electroencephalograms (EEGs); right and left electro-oculograms; a bipolar submental electromyogram; thoracic and abdominal inductance bands; airflow with a nasal-oral thermocouple, finger pulse oximetry, and a bipolar electrocardiogram lead. In a SHHS study of 64 persons with laboratory and home sleep studies, there was increased sleep time and sleep efficiency with the home study and essentially the same severity of sleep apnea.¹⁴

SCORING OF POLYSOMNOGRAMS

For both the HD and SHHS studies, data processing and scoring followed identical procedures and were completed by centrally trained scoring staff blinded to the clinical characteristics of

the participants. The PSG scoring for both samples followed a rigorous quality control process.¹³ Sleep stages were scored according to the guidelines developed by Rechtschaffen and Kales.¹⁵ Arousals were identified according to American Sleep Disorders Association criteria.¹⁶ An apnea was defined as a complete or almost complete cessation of airflow, as measured by the amplitude of the thermocouple signal, lasting 10 seconds or longer. Hypopneas were identified if the amplitude of a measure of flow or volume (detected by the thermocouple or thoracic or abdominal inductance band signals) decreased to less than 70% of the amplitude of baseline breathing for 10 seconds or longer, but did not meet the criteria for apnea. Only apneas or hypopneas associated with at least a 3% oxyhemoglobin desaturation were considered in the calculation of the Apnea-hypopnea Index (AHI), which is the sum of apneas and hypopneas per hour of sleep.

SUBJECTIVE SLEEP QUALITY

Sleep symptoms were assessed using the Sleep Habits Questionnaire on a 5-point Likert scale to the items “Have trouble falling asleep,” “Wake up during the night and have difficulty getting back to sleep,” “Wake up too early in the morning and be unable to get back to sleep,” and “Take sleeping pills or other medication to help you sleep.” Daytime symptoms were “Unrested during the day,” “Overly sleepy,” and “Not enough sleep”. Response options were Never, Rarely (1/month or less), Sometimes (2–4/month), Often (5–15/month), and Almost Always (16–30/month). For analysis, these variables were collapsed into 2 categories: Infrequent, comprising the responses Never and Rarely; and Frequent, comprising the responses Sometimes, Often, and Almost Always. Participants were also asked if they had a diagnosis of restless legs syndrome. Epworth Sleepiness Scale (ESS) is an 8-item self-report measure of sleepiness.^{17,18} Scores range from 0–24 and values greater than or equal to 10 are considered to indicate significant sleepiness.

OTHER COVARIATE DEFINITIONS

Cardiovascular disease was defined as an affirmative response to a history of physician-diagnosed heart failure, myocardial infarction or heart attack, or previous coronary artery bypass or angioplasty. Lung disease was based on an affirmative answer to diagnosed bronchitis, asthma, or emphysema. Diabetes was defined as the current use of insulin or oral hypoglycemic agents. Smoking was classified as a greater than 20 pack lifetime exposure. Alcohol exposure was measured by the total number of beer, wine, and hard liquor beverages consumed in the average week. Caffeine exposure was characterized using the number of cups of caffeinated coffee, tea, and soft drinks consumed per day.

SLEEP PARAMETER DEFINITIONS

Sleep time, sleep efficiency and AHI were derived and examined as dichotomous variables. Sleep efficiency was defined as the percentage total time asleep, divided by the total time in bed after lights off to the time of final awakening. Inefficient sleep was characterized as a sleep efficiency of less than 70%. Short sleep time was defined as total time asleep of less than five hours. Severe sleep apnea was classified as AHI greater than thirty events per hour. In a secondary analysis Log-transformed AHI rather than dichotomous AHI to adjust for sleep apnea.

STATISTICAL ANALYSIS

Baseline sleep, demographic, and chronic health conditions were described using means (SD) or medians for continuous variables and as frequency distributions for categorical variables. Statistical significance of the differences between groups (e.g., presence of diabetes) was tested using two-sample *t* tests or ANOVA for continuous variables and χ^2 tests for categorical variables. The strength of associations between self-reported sleep quality and PSG findings

was examined using the Spearman correlation coefficient. Adjusted analyses were performed using conditional logistic regression.^{19,20} Two models were presented; the first model was adjusted for CVD and diabetes and the second model further adjusted for severe sleep apnea. In all comparisons between samples using regression, the analyses accounted for the matching of HD cases to the comparison control subjects. Logistic regression was used to examine the association between the dependent variables and the presence of chronic health conditions and severe SDB in each exposure group. Analyses were repeated excluding subjects using antidepressants and benzodiazepines. Analyses were performed using SAS (version 8.1; SAS Institute, Cary, NC).

