Heliyon 10 (2024) e27377

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Associations between sleep problems and cardiometabolic risk in maintenance hemodialysis patients: A multicenter study

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Abbreviations: BMI, Body mass index; CKD, Chronic kidney disease; CI, Confidence interval; DBP, Diastolic blood pressure; ESRD, End-stage renal disease; HDL, High-density lipoprotein cholesterol; LDL, Low-density lipoprotein cholesterol; M, Mean; OR, Odds ratio; SBP, Systolic blood pressure; SD, Standard deviation; TC, Total cholesterol; TG, Triglyceride.

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https://doi.org/10.1016/j.heliyon.2024.e27377
Received 7 July 2023; Received in revised form 26 February 2024; Accepted 28 February 2024
Available online 7 March 2024

ARTICLE INFO

Keywords:
Hematodialysis
Sleep duration
Cardiometabolic risk
Sleep quality

ABSTRACT

The incidence of cardiovascular disease is increasing around the world, and it is one of the main causes of death in chronic kidney diseases patients. It is urgent to early identify the factors of cardiometabolic risk. Sleep problems have been recognized as a risk factor for cardiometabolic risk in both healthy people and chronic patients. However, the relationship between sleep problems and cardiometabolic risk has not been clearly explored in hemodialysis patients. This study aimed to investigate the relationship between sleep problems and cardiometabolic risk in 3025 hemodialysis patients by a multicenter study. After adjusting for confounders, binary logistic regression models showed that hemodialysis patients reported sleep duration greater than 7 h were more likely to be with hypertension, hyperglycemia, hypertriglyceridemia, and hypercholesterolemia. Patients reported sleep duration less than 7 h were more likely to be with hypertriglyceridemia and hypercholesterolemia, but the risks of hyperglycemia and Low HDL-cholesterol were decreased. Poor sleep quality was negatively correlated to low HDL cholesterol and hypertriglyceridemia. Moreover, gender-based differences were explained.

1. Introduction

End-stage renal disease (ESRD) is the final stage of progression of chronic kidney disease (CKD). According to report, up to 30% of mortality occurred during the first year of the transition from CKD to ESRD [1]. Maintenance hemodialysis has become a main alternative treatment for patients with ESRD, with more than 90% of patients undergoing hemodialysis treatment [2]. Hemodialysis is beneficial for prolonging the life of patients, but it can also lead to physiological disorders and poor quality of life, and aggravate the prognosis of the disease [3]. The negative effects of the progression of CKD can involve multiple body systems, such as the cardiovascular system and the urinary system. In recent years, one study has shown that cardiovascular risk was significantly higher in CKD patients [4].

The prevalence of the cardiovascular disease is increasing worldwide [5]. It is the leading cause of death in CKD patients [6]. Therefore, early prediction of cardiometabolic risk is extremely important. Cardiometabolic risk factors contain high body mass index (BMI), raised low-density lipoprotein cholesterol (LDL), reduced high-density lipoprotein cholesterol (HDL), ascended total cholesterol (TC), raised triglyceride (TG), increased systolic blood pressure (SBP) and diastolic blood pressure (DBP), and elevated fasting glucose [7], all of which are associated with an increased risk of cardiovascular disease. One study showed that cardiometabolic risk was associated with abnormal glomerular filtration rate in the general population [8], and there was a significant association between cardiovascular disease risk and the severity of CKD [9,10]. Another study has shown a causal relationship between cardiometabolic risk and CKD [11]. In the population undergoing hemodialysis, dyslipidemia and insulin resistance are common cardiometabolic risk factors [12], and the presence of metabolic syndrome increased the risk of cardiovascular disease [13]. A study from Japan showed that patients undergoing hemodialysis have a higher cardiometabolic risk compared to the general population [14].

The main environmental factors of cardiometabolic risk include diet, smoking, sleep and residential environment [15–18]. Sleep, as a health-related behavior, is believed to play an important role in regulating complex physiological processes which are essential for maintaining metabolic homeostasis [19]. A previous study showed that 69% of patients undergoing hemodialysis reported the symptom of insomnia [20]. A study from Malaysia showed that more than half of hemodialysis patients had poor sleep [21]. Another cross-sectional study found that 27.5% of hemodialysis patients had sleep disturbances [22]. As well, sleep-related dysfunction is an important predictor of all-cause mortality in hemodialysis patients [23].

Sleep problems were proved to be associated with an increased cardiometabolic risk [24]. In healthy populations, short sleep duration was correlated to an increased risk of hypertension, poor glucose tolerance and hypercholesterolemia [25]. In obese people with breast cancer, sleep quality was negatively associated with variation in cardiometabolic risk markers [26]. There was also an association between poor sleep quality and the prevalence of coronary artery disease in hemodialysis patients [27]. Although some studies have found the independent associations between sleep behaviors and blood pressure, BMI, or lipids in hemodialysis patients, no study has comprehensively analyzed the associations between sleep problems and cardiometabolic risk in hemodialysis patients. Therefore, this study was conducted to observe whether sleep problems are associated with higher cardiometabolic risk in a large sample of hemodialysis population in Anhui Province, China.

