



## Trends and prevalence of nocturia among US adults, 2005–2016

Pinar Soysal<sup>1</sup> · Chao Cao<sup>2,3</sup> · Tianlin Xu<sup>4</sup> · Lin Yang<sup>5,6</sup> · Ahmet Turan Isik<sup>7</sup> · Rumezta Turan Kazancioglu<sup>8</sup> · Qinran Liu<sup>3</sup> · Damiano Pizzol<sup>9</sup> · Nicola Veronese<sup>10</sup> · Jacopo Demurtas<sup>11</sup> · Lee Smith<sup>12</sup>

Received: 22 October 2019 / Accepted: 11 December 2019 / Published online: 19 December 2019  
© Springer Nature B.V. 2019

### Abstract

**Purpose** Increased nocturia episodes can be a clinical marker of poor health status. The present study aimed to evaluate patterns and temporal trends in nocturia and sociodemographic and lifestyle correlates in the US population.

**Methods** Participants, aged 20 years or older, were included in this repeated cross-sectional study. The National Health and Nutrition Examination Survey from 2005 to 2016 was used. Participants were asked “During the past 30 days, how many times per night did you most typically get up to urinate, from the time you went to bed at night until the time you got up in the morning?”. Individuals were categorized as either  $\geq 1$  nocturia episode or  $\geq 2$  nocturia episodes per night.

**Results** The estimated prevalence of  $\geq 1$  nocturia was high among men (20–39 years, 56.8%; 40–59 years, 70.2%;  $\geq 60$  years, 82.7%) and women (20–39 years, 68.9%; 40–59 years, 74.3%;  $\geq 60$  years, 84.7%), particularly in Non-Hispanic-blacks. From 2005–2016, the trends in prevalence of  $\geq 1$  nocturia increased for the age groups 20–39 and 40–59 years among men ( $p < 0.001$  and  $p = 0.001$ , respectively) and women 20–39 and 40–59 years ( $p < 0.001$  and  $p = 0.032$ , respectively), but a stable trend was observed among men and women who were 60 years and older ( $p = 0.814$ , and  $p = 0.64$ , respectively). A significant increasing trend of  $\geq 2$  nocturia episodes was observed among men only aged 40–59 years ( $p = 0.007$ ).

**Conclusions** From 2005 through 2016, the secular trend in the frequency of nocturia increased in both men and women in general, which was significant under the age of 60 years, particularly in Non-Hispanic-blacks.

**Keywords** Nocturia · Trend · United States · NHANES

✉ Chao Cao  
caochao@wustl.edu

<sup>1</sup> Department of Geriatric Medicine, Faculty of Medicine, Bezmialem Vakif University, Istanbul, Turkey

<sup>2</sup> Program in Physical Therapy, Washington University School of Medicine, 4444 Forest Park Avenue, St. Louis, MO 63110, USA

<sup>3</sup> Division of Public Health Sciences, Department of Surgery, Washington University School of Medicine, St. Louis, MO, USA

<sup>4</sup> Department of Biostatistics, School of Public Health, The University of Texas Health Science Center at Houston, Houston, TX, USA

<sup>5</sup> Department of Cancer Epidemiology and Prevention Research, Alberta Health Services, Calgary, Canada

<sup>6</sup> Departments of Oncology and Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, AB, Canada

<sup>7</sup> Unit for Aging Brain and Dementia, Department of Geriatric Medicine, Faculty of Medicine, Dokuz Eylul University, Izmir, Turkey

<sup>8</sup> Department of Nephrology, Bezmialem Vakif University, Faculty of Medicine, Istanbul, Turkey

<sup>9</sup> Italian Agency for Development Cooperation, Jerusalem, Israel

<sup>10</sup> Azienda ULSS 3 Serenissima, Primary Care Department, District 3, Venice, Italy

<sup>11</sup> Primary Care Department, Azienda Usl Toscana Sud Est, Grosseto, Italy

<sup>12</sup> The Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, UK

## Introduction

Persistent lower urinary tract symptoms (LUTS) significantly reduce quality of life in men and women of all ages [1]. Nocturia is defined as a person waking up and urinating one or more times per night, regardless of poor sleep [2]. Although at least one voiding episode is sufficient for the definition of nocturia, two and more episodes of nocturia have been shown to be associated with more adverse clinical outcomes [3]. For example, according to the data from The National Health and Nutrition Examination Survey (NHANES), the prevalence of those with nocturia of 2 or more voiding episodes overnight is 15.5% for males and 20.9% for females, and importantly mortality rises with increased frequency of nocturia [4]. Moreover, this association between nocturia and mortality was found to be stronger in young adults than in older adults [4]. Another study conducted in only older women revealed that  $\geq 2$  nocturia episodes per night was associated with recurrent falls, polypharmacy, insomnia, decreased walking speed, while  $\geq 3$  nocturia was found to be associated with decreased Instrumental Activities of Daily Living and  $\geq 4$  nocturia was related to frailty [3]. In another study, three or more nocturia episodes were associated with mortality in older men [5]. Similar studies also suggest that nocturia may be an indicator of poor health rather than a simple LUTS.

Nocturia is a multifactorial condition. In addition to changes in the age-related urinary system, biochemical changes such as decreased melatonin secretion and increased plasma natriuretic peptide levels cause nocturia [6, 7]. On the other hand, nocturia is also associated with several modifiable or treatable risk factors such as lifestyle factors (drinking less water at night, reducing coffee consumption), obstructive sleep apnea, hypertension, diabetes mellitus, and medications (e.g., diuretics, calcium channel blockers) [6]. When lifestyle interventions, and the optimal treatments of underlying diseases (improving diabetes mellitus and metabolic syndrome control), are applied, clinicians may reduce not only nocturia episodes per night, but also many negative outcomes related to nocturia.