RESULTS

The characteristics and burden of chronic disease for the HD and SHHS matched sample are shown in Table 1. The mean age was 62.7 years (SD 10.1), the mean BMI was 28 kg/m² (SD 5.3); 72% were men and 63% were white. As expected based on the sampling design, the groups were comparable on age, sex, race, and BMI. There was a similar degree of cigarette smoking and caffeine use in both groups, but higher alcohol use in the community sample. The HD group had a higher systolic blood pressure and a higher proportion of diabetes and cardiovascular disease.

The HD sample had been on thrice-weekly in-center HD for a median of 22 months at the time of the sleep studies (interquartile range 9–46 months). The cause of ESRD was diabetes (n=20; 44%), hypertension (n=11; 24%), glomerulonephritis (n=5; 11%), transplant related (n=3; 7%), and other causes of end-stage renal disease (n=7; 15%). The average hemoglobin was 12.5 (4.5) mg/dl (hemoglobin in g/dL may be converted to g/L by multiplying by 10), mean serum phosphate was 5.0 (1.04) mg/dl (serum phosphate in mg/dL may be converted to mmol/L by multiplying by 0.3229) and mean serum bicarbonate 23.0 (2.6) mEq/L (serum bicarbonate levels expressed in mEq/L and mmol/L are equivalent). The patients were receiving an adequate dose of dialysis as demonstrated by a single-pool Kt/V >1.2 or urea reduction ratio >0.66.

The differences in subjective and objective sleep parameters across study samples are shown in Table 2. Polysomnography in the HD sample demonstrated that approximately 44% had a sleep duration <5 hours and 50% had poor sleep efficiency compared to a prevalence of 13% and 34% for these respective findings in the SHHS sample. Compared to the control sample, the HD population had a lower proportion with <10% slow wave sleep (SWS) and a higher proportion with <10% REM. The prevalence of all sleep disturbances, as well as frequency of daytime napping and daytime sleepiness, was higher in the HD than control group. There were 8 ESRD patients that were diagnosed with restless legs compared to 1 of the SHHS controls (Fisher's exact test p<0.001). There was no difference in subjective or objective sleep quality parameters when the 19 participants were studied the evening of HD were compared to the 27 were studied using PSG during a day off of hemodialysis. Nor were there significant differences in self-reported sleep quality, sleep stages, or severity of sleep apnea between those undergoing hemodialysis in the morning compared to the afternoon shift.

Table 3 further illustrates differences in the prevalence of sleep disturbances in each sample. The HD sample had significantly higher odds of short sleep and less efficient sleep, each as measured by PSG. The strength of associations with short sleep and sleep efficiency increased with adjustment for CVD, DM, and severe sleep apnea. The HD group had a significantly higher likelihood of <10% REM sleep [Odds Ratio 18.7; 95% confidence intervals (4.2, 82.6)]. However, there were too few control participants with <10% REM sleep to perform multivariable modeling. The HD sample had significantly higher odds of self-reported short sleep, napping, difficulty getting back to sleep and waking up too early. In contrast, the daytime

sleep complaints and subjective sleepiness were not significantly different between the two groups. There was no material difference in the findings from sensitivity analyses excluding subjects using antidepressants and benzodiazepines. There were also no substantive changes in the interpretation of our findings when performing these analyses using the log-transformed AHI or a cut-off of and AHI >15 rather than the cut-off of >30 events per hour. Additionally, we examined the extent to which the parameter estimates changed by including the covariates of alcohol use and lung disease. In this analysis, there were no substantial changes in the point estimates and a slightly increase in confidence intervals.

The relationships between self-reported sleep habits and PSG parameters for the hemodialysis and control populations are shown in Table 4. While there was a weak correlation between PSG sleep time and self-reported sleep time on weekdays and weekends, the strength of this association was lower in the HD population compared to the SHHS controls. There were similar strengths of association for the HD and control group between difficulty getting back to sleep and sleep efficiency as well as feeling unrested and arousal index. There was a significant association between waking up too early and sleep efficiency among the HD population but no association among the controls. There was also a very weak correlation between subjective sleepiness as measured by the ESS and the severity of sleep apnea as measured by the AHI for the HD population compared to the SHHS controls.