2. Materials and methods

2.1. Participant

A cross-sectional study of hemodialysis patients was conducted in 27 blood purification centers of Anhui Province in China between January 1st and December 31st, 2020. The inclusion criteria of participants were showed as follows: (a) patients aged $\geq$18 years; (b) patients undergoing hemodialysis for more than three months; (c) patients who volunteered for the study. These patients were excluded from this study: (a) patients who cannot provide informed consent; (b) heart failure with NYHA III grade or above; (c)

complicated with severe liver, lung, brain and other organ failure disease, such as cirrhosis, chronic respiratory failure and hemiplegia; (d) HIV infection or AIDS; (e) complicated with malignant tumor; (f) psychiatric patient. A total of 3025 patients were enrolled.

2.2. Measurement

The "h6world" platform supported by Clinical Big data Platform Research Group of Peking University was used to collect data. Each center logged in the platform for investigation data entry. All data was summarized to the project leader and was checked by quality controller.

2.2.1. Basic information

Basic information was collected by a self-reported questionnaire, including sex (male/female), age, family residence (urban/rural), smoking (yes/no) and alcohol use (yes/no), antihypertensive drugs (yes/no), lipid-lowering drugs (yes/no), hypnotic drugs (yes/no).

Dialysis vintage, primary kidney disease, disease diabetes, hypertension and the incidence of cardiovascular events were obtained from medical records.

Table 1
The gender-based differences in characteristics among hemodialysis patients.

Variables	Total (n = 3025)	Gender [M±SD/n (%)/Median (Q1, Q3)]		*P* value
		Males (n = 1819)	Females (n = 1206)	
Age	54.81 ± 12.79	54.80 ± 13.08	54.84 ± 12.34	0.942
Family residence				<0.001
Rural	1352(44.7)	764(42.0)	588(48.8)	
Urban	1673(55.3)	1055(58.0)	618(51.2)	
Educational level				<0.001
Illiterate	545(18.0)	203(11.1)	342(28.3)	
Elementary school	833(27.5)	438(24.1)	395(32.8)	
Middle school	1417(46.8)	985(54.2)	432(35.8)	
High school and above	230(7.6)	193(10.6)	37(3.01)	
Smoking				<0.001
Yes	462(15.3)	433(23.8)	29(2.4)	
No	2563(84.7)	1386(76.2)	1177(97.6)	
Alcohol use				<0.001
Yes	360(11.9)	325(17.9)	35(2.9)	
No	2665(88.1)	1494(82.1)	1171(97.1)	
Primary cause of ESRD				<0.001
Chronic glomerulonephritis	1225(40.5)	696(38.3)	529(43.9)	
Diabetic nephropathy	579(19.1)	390(21.4)	189(15.7)	
Hypertensive nephropathy	477(15.8)	305(16.8)	172(14.3)	
Others	394(13.0)	234(12.9)	160(13.2)	
Unknow	350(11.6)	194(10.6)	156(12.9)	
Dialysis vintage (years)	4.97(2.57, 7.54)	4.58(2.25, 7.04)	5.53(3.01, 8.01)	<0.001
Medications				
Antihypertensive	2117(70.0)	1284(70.6)	833(69.1)	0.373
Hypolipidemic	480(15.9)	297(16.3)	183(15.2)	0.395
Hypnotic	165(5.5)	89(4.9)	76(6.3)	0.095
Comorbidities				
Diabetes	732(24.2)	497(27.3)	235(19.5)	<0.001
Hypertension	2277(75.3)	1401(77.0)	876(72.6)	0.006
Cardiovascular disease	426(14.1)	260(14.3)	166(13.8)	0.682
SBP (mmHg)	142(129, 157)	143(130, 157)	140(125, 156.5)	0.002
DBP (mmHg)	80(71, 90)	80(71, 90)	80(70, 90)	0.013
TC (mmol/L)	4.58(3.55, 5.06)	4.42(3.40, 5.06)	4.79(3.80, 5.06)	<0.001
TG (mmol/L)	1.92(1.26, 1.92)	1.92(1.22, 1.92)	1.92(1.32, 1.92)	0.049
HDL (mmol/L)	1.16(0.98, 1.18)	1.16(0.95, 1.16)	1.16(1.06, 1.26)	<0.001
LDL (mmol/L)	2.38(1.82, 2.38)	2.38(1.76, 2.38)	2.38(1.94, 2.38)	<0.001
Glu (mmol/L)	6.62(4.90, 6.62)	6.62(4.94, 6.62)	6.56(4.80, 6.62)	0.086
Overweight or obesity	496(16.4)	327(18.0)	169(14.0)	0.004
Sleep duration				0.042
< 7 h	2010(66.4)	1179(64.8)	831(68.9)	
7 h	480(15.9)	310(17.0)	170(14.1)	
> 7 h	535(17.7)	330(18.1)	205(17.0)	
Sleep quality				0.024
Good	2249(74.3)	1379(75.8)	870(72.1)	
Poor	776(25.7)	440(24.2)	336(27.9)	

Note: TG = triglyceride, TC = total cholesterol, HDL = high-density lipoprotein, LDL = low-density lipoprotein, BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, Glu = glucose.