DISCUSSION

When compared to a community-based sample of middle-aged and older adults, our cohort of HD patients undergoing thrice-weekly in-center HD had objective evidence of shorter sleep time, less efficient sleep, and an increased frequency of insomnia problems. A high prevalence of insomnia symptoms in the HD group was supported by the finding that more than half of the HD patients reported difficulty getting back to sleep, waking up too early, feeling unrested, and not getting enough sleep. The findings of this report may be generalizable to the adult thrice-weekly HD patient. The average age and BMI of the HD sample is similar to the average and BMI those undergoing HD in the United States. Furthermore, the HD sample reported herein represents a racially diverse group from a number of HD units, and selection was not based on sleep complaints. Because of a strict matching scheme used in this study, such group differences could not be attributed to age or sex differences between the HD patients and community controls. Even after adjusting for chronic health conditions and severe sleep apnea, HD patients were found to be three to five-fold more likely to have short sleep and decreased sleep efficiency. Our findings support an association between HD and both poor subjective and objective sleep quality and show that this association cannot be explained by advanced age or chronic health conditions including sleep apnea.

The marked impairment in sleep quality prevalent in this population may contribute to the poor outcomes, cognitive deficits, and diminished quality of life found in patients undergoing thrice-weekly hemodialysis. The health burden associated with sleep disturbances is significant and studies in the general population have linked these problems to greater use of health services²¹, increased use of hypnotics²², and reduced functional capabilities²³. The urgent need to understand sleep quality in the HD population has been underscored by findings of a 15–31% prevalence of hypnotic use in populations of dialysis patients^{2,24}, although our findings demonstrate a 9% use of benzodiazepines which may be somewhat lower than previous estimates due to the older age of this study population. Among incident and prevalent dialysis patients, those with poor sleep quality have been found to have a higher prevalence of self-reported poor physical and mental well-being, decreased vitality, and more bodily pain and those with lower sleep quality have been shown to have a higher risk of mortality.^{25,26} Kutner et. al. have demonstrated that self-reported sleep quality was associated with cognitive symptoms in the dialysis population.^{27,28} These studies and others have demonstrated that

sleep quality may be reliably measured and clinically meaningful for patients receiving thrice-weekly hemodialysis.

Short and fragmented sleep has been associated with daytime symptoms, decreased psychomotor vigilance, poor driving performance, diminished memory, increased risk of cardiovascular disease events and premature death.^{29,30} Disruption of sleep is reflected by low sleep efficiency. Older adults in the general population with sleep efficiency less than 80% were at nearly two times greater risk of death.³¹ This report is consistent with in-laboratory PSG studies that have demonstrated short and fragmented sleep^{32–34} and further shows that this short and poorly efficient sleep was not explained by age or chronic health conditions, in particular sleep apnea. Of note, the 4-fold higher likelihood of regular napping among the ESRD population may help to explain the decreased sleep at night as measured by both single-night PSG and self-report.

The weak correlations between subjective complaints and objective evidence of poor sleep underscore the challenge of managing sleep complaints in HD patients. Although our data do not address the role of PSG as compared to the assessment of subjective symptoms in the management of HD patients, they do emphasize the complementary nature of the data from each source. The low correlations between subjective and objective sleep disturbances highlight that indices derived from either domain cannot serve as a surrogate for the other domain. The potentially unique aspects of self-reported data are suggested by neuroimaging studies that have suggested patient self-report may reflect neurophysiologic findings that are not measured by PSG.³⁵ Furthermore, individuals with complaints of insomnia can have PSG findings comparable to normal sleepers.^{36,37} Indeed, self-reported outcomes may be critical in those patients with chronic illness^{38,39} and the impact of more frequent hemodialysis treatments on patient perception of fatigue and sleepiness may be the most important factor in their acceptance of this therapy⁴.

The study should be interpreted in light of several limitations. First, the HD sample and the SHHS PSG studies were recorded using similar but not identical devices and scored at different times. However, measurement variability between the HD and SHHS samples was minimized by using a centralized PSG Reading Center, utilizing similar sensors and amplifiers, identical sampling rates, and evaluating PSGs using identical scoring rules. Second, because the SHHS study did not include measurement of periodic leg movements, we could not assess the extent to which leg movements contributed to group differences in sleep quality. However, periodic leg movements, although common in the elderly, are associated with few objective changes in sleep quality.⁴⁰ There were significant differences observed in the prevalence of diagnosis of restless legs syndrome, but the number of patients that endorsed this diagnosis was too small to explain the differences between the groups. Third, the SHHS study did not use a measure of depression. However, the use of anti-depressant medication was similar between groups and the exclusion of this group did not substantially influence the study findings. Fourth, we do not have comparable socio-economic status data or measure of depressed mood in the ESRD and SHHS groups permitting us to account for potential differences in SES and subclinical depression.

In conclusion, this study shows that patients undergoing thrice-weekly hemodialysis have markedly impaired subjective and objective sleep quality. The poor subjective and objective sleep quality in this population is likely multi-factorial and may include insomnia, restless legs syndrome, poor sleep hygiene, as well as the heat load delivered to patients during routine hemodialysis treatments.⁴¹ It remains unclear whether poor sleep starts prior to the initiation of hemodialysis or whether changing the time of dialysis treatments, intensity of dialysis treatments or temperature of dialysis treatments would improve sleep quality. Therefore, further work should focus on the natural history of sleep in chronic kidney disease^{42–44} and

begin to examine the impact of treating sleep disorders on mood, memory, cardiovascular disease, and health-related quality of life. Despite the complex factors contributing to poor sleep in ESRD, growing evidence in the general population and the hemodialysis population supports the position that this is a crucial challenge to meet.

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References

1. Iliescu EA, Coe H, McMurray MH, et al. Quality of sleep and health-related quality of life in haemodialysis patients. *Nephrology Dialysis Transplantation* 2003;18:126–132.
2. Unruh M, Hartunian M, Chapman M, Jaber B. Sleep quality and clinical correlates in patients on maintenance hemodialysis. *Clin Nephrol* 2003;59:280–288. [PubMed: 12708568]
3. Hays RD, Kallich JD, Mapes DL, Coons SJ, Carter WB. Development of the kidney disease quality of life (KDQOL) instrument. *Quality of Life Research* 1994;3:329–338. [PubMed: 7841967]
4. Ramkumar N, Beddhu S, Eggers P, Pappas LM, Cheung AK. Patient preferences for in-center intense hemodialysis. *Hemodial Int* 2005;9:281–295. [PubMed: 16191079]
5. Walsleben JA, Kapur VK, Newman AB, et al. Sleep and reported daytime sleepiness in normal subjects: the Sleep Heart Health Study. *Sleep* 2004;27:293–298. [PubMed: 15124725]
6. Ohayon MM, Carskadon MA, Guilleminault C, Vitiello MV. Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep* 2004;27:1255–1273. [PubMed: 15586779]
7. Foley DJ, Monjan AA, Brown SL, Simonsick EM, Wallace RB, Blazer DG. Sleep complaints among elderly persons: an epidemiologic study of three communities. *Sleep* 1995;18:425–432. [PubMed: 7481413]
8. National Sleep Foundation: 2005 Sleep in America Poll. 2007 [Accessed Jan 30, 2007]. http://www.sleepfoundation.org/_content/hottopics/2005_summary_of_findings.pdf
9. Unruh ML, Sanders MH, Redline S, et al. Sleep apnea in patients on conventional thrice-weekly hemodialysis: comparison with matched controls from the Sleep Heart Health Study. *J Am Soc Nephrol* 2006;17:3503–3509. [PubMed: 17082238]
10. Quan SF, Howard BV, Iber C, et al. The Sleep Heart Health Study: design, rationale, and methods. *Sleep* 1997;20:1077–1085. [PubMed: 9493915]