2.2.2. Cardiometabolic markers

Laboratory data for cardiometabolic markers included TC, HDL, LDL, TG, and fasting glucose. All the above data were collected from medical records which were queried at the hemodialysis center by the research staff.

Height and weight were measured by using a fully automated electronic height and weight meter, and BMI is calculated as the ratio of an individual's weight in kilograms (measured to the nearest 0.1 kg) divided by the height in meters (measured to the nearest 0.01 m) squared. Participants were required to rest quietly for several minutes prior to blood pressure measurement, after which resting blood pressure was measured using an electronic sphygmomanometer before hemodialysis.

Based on the KDOQI clinical practice guidelines for cardiovascular disease in dialysis patients and the WHO Expert Advisory Council criteria for obesity in Asia, SBP <140 mmHg, DBP <90 mmHg and BMI <25 kg/m^2 were defined as the normal reference values. According to the 2019 updated cardiovascular prevention guidelines of the Brazilian Society of Cardiology [28], HDL>1.04 mmol/L, LDL<2.59 mmol/L, TG < 1.69 mmol/L, and TC < 4.92 mmol/L were defined as the normal reference values. Blood glucose <7.0 mmol/L was defined as the normal reference values [29].

2.2.3. Sleep problems

The Pittsburgh Sleep Quality Index was used to assess the sleep status of the hemodialysis patients [30]. Two main types of sleep problems were assessed. Sleep quality was assessed by asking "During the past month, how would you rate your sleep quality overall?". The answers of very good or fairly good were defined as good sleep quality; and the answers of fairly bad or very bad were defined as poor sleep quality. Sleep duration was evaluated by asking "During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)", and 7 h was defined as cut-off point [31–33].

2.3. Statistical analysis

Continuous variables of Gaussian distribution were represented as mean and standard deviation (SD), continuous variables of skewed distribution were expressed as median and interquartile range. Categorical variables were summarized using frequencies (n) and percentages (%). Two independent samples *t*-tests and rank sum tests were used to examine the gender-based differences in clinical information. Chi-square test was used to analyze the differences in cardiometabolic risk between different groups of sleep problems. Binary logistic regression models were used to analyze the associations between sleep problems and cardiometabolic risk, after adjusting for age, sex, dialysis vintage, educational level, smoking, and alcohol consumption. All statistical analysis was performed by SPSS 25.0 software. All statistical tests were two-sided and significance was set at $P < 0.05$.

Table 2
The differences in cardiometabolic risk between different groups of sleep problems stratified by gender.

Cardiometabolic risk	Sleep duration					Sleep quality			
	< 7 h	7 h	> 7 h	χ^2 value	*P* value	Good	Poor	χ^2 value	*P* value
Hypertension									
Total	1181(58.8)	282(58.8)	358(66.9)	12.241	0.002	1344(59.8)	477(61.5)	0.703	0.402
Males	722(61.2)	188(60.6)	223(67.6)	4.837	0.089	848(61.5)	285(64.8)	1.527	0.217
Females	459(55.2)	94(55.3)	135(65.9)	7.816	0.020	496(57.0)	192(57.1)	0.002	0.967
Hyperglycemia									
Total	308(15.3)	89(18.5)	127(23.7)	21.484	< 0.001	374(16.6)	150(19.3)	2.937	0.087
Males	186(15.8)	61(19.7)	74(22.4)	8.901	0.012	227(16.5)	94(21.4)	5.516	0.019
Females	122(14.7)	28(16.5)	53 (25.9)	14.681	0.001	147(16.9)	56(16.7)	0.009	0.924
High LDL-cholesterol									
Total	290(14.4)	76(15.8)	81(15.1)	0.676	0.713	328(14.6)	119(15.3)	0.258	0.611
Males	135(11.5)	47(15.2)	47(14.2)	4.073	0.130	168(12.2)	61(13.9)	0.856	0.355
Females	155(18.7)	29(17.1)	34(16.6)	0.613	0.736	160(18.4)	58(17.3)	0.209	0.648
Low HDL-cholesterol									
Total	549(27.3)	174(36.3)	174(32.5)	17.402	< 0.001	691(30.7)	206(26.5)	4.829	0.028
Males	357(30.3)	136(43.9)	118(35.8)	21.175	< 0.001	482(35.0)	129(29.3)	4.748	0.029
Females	192(23.1)	38(22.4)	56(27.3)	1.816	0.403	209(24.0)	77(22.9)	0.164	0.686
Hypertriglyceridemia									
Total	1218(60.6)	263(54.8)	344(64.3)	9.733	0.008	1392(61.9)	433(55.8)	8.956	0.003
Males	699(59.3)	169(54.5)	208(63.0)	4.821	0.090	835(60.6)	241(54.8)	4.610	0.032
Females	519(62.5)	94(55.3)	136(66.3)	4.957	0.084	557(64.0)	192(57.1)	4.875	0.027
Hypercholesterolemia									
Total	910(45.3)	187(39.0)	243(45.4)	6.595	0.037	1027(45.7)	313(40.3)	6.642	0.010
Males	513(43.5)	117(37.7)	141(42.7)	3.365	0.186	592(42.9)	179(40.1)	0.690	0.406
Females	397(47.8)	70(41.2)	102(49.8)	3.122	0.210	435(50.0)	134(39.9)	9.959	0.002
Obesity									
Total	335(16.7)	70(14.6)	91(17.0)	1.405	0.495	376(16.7)	120(15.5)	0.662	0.416
Males	210(17.8)	55(17.7)	62(18.8)	0.181	0.914	258(18.7)	69(15.7)	2.073	0.150
Females	125(15.0)	15(8.8)	29(14.1)	4.533	0.104	118(13.6)	51(15.2)	0.525	0.469