11. Lind BK, Goodwin JL, Hill JG, Ali T, Redline S, Quan SF. Recruitment of healthy adults into a study of overnight sleep monitoring in the home: experience of the Sleep Heart Health Study. *Sleep & Breathing* 2003;7:13–24. [PubMed: 12712393]
12. Psaty BM, Lee M, Savage PJ, Rutan GH, German PS, Lyles M. Assessing the use of medications in the elderly: methods and initial experience in the Cardiovascular Health Study. The Cardiovascular Health Study Collaborative Research Group. *J Clin Epidemiol* 1992;45:683–692. [PubMed: 1607909]
13. Redline S, Sanders MH, Lind BK, et al. Methods for obtaining and analyzing unattended polysomnography data for a multicenter study. Sleep Heart Health Research Group. *Sleep* 1998;21:759–767. [PubMed: 11300121]
14. Iber C, Redline S, Kaplan Gilpin AM, et al. Polysomnography performed in the unattended home versus the attended laboratory setting--Sleep Heart Health Study methodology. *Sleep* 2004;27:536–540. [PubMed: 15164911]
15. Rechtschaffen, A.; Kales, A. A manual of standardized terminology, Techniques and scoring system for sleep stages of human subjects. Washington D.C: NIMH; 1968.
16. Report ASD: EEG arousals: scoring rules and examples. *Sleep* 1992;15:173–184. [PubMed: 11032543]
17. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991;14:540–545. [PubMed: 1798888]
18. Johns MW. Reliability and factor analysis of the Epworth Sleepiness Scale. *Sleep* 1992;15:376–381. [PubMed: 1519015]
19. Fleiss, J.; Levin, B.; Paik, M. Statistical Methods for Rates and Proportions. Hoboken: John Wiley & Sons; 2003.
20. Breslow N, Day N. Statistical Methods in Cancer Research LYON, International Agency for Research on Cancer. 1980
21. Kapur VK, Redline S, Nieto FJ, et al. The relationship between chronically disrupted sleep and healthcare use. *Sleep* 2002;25:289–296. [PubMed: 12003159]
22. Klink ME, Quan SF, Kaltenborn WT, Lebowitz MD. Risk factors associated with complaints of insomnia in a general adult population. Influence of previous complaints of insomnia.[comment]. *Archives of Internal Medicine* 1992;152:1634–1637. [PubMed: 1497397]
23. Foley DJ, Monjan A, Simonsick EM, Wallace RB, Blazer DG. Incidence and remission of insomnia among elderly adults: an epidemiologic study of 6,800 persons over three years. *Sleep* 1999;22:S366–S372. [PubMed: 10394609]
24. Unruh ML, Levey AS, D'Ambrosio C, Fink NE, Powe NR, Meyer KB. Restless legs symptoms among incident dialysis patients: association with lower quality of life and shorter survival. *Am J Kidney Dis* 2004;43:900–909. [PubMed: 15112181]
25. Elder SJ, Pisoni RL, Akizawa T, et al. Sleep Quality Predicts Quality of Life And Mortality Risk in Haemodialysis Patients: Results From The Dialysis Outcomes And Practice Patterns Study (DOPPS). *Nephrol Dial Transplant*. 2007
26. Unruh ML, Buysse DJ, Dew MA, et al. Sleep quality and its correlates in the first year of dialysis. *Clin J Am Soc Nephrol* 2006;1:802–810. [PubMed: 17699290]
27. Kutner NG, Zhang R, Huang Y, Bliwise DL. Association of sleep difficulty with Kidney Disease Quality of Life cognitive function score reported by patients who recently started dialysis. *Clin J Am Soc Nephrol* 2007;2:284–289. [PubMed: 17699426]
28. Kutner NG, Zhang R, Huang Y, Bliwise DL. Patient-reported sleep difficulty and cognitive function during the first year of dialysis. *Int Urol Nephrol* 2008;40:203–210. [PubMed: 17342449]
29. Ayas NT, White DP, Manson JE, et al. A prospective study of sleep duration and coronary heart disease in women. *Arch Intern Med* 2003;163:205–209. [PubMed: 12546611]
30. Patel SR, Ayas NT, Malhotra MR, et al. A prospective study of sleep duration and mortality risk in women. *Sleep* 2004;27:440–444. [PubMed: 15164896]
31. Dew M, Hoch C, Buysse D, et al. Health Older Adults' Sleep Predicts All-Cause Mortality at 4 to 19 Years of Followup. *Psychosomatic Medicine* 2003;65:63–73. [PubMed: 12554816]

32. Parker KP, Kutner NG, Bliwise DL, Bailey JL, Rye DB. Nocturnal sleep, daytime sleepiness, and quality of life in stable patients on hemodialysis. *Health Qual Life Outcomes* 2003;1:68. [PubMed: 14633280]
33. Hanly PJ, Gabor JY, Chan C, Pierratos A. Daytime sleepiness in patients with CRF: impact of nocturnal hemodialysis. *American Journal of Kidney Diseases* 2003;41:403–410. [PubMed: 12552503]
34. Benz RL, Pressman MR, Hovick ET, Peterson DD. A preliminary study of the effects of correction of anemia with recombinant human erythropoietin therapy on sleep, sleep disorders, and daytime sleepiness in hemodialysis patients (The SLEEPO study). *Am J Kidney Dis* 1999;34:1089–1095. [PubMed: 10585319]
35. Nofzinger EA. Neuroimaging and sleep medicine. *Sleep Med Rev* 2005;9:157–172. [PubMed: 15893247]
36. Edinger JD, Fins AI, Glenn DM, et al. Insomnia and the eye of the beholder: are there clinical markers of objective sleep disturbances among adults with and without insomnia complaints? *J Consult Clin Psychol* 2000;68:586–593. [PubMed: 10965634]
37. Salin-Pascual RJ, Roehrs TA, Merlotti LA, Zorick F, Roth T. Long-term study of the sleep of insomnia patients with sleep state misperception and other insomnia patients. *Am J Psychiatry* 1992;149:904–908. [PubMed: 1609869]
38. Kalantar-Zadeh K, Unruh M. Health related quality of life in patients with chronic kidney disease. *Int Urol Nephrol* 2005;37:367–378. [PubMed: 16142573]
39. Unruh ML, Weisbord SD, Kimmel PL. Health-related quality of life in nephrology research and clinical practice. *Semin Dial* 2005;18:82–90. [PubMed: 15771650]
40. Claman DM, Redline S, Blackwell T, et al. Prevalence and correlates of periodic limb movements in older women. *J Clin Sleep Med* 2006;2:438–445. [PubMed: 17557474]
41. Parker KP, Bailey JL, Rye DB, Bliwise DL, Van Someren EJ. Lowering dialysate temperature improves sleep and alters nocturnal skin temperature in patients on chronic hemodialysis. *J Sleep Res* 2007;16:42–50. [PubMed: 17309762]
42. Parker KP, Bliwise DL, Bailey JL, Rye DB. Polysomnographic measures of nocturnal sleep in patients on chronic, intermittent daytime haemodialysis vs those with chronic kidney disease. *Nephrol Dial Transplant*. 2005
43. Iliescu EA, Yeates KE, Holland DC. Quality of sleep in patients with chronic kidney disease. *Nephrol Dial Transplant* 2004;19:95–99. [PubMed: 14671044]
44. Cohen SD, Patel SS, Khetpal P, Peterson RA, Kimmel PL. Pain, sleep disturbance, and quality of life in patients with chronic kidney disease. *Clin J Am Soc Nephrol* 2007;2:919–925. [PubMed: 17702733]

Table 1
 Characteristics of Hemodialysis and Community Control Samples

Variable	HD patients N=46	Matched Controls N=137	p-value
Age (years)	62.7±10.1	62.7±10.1	0.9
Men, sex	33(71.7)	98(71.5)	0.9
Race White	29(63.0)	87(63.5)	0.8
African-American	16(35.0)	47(34.3)	
Native American	1(2.0)	3(2.2)	
Body Mass Index (kg/m ²)	28.0±5.4	28.1±5.3	0.9
History of tobacco use	26(56.5)	73(53.3)	0.7
Caffeinated Beverage (servings/day) ^I	2(0–3)	2(1–3)	0.5
Alcohol (servings/week) ^I	0(0–1)	1(0–6)	< 0.01
Benzodiazepine use	4(8.7)	6(4.4)	0.3
Antidepressant use	6(13.0)	13(9.5)	0.5
Systolic blood pressure (mmHg)	137(30.1)	120.5(14.9)	<0.001
Diastolic blood pressure (mmHg)	73.0(15.0)	72.7(9.7)	0.2
Lung disease	5(10.8)	23(16.7)	0.3
Cardiovascular disease	15(32.6)	17(12.5)	0.002
Diabetes mellitus	15(32.6)	12(8.8)	< 0.01
Apnea-Hypopnea Index	27.4±19.4	15.2±14.9	<0.001