Note: HDL = high-density lipoprotein, LDL = low-density lipoprotein.

3. Results

3.1. Characteristic distribution of hemodialysis patients stratified by gender

Table 1 describes the gender-based differences in the characteristics of hemodialysis patients. The mean age of the hemodialysis patients was 54.81 years (SD: 12.79), and the male patients accounted for 60.1% (1819/3025). The proportion of patients living in urban areas were higher in males (58.0%) than that of females (51.2%). Higher percentages of high level of education were reported in males than those of females (Middle school: 54.2% *vs*. 35.8%; High school and above: 10.6% *vs*. 3.01%). The percentage of patients who were current smokers (23.8% vs. 2.4%) and drinkers (17.9% vs. 2.9%) in males were prominently higher than those of females. Compared to females, the prevalence of diabetes mellitus (27.3% *vs*. 19.5%), hypertension (77.0% *vs*. 72.6%) was higher in males. The levels of TC and HDL were higher in females than those of males. A higher rate of overweight or obesity was found in males than that of females (18.0% vs 14.0%). Poor sleep quality were more common in female patients.

3.2. The differences in cardiometabolic risk between different groups of sleep problems stratified by gender

As shown in Table 2, compared to patients who slept 7 h, patients who slept more than 7 h had a higher prevalence of hypertension (66.9% *vs*. 58.8%), hyperglycemia (23.7% *vs*. 18.5%), hypertriglyceridemia (64.3% *vs*. 54.8%) and hypercholesterolemia (45.4% *vs*. 39.0%). The risk of hypertension was significantly higher in female patients who slept more than 7 h (65.9% *vs*. 55.3% *vs*. 55.2%). Patients who slept more than 7 h had higher rates of hyperglycemia in all patients (23.7% *vs*. 18.5% *vs*. 15.3%). Male patients who slept more than 7 h had higher rates of low HDL cholesterol than those patients who slept less than 7 h (35.8% *vs*. 30.3%). The rate of hyperglycemia was higher in male patients with poor sleep quality compared to those with good sleep quality (21.4% *vs*. 16.5%). Male patients with good sleep quality had higher rates of low HDL cholesterol than male patients with poor sleep quality (35.0% *vs*. 29.3%). The rates of hypertriglyceridemia were higher in all patients who had good sleep quality (61.9% *vs*. 55.8%), and in both males (60.6% *vs*. 54.8%) and females (64.0% *vs*. 57.1%). The rate of hypercholesterolemia was higher in female patients with good sleep quality than in female patients with poor sleep quality (50.0% *vs*. 39.9%).

3.3. Associations of sleep problems with cardiometabolic risk in all patients

The results of the associations between sleep problems and cardiometabolic risk in hemodialysis patients is shown in Table 3. In the crude model, hemodialysis patients reported sleep duration great than 7 h have increased risks of hypertension (*OR*:1.42, *95%CI*: 1.10–1.83), hyperglycemia (*OR*:1.37, *95%CI*:1.01–1.85), hypertriglyceridemia (*OR*:1.49, *95%CI*:1.16–1.91) and hypercholesterolemia (*OR*:1.30, *95% CI*:1.02–1.68). Patients reported sleeping less than 7 h had an increased risk of hypertriglyceridemia (*OR*:1.27, *95% CI*:1.04–1.55) and hypercholesterolemia (*OR*:1.30, *95%CI*:1.06–1.59) and a decreased risk of low HDL cholesterol (*OR*:0.66, *95% CI*:0.54–0.82). Hemodialysis patients with poor sleep quality reported decrease risks of low HDL cholesterol (*OR*:0.82, *95%*

Table 3
Associations between sleep problems and cardiometabolic risk in patients undergoing hemodialysis.

		Crude model		Adjusted model	
		OR (95% *CI*)	*P* value	*OR* (95% *CI*)	*P* value
Hypertension	Sleep duration < 7 h[a]	1.00(0.82–1.22)	0.998	1.03(0.84–1.26)	0.781
	Sleep duration > 7 h[a]	1.42(1.10–1.83)	0.007	1.43(1.10–1.84)	0.007
	Poor sleep quality[b]	1.07(0.91–1.27)	0.402	1.08(0.91–1.28)	0.357
Hyperglycemia	Sleep duration < 7 h[a]	0.80(0.61–1.03)	0.084	0.72(0.56–0.95)	0.017
	Sleep duration > 7 h[a]	1.37(1.01–1.85)	0.044	1.43(1.05–1.95)	0.027
	Poor sleep quality[b]	1.20(0.97–1.48)	0.087	1.07(0.87–1.33)	0.514
High LDL-cholesterol	Sleep duration < 7 h[a]	0.90(0.68–1.18)	0.435	0.85(0.65–1.12)	0.248
	Sleep duration > 7 h[a]	0.95(0.68–1.33)	0.760	0.93(0.66–1.32)	0.696
	Poor sleep quality[b]	1.06(0.85–1.33)	0.611	1.00(0.79–1.25)	0.944
Low HDL-cholesterol	Sleep duration < 7 h[a]	0.66(0.54–0.82)	< 0.001	0.67(0.54–0.83)	< 0.001
	Sleep duration > 7 h[a]	0.85(0.65–1.09)	0.212	0.86(0.66–1.12)	0.293
	Poor sleep quality[b]	0.82(0.68–0.98)	0.028	0.80(0.66–0.96)	0.018
Hypertriglyceridemia	Sleep duration < 7 h[a]	1.27(1.04–1.55)	0.020	1.36(1.11–1.67)	0.003
	Sleep duration > 7 h[a]	1.49(1.16–1.91)	0.002	1.47(1.14–1.89)	0.003
	Poor sleep quality[b]	0.77(0.66–0.92)	0.003	0.82(0.70–0.98)	0.022
Hypercholesterolemia	Sleep duration < 7 h[a]	1.30(1.06–1.59)	0.012	1.35(1.01–1.67)	0.005
	Sleep duration > 7 h[a]	1.30(1.02–1.68)	0.038	1.29(1.00–1.67)	0.047
	Poor sleep quality[b]	0.80(0.68–0.95)	0.010	0.85(0.72–1.01)	0.056
Obesity	Sleep duration < 7 h[a]	1.17(0.89–1.55)	0.267	1.17(0.88–1.55)	0.289
	Sleep duration > 7 h[a]	1.20(0.86–1.69)	0.291	1.21(0.86–1.70)	0.271
	Poor sleep quality[b]	0.91(0.73–1.14)	0.416	0.94(0.74–1.17)	0.554

Note: Adjusting for age, sex, dialysis vintage, educational level, smoking, and alcohol consumption.
[a] reference: sleep duration = 7 h.
[b] reference: good sleep quality.

CI:0.68–0.98), hypertriglyceridemia (*OR*:0.77, *95%CI*:0.66–0.92) and hypercholesterolemia (*OR*:0.80, *95%CI*:0.68–0.95).

After adjusting for age, sex, dialysis vintage, educational level, smoking, and alcohol consumption, hemodialysis patients with sleep duration great than 7 h reported increased risks of hypertension (*OR*:1.43, *95%CI*:1.10–1.84), hyperglycemia (*OR*:1.43, *95% CI*:1.05–1.95), hypertriglyceridemia (*OR*:1.47, *95%CI*:1.14–1.89) and hypercholesterolemia (*OR*:1.29, *95%CI*:1.00–1.67). Patients who slept less than 7 h had an increased risk of hypertriglyceridemia (*OR*:1.36, *95%CI*:1.11–1.67) and hypercholesterolemia (*OR*:1.35, *95%CI*:1.01–1.67), but a decreased risk of hyperglycemia (*OR*:0.72, *95%CI*:0.56–0.95) and low HDL cholesterol (*OR*:0.67, *95% CI*:0.54–0.83). Hemodialysis patients with poor sleep quality reported a decrease risk of low HDL-cholesterol (*OR*:0.80, *95% CI*:0.66–0.96) and hypertriglyceridemia (*OR*:0.82, *95%CI*:0.70–0.98); however, there was no associations between sleep quality and hypercholesterolemia.

3.4. Associations of sleep problems with cardiometabolic risk stratified by gender

Table 4 describes the results of the associations between sleep problems and cardiometabolic risk in male patients. In the crude model, male patients reported sleep duration greater than 7 h had an increased risk of hypertriglyceridemia (*OR*: 1.42, *95% CI*: 1.04–1.95) and a decreased risk of low HDL cholesterol (*OR*:0.71, *95%CI*: 0.52–0.97). Male patients reported poor sleep quality had an increased risk of developing low HDL-cholesterol (*OR*:1.30, *95%CI*:1.02–1.64), hypertriglyceridemia (*OR*:1.27, *95%CI*:1.02–1.57). After adjusting for age, dialysis vintage, educational level, smoking, and alcohol consumption, male patients reported sleep duration longer than 7 h had an increased risk of hypertriglyceridemia (*OR*:1.39, *95% CI*:1.01–1.92), but a decreased risk of low HDL-cholesterol (*OR*:0.72, *95% CI*:0.52–0.99). Male patients who reported sleep duration of less than 7 h had an increased risk of hypertriglyceridemia (*OR*:1.33, *95%CI*:1.03–1.72) and hypercholesterolemia (*OR*:1.32, *95%CI*:1.02–1.71). Male patients reported poor sleep quality had an increased risk of low HDL-cholesterol (*OR*:1.34, *95%CI*:1.06–1.70).