Values are presented as mean (standard deviation) or as number (%)

^I Median and interquartile range

NS = not significant (p > 0.05)

Table 2

Sleep Habits and Polysomnographic Parameters among Hemodialysis and Community participants

Variable	HD population (n=46)	Matched Controls (n=137)
Short Sleep (<5 hours)	20 (43.5)	18 (13.1)
Poor sleep efficiency (<70% sleep efficiency)	23(50.0)	46 (33.6)
Low Slow Wave Sleep (<10% of total sleep time)	9 (19.6)	51 (37.2)
Low REM (<10% of total sleep time)	14 (30.4)	4 (3.0)
Hours sleep on a weekday ^I	6 (5–8)	7 (6–8)
Hours sleep on a weekend ^I	7(6–8)	7(6–8)
Number of naps per week ^I	3 (1–4)	1 (0–3)
Trouble falling asleep	22 (47.8)	55(40.2)
Difficulty getting back to sleep	28 (60.9)	66 (48.2)
Wake up too early	26 (56.5)	54 (39.4)
Feel unrested	24(52.2)	52 (38.0)
Do not get enough	28 (62.2)	70 (53.4)
Epworth Sleepiness Scale ≥10	19 (44.2)	42 (31.6)

Values are presented as mean (standard deviation) or as number (%)

^I Median and interquartile range

Table 3

Association between renal failure treated with conventional hemodialysis and sleep habits and polysomnographic parameters

	Crude ^I Odds Ratio (95% Confidence Interval)	Adjusted for history of CVD and diabetes Odds Ratio (95% Confidence Interval)	Adjusted for history of CVD, diabetes and Sleep Apnea Odds Ratio (95% Confidence Interval)
Polysomnography			
Findings			
Short Sleep (<5 hours)	2.5 (1.14–5.57)	3.6 (1.34–10.0)	3.27 (1.16–9.25)
Poor sleep efficiency (<70% sleep efficiency)	3.06(1.2–7.3)	6.32 (1.8–21.4)	5.5 (1.5–19.6)
Low Slow Wave Sleep (<10%)	0.42(0.19–0.93)	0.46 (0.2–1.10)	0.40 (0.16–1.01)
Self-Reported Sleep			
Self-reported short sleep (<5hours)	3.37 (1.42–8.0)	4.98 (1.62–15.28)	5.72 (1.67–19.6)
Napping > 3/week	3.9 (1.95–7.74)	4.15 (1.87–9.25)	4.47 (1.91–10.5)
Trouble Falling Asleep	1.41(0.70–2.85)	1.81 (0.78–4.2)	1.82(0.73–4.30)
Difficulty getting back to sleep	1.66(0.84–3.28)	2.35 (1.17–4.72)	2.25 (1.11–4.60)
Wake up too early	2.26(1.08–4.73)	2.61(1.13–6.06)	2.39(1.01–5.66)
Feel unrested	1.81(0.90–3.63)	2.03 (0.93–4.44)	1.80 (0.80–4.05)
Do not get enough sleep	1.48 (0.72–3.0)	1.53 (0.69–3.47)	1.52 (0.66–3.52)
Epworth Sleepiness Scale ≥10	1.55(0.77–3.29)	1.91 (0.82–4.44)	1.96 (0.83–4.72)

^I Matched for age, sex, race, and body mass index

CVD: cardiovascular disease

Table 4

Self-reported sleep habits and PSG sleep parameters in the Hemodialysis and Community Control Samples

	HD population (n=46)	Matched Controls (n=137)
Self-reported sleep time and PSG Sleep time	$r=0.09$; $p=0.5$	$r=0.18$; $p=0.04$
Trouble Falling Asleep and PSG sleep time	$r=0.02$; $p=0.9$	$R=-0.22$; $P=0.009$
Difficulty getting back to sleep and PSG sleep efficiency	$r=-0.25$; $p=0.09$	$r=-0.17$; $p=0.04$
Wake up too early and PSG sleep efficiency	$r=-0.34$; $p=0.02$	$r=-0.07$; $p=0.4$
Feel unrested and arousal index	$r=0.22$; $p=0.1$	$r=0.15$; $p=0.08$
Epworth sleepiness scale and respiratory disturbance index	$r=0.10$; $p=0.5$	$r=0.15$; $p=0.09$