Table 5 depicts the results of associations of sleep problems with cardiometabolic risk among female patients. In the crude model, females reported sleep duration great than 7 h have an increased risk of hypertension (*OR*:1.56, *95%CI*:1.03–2.37), hyperglycemia (*OR*:1.77, *95%CI*:1.06–2.95) and hypertriglyceridemia (*OR*:1.59, *95%CI*:1.05–2.42). Female patients reported sleep duration less than 7 h had an increased risk of obesity (*OR*:1.83, *95%CI*:1.04–3.21). Females with poor sleep quality have an increased risk of hypertriglyceridemia (*OR*:1.34, *95%CI*:1.03–1.73) and hypercholesterolemia (*OR*:1.51, *95%CI*:1.17–1.95). After adjusting for age, dialysis vintage, educational level, smoking, and alcohol consumption, an increased risk of hypertension (*OR*:1.58, *95%CI*:1.04–2.41), hyperglycemia (*OR*:1.82, *95%CI*:1.08–3.07) and hypertriglyceridemia (*OR*: 1.59, *95%CI*:1.04–2.42) were found in females with sleep duration great than 7 h. The risk of hypercholesterolemia (*OR*:1.43, *95%CI*:1.02–2.02) was increased in female patients who slept less than 7 h. Higher risks of hypertriglyceridemia (*OR*:1.32, *95%CI*:1.01–1.69) and hypercholesterolemia (*OR*:1.48, *95%CI*:1.14–1.92) were reported in females with poor sleep quality.

Table 4
Associations between sleep problems and cardiometabolic risk in male patients undergoing hemodialysis.

		Crude model		Adjusted model	
		OR (95% *CI*)	*P* value	*OR* (95% *CI*)	*P* value
Hypertension	Sleep duration < 7 h[a]	1.03(0.79–1.33)	0.849	1.03(0.79–1.33)	0.840
	Sleep duration > 7 h[a]	1.35(0.98–1.87)	0.068	1.33(0.96–1.85)	0.084
	Poor sleep quality[b]	0.87(0.69–1.09)	0.217	0.86(0.68–1.08)	0.180
Hyperglycemia	Sleep duration < 7 h[a]	0.77(0.56–1.05)	0.101	0.70(0.51–0.98)	0.035
	Sleep duration > 7 h[a]	1.18(0.81–1.72)	0.395	1.23(0.84–1.82)	0.294
	Poor sleep quality[b]	0.73(0.55–0.95)	0.019	0.82(0.62–1.08)	0.160
High LDL-cholesterol	Sleep duration < 7 h[a]	0.72(0.51–1.03)	0.077	0.67(0.47–0.97)	0.032
	Sleep duration > 7 h[a]	0.93(0.60–1.44)	0.743	0.91(0.59–1.42)	0.680
	Poor sleep quality[b]	0.86(0.63–1.18)	0.355	0.90(0.65–1.24)	0.510
Low HDL-cholesterol	Sleep duration < 7 h[a]	0.56(0.43–0.72)	<0.001	0.56(0.43–0.72)	<0.001
	Sleep duration > 7 h[a]	0.71(0.52–0.97)	0.036	0.72(0.52–0.99)	0.044
	Poor sleep quality[b]	1.30(1.02–1.64)	0.030	1.34(1.06–1.70)	0.015
Hypertriglyceridemia	Sleep duration < 7 h[a]	1.22(0.94–1.56)	0.130	1.33(1.03–1.72)	0.029
	Sleep duration > 7 h[a]	1.42(1.04–1.95)	0.029	1.39(1.01–1.92)	0.043
	Poor sleep quality[b]	1.27(1.02–1.57)	0.032	1.15(0.92–1.43)	0.230
Hypercholesterolemia	Sleep duration < 7 h[a]	1.27(0.98–1.64)	0.068	1.32(1.02–1.71)	0.039
	Sleep duration > 7 h[a]	1.23(0.90–1.69)	0.199	1.21(0.88–1.67)	0.246
	Poor sleep quality[b]	1.10(0.88–1.36)	0.406	1.00(0.80–1.25)	0.972
Obesity	Sleep duration < 7 h[a]	1.01(0.72–1.40)	0.977	1.00(0.72–1.60)	0.987
	Sleep duration > 7 h[a]	1.07(0.72–1.60)	0.732	1.07(0.72–1.60)	0.748
	Poor sleep quality[b]	1.24(0.93–1.65)	0.150	1.20(0.89–1.61)	0.227

Note: Adjusting for age, dialysis vintage, educational level, smoking, and alcohol consumption.
[a] reference: sleep duration = 7 h.
[b] reference: good sleep quality.

Table 5
Associations between sleep problems and cardiometabolic risk in female patients undergoing hemodialysis.

		Model 1		Model 2	
		OR (95% *CI*)	*P* value	*OR* (95% *CI*)	*P* value
Hypertension	Sleep duration < 7 h[a]	1.00(0.72–1.39)	0.989	1.03(0.73–1.44)	0.867
	Sleep duration > 7 h[a]	1.56(1.03–2.37)	0.037	1.58(1.04–2.41)	0.032
	Poor sleep quality[b]	1.00(0.77–1.28)	0.967	1.02(0.79–1.31)	0.904
Hyperglycemia	Sleep duration < 7 h[a]	0.87(0.56–1.37)	0.552	0.78(0.49–1.23)	0.289
	Sleep duration > 7 h[a]	1.77(1.06–2.95)	0.029	1.82(1.08–3.07)	0.025
	Poor sleep quality[b]	1.01(0.73–1.42)	0.924	1.12(0.80–1.59)	0.505
High LDL-cholesterol	Sleep duration < 7 h[a]	1.22(0.72–1.72)	0.625	1.15(0.74–1.80)	0.536
	Sleep duration > 7 h[a]	0.97(0.56–1.66)	0.743	0.99(0.57–1.70)	0.967
	Poor sleep quality[b]	1.08(0.78–1.50)	0.903	1.15(0.82–1.61)	0.406
Low HDL-cholesterol	Sleep duration < 7 h[a]	1.04(0.70–1.55)	0.832	1.00(0.67–1.50)	0.992
	Sleep duration > 7 h[a]	1.31(0.81–2.10)	0.270	1.32(0.82–2.13)	0.260
	Poor sleep quality[b]	1.06(0.79–1.43)	0.686	1.11(0.82–1.50)	0.506
Hypertriglyceridemia	Sleep duration < 7 h[a]	1.35(0.96–1.88)	0.081	1.39(0.99–1.95)	0.059
	Sleep duration > 7 h[a]	1.59(1.05–2.42)	0.029	1.59(1.04–2.42)	0.031
	Poor sleep quality[b]	1.34(1.03–1.73)	0.027	1.32(1.01–1.69)	0.044
Hypercholesterolemia	Sleep duration < 7 h[a]	1.31(0.94–1.83)	0.117	1.43(1.02–2.02)	0.040
	Sleep duration > 7 h[a]	1.42(0.94–2.13)	0.097	1.43(0.95–2.16)	0.090
	Poor sleep quality[b]	1.51(1.17–1.95)	0.002	1.48(1.14–1.92)	0.003
Obesity	Sleep duration < 7 h[a]	1.83(1.04–3.21)	0.035	1.67(0.94–2.95)	0.080
	Sleep duration > 7 h[a]	1.70(0.88–3.29)	0.114	1.69(0.87–3.28)	0.123
	Poor sleep quality[b]	0.88(0.61–1.25)	0.469	0.88(0.61–1.26)	0.473

Note: Adjusting for age, dialysis vintage, educational level, smoking, and alcohol consumption.
[a] reference: sleep duration = 7 h.
[b] reference: good sleep quality.

4. Discussion

To our knowledge, there are no studies that have comprehensively analyzed the correlations between sleep problems and cardiometabolic risk in a large sample of hemodialysis patients. Sleep problems are common in CKD population. In this study, we found that 66.4% of hemodialysis patients reported less than 7 h of nighttime sleep, 17.7% of hemodialysis patients reported greater than 7 h of nighttime sleep, and 25.7% of patients have experienced poor sleep quality. The percentages of poor sleep quality and sleep insufficiency in males were greater than those of females. Several studies have shown that the prevalence of sleep disorders is higher in patients with ESRD than in the general population [34,35]. Agarwal et al. [36] also found that after adjusting for clinical variables, sleep efficiency was significantly lower in patients with CKD compared to those without CKD.

Previous studies have demonstrated the associations of sleep and single cardiometabolic risk. One study found that sleep deprivation was associated with low HDL cholesterol [37]. Another study has demonstrated that short sleep duration was associated with increased risk of higher blood pressure and hypertension [38]. A national health interview survey found that the prevalence of hypertension gradually increased when sleep time dropped below 7 h [39]. Recently, a cohort study showed that the risk of death from cardiovascular disease increased substantially when sleep duration was ≥10 h [40]. Another study found an increased risk of metabolic syndrome in people who slept more than 7 h [41]. The results of a meta-regression analysis showed a linear association between longer sleep duration and cardiovascular disease [42]. A study found impaired glucose tolerance in adults who reported sleeping for 9–10 h [43]. Our study showed that the prevalence of hypertension, hyperglycemia, hypertriglyceridemia and hypercholesterolemia increased in patients with more than 7 h of sleep duration. Although the results were inconsistent, it is revealed that sleeping too long or too short may not be good for your health, moderate amounts need to be maintained. Our study found that poor sleep quality was a risk factor for hypercholesterolemia and hypertriglyceridemia in female patients, which was consistent with another study that indicated poorer sleep quality was positively associated with serum triglyceride levels in the hemodialysis population [44]. However, in the total sample, poor sleep quality was a protective factor for hypertriglyceridemia and low HDL cholesterol. The reason for this is that sleep quality is presumably affected by sleep duration, phase of sleep, chronotype, and circadian rhythm, but some of the other factors in this paper are not considered and may increase the difficulty of explaining the results presented in the data. Furthermore, there was no significant correlation between sleep problems and obesity in our study. Short sleep duration was independently related to the increased different regional body fat in US adults, especially in males [45]. However, a longitudinal study from the UK showed that there was no significant association between sleep duration and future BMI in elderly people [46]. This is similar to our results. However, sleep duration and sleep quality were self-reported in our study. Otherwise, optimal sleep and circadian health in the maintenance of metabolic health and body weight regulation were important, circadian rhythm data were not collected in our study, which might both attenuate the strength of association.

Regarding the gender-based differences in the associations of sleep problems with cardiometabolic risk, after controlling for confounders, this study found that the risk of hyperglycemia was lower in male patients with short sleep duration. The risks of hyperglycemia, hypertension and hypertriglyceridemia were higher in female patients who reported sleeping longer than 7 h. A study found that compared to women, men with kidney disease were more likely to have systemic arterial hypertension, obesity and other

cardiometabolic risk factors [47]. Our findings indicated that low HDL cholesterol was significantly associated with sleep quality and sleep duration in male patients, not in female patients. The fact was that HDL levels were slightly higher in females than in males in our study, and higher HDL cholesterol levels in women are a major protective factor against the development of cardiovascular disease [48].

It is explicable to examine the correlations between sleep and cardiometabolic risk in the hemodialysis patients, and the underlying mechanisms need to be further explored. Sleep is regulated by circadian rhythms, and circadian rhythm dysfunction is thought to be the main mechanism by which sleep problems lead to increased cardiometabolic risk. Grimaldi et al. [49] found that circadian rhythm disorders have a negative impact on cardiovascular function. An animal study showed early signs of cardiac aging in mice after disruption of the cardiomyocyte biological clock [50]. Another study pointed out hypothalamic-pituitary-adrenal (HPA) axis might be an important factor in the effect of sleep on cardiometabolism. Hyposecretion of cortisol hormones by the HPA axis disrupts circadian rhythms, causes an overreaction to inflammation, and promotes the development of cardiometabolic disorders [51]. Inflammation [52], unhealthy diet [53] and altered growth hormone metabolism [54] also play an important role in sleep problems impacting cardiac metabolism.

A multi-center design with a large sample included was a significant strength of our study. However, some limitations should be addressed. Firstly, this study is a cross-sectional study, which cannot conclude the causal associations between sleep problems and cardiometabolic risk. Prospective cohort studies and randomized controlled trials are needed in the future. Secondly, the diversity of cardiometabolic risk measurements in the existing studies limits the extrapolation of the results. Waist circumference may be one of the cardiometabolic risk factors [55], but it was not provided in our study. Finally, the assessments of sleep problems were based on a self-administered questionnaire, and recall bias was inevitable. However, the Pittsburgh Sleep Quality Index was well-validated worldwide and the negative effect could be alleviated.

5. Conclusion

This study is the first to find a correlation between sleep problems and cardiometabolic risk in the hemodialysis population, and the results presented gender-based differences. Sleep problems are common in hemodialysis patients and create a significant public health burden for hemodialysis patients,. understanding of the potential mechanisms will help health care professional to propose comprehensive intervention strategies targeting sleep to improve cardiometabolic health.

Funding

The study was supported by ScienceFoundation of Anhui Medical University (2019xkj140); Clinical Research Incubation Program of The Second Hospital of Anhui Medical University (2020LCZD01); Co-construction project of clinical and preliminary disciplines of Anhui Medical University in 2020 (2020lcxk022)

Patient consent for publication

Not required.

Ethics approval

This study was approved by the Ethics Committee of The Second Hospital of Anhui Medical University (No. PJ-YX2020-006). Electronic informed consent was obtained from all participants before completing the survey.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author, upon reasonable request.

CRediT authorship contribution statement

Huan Yang: Writing – original draft, Formal analysis. **Yingxin Zhang:** Investigation, Data curation. **Xiuyong Li:** Investigation, Data curation. **Zhi Liu:** Investigation, Data curation. **Youwei Bai:** Investigation, Data curation. **Guangrong Qian:** Investigation, Data curation. **Han Wu:** Investigation, Data curation. **Ji Li:** Investigation, Data curation. **Yuwen Guo:** Investigation, Data curation. **Shanfei Yang:** Investigation, Data curation. **Lei Chen:** Investigation, Data curation. **Jian Yang:** Investigation, Data curation. **Jiuhuai Han:** Investigation, Data curation. **Shengyin Ma:** Investigation, Data curation. **Jing Yang:** Investigation, Data curation. **Linfei Yu:** Investigation, Data curation. **Runzhi Shui:** Investigation, Data curation. **Xiping Jin:** Investigation, Data curation. **Hongyu Wang:** Investigation, Data curation. **Fan Zhang:** Investigation, Data curation. **Tianhao Chen:** Investigation, Data curation. **Xinke Li:** Investigation, Data curation. **Xiaoying Zong:** Investigation, Data curation. **Li Liu:** Investigation, Data curation. **Jihui Fan:** Investigation, Data curation. **Wei Wang:** Investigation, Data curation. **Yong Zhang:** Investigation, Data curation. **Guangcai Shi:** Investigation, Data curation. **Deguang Wang:** Funding acquisition. **Shuman Tao:** Project administration.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e27377.

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