Therefore, it is important to examine in detail the contemporary prevalence of nocturia and the secular trend over time to provide information about the general health status of the societies and developing appropriate management strategies. The aim of this study was to investigate the frequency trends of nocturia in the United States between 2005 and 2016 using NHANES data according to different age groups.

## Methods

### Study design

NHANES is nationally representative series of surveys and physical examinations conducted by Centers for Disease

Control and Prevention (CDC). It was designed to evaluate the health and nutritional status of adults and children in the United States and was approved by the National Center for Health Statistics (NCHS) Ethics Review Board. Additional written consent was provided by each participant. Between 2005 and 2016 NHANES collected information on several urological health outcomes, including nocturia issues. We combined datasets on sociodemographic characteristics, weight and height, lifestyle factors, and kidney functions among adults aged 20 years and above from six consecutive NHANES 2-year cycles, from 2005–2006 to 2015–2016, with available information on nocturia.

### Variable definitions

Our main outcome, nocturia, was defined based on the urinary symptoms questionnaire. The question, “during the past 30 days, how many times per night did you most typically get up to urinate, from the time you went to bed at night until the time you got up in the morning?” was used. Individuals were either categorized as one or more or two or more nocturia episodes per night.

Leisure-time physical activity was defined by having any moderate or vigorous physical activity during leisure time. Participants also answered the question “How often {do you/does SP} have urinary leakage?”. Urinary leakage was defined as a binary variable if they have urinary leakage a few times a month or more.

### Statistical analysis

Statistical analysis was performed with SAS, version 9.4 and STATA, version 16. All analyses considered sample weights, strata and cluster design variables to account for the complex NHANES design as guided by the NCHS and to make the sample representative of the United States Census civilian noninstitutionalized population. Tests of significance were performed with the *t* test for continuous variables and the Chi-square test for categorical variables. Weighted estimated prevalence and 95% CI of outcome variables were calculated by gender, age groups and year cycles. Crude linear trends were assessed using linear regression models while treating survey cycle as a continuous variable. Both coefficients and 95% CI were reported. Moreover, trends of nocturia among men and women stratified by race/ethnicity groups were visually illustrated.

Multivariable logistic regression were used to calculate the odds ratios (ORs) and 95% CI of independent variables against outcome variables. Multivariable-adjusted logistic regression, mentioned above, was used to evaluate linear trends and potential correlates. The *p* value for the statistical tests were 2-sided with statistically significant considered as  $p < 0.05$ .

## IRB approval

All NHANES protocols were approved by National Center for Health Statistics. All participants provided signed consent forms.

## Results

After excluding participants without information on nocturia, a total of 24,800 individuals aged 20 years and older were included in present analysis, including 11,438 men and 13,362 women. Table 1 shows the characteristics of the study population in 2015–2016.

### ≥ 1 Nocturia episode per night

In the 2015–2016 cycle, 56.8% of men aged between 20 and 39 years reported urinating one or more than one time per night (95% CI 52.4–61.2%) (Table 2). The estimated prevalence was 70.2% (95% CI 65.5–74.9) among men who aged between 40 and 59 years and 82.7% (77.9–87.6%) among those 60 years or older. Compared with the 2005–2006 cycle, the 2015–2016 estimated prevalence was higher in all three age groups. Among men aged 20–39 and 40–59 years, the estimated prevalence increased by 14.9% (95% CI 9.5–20.4%) and 9.6% (95% CI 3.5–15.7%), respectively. We also observed a statistically significant increasing trend for those two age groups among men ( $p < 0.001$ ;  $p = 0.001$ ). However, a stable trend was observed among men who were 60 years and older ( $p = 0.814$ ). For women, among those aged 20–39 years, the estimated prevalence was 68.9% (95% CI 63.9–73.8%). Among those aged 40–59 years, the estimated prevalence was 74.3% (95% CI 69.8–78.8%) and the estimated prevalence was 84.7% (95% CI 81.1–88.3%) among those aged 60 years and older. Similar to men, we observed an increasing trend from 2005–2006 to 2015–2016 for women aged 20–39 ( $p < 0.001$ ) and 40–59 ( $p = 0.032$ ) and a steady trend for women who were 60 years and older ( $p = 0.64$ ).

From the result from multivariable weighted logistic regression, we observed significantly higher prevalence in both men and women among non-Hispanic black, obese and people with urinary incontinence (Table 3). Compared to non-Hispanic-white, the OR for non-Hispanic black men was 1.50 (95% CI 1.37–1.64); and for non-Hispanic black women, 1.94 (95% CI 1.72–2.20). Among all three race/ethnicity groups, non-Hispanic black had the highest estimated prevalence over time (Fig. 1). Compared to people with BMI less than 25 kg/m<sup>2</sup>, the OR for obese men was 1.24 (95% CI 1.10–1.41) and for obese women 1.35 (95% CI 1.22–1.50). Men with urinary incontinence had 5.61 times higher odds (95% CI 4.45–7.07) of urinating one or more times per night

compared to men without urinary incontinence. The same odds was 2.54 times (95% CI 2.29–2.83) in women with urinary incontinence compared to women without. Moreover, family poverty ratio and educational attainment were negatively associated with urinating one or more times per night. It was observed that, as the ratio of annual household income of poverty went up, the OR went down ( $p < 0.001$ ). Similarly, the OR went down as education level went up ( $p < 0.001$ ).

### ≥ 2 Nocturia episode per night

In the 2015–2016 cycle, 24.3% (95% CI 19.6–28.9%) of men aged 20–39 years, 34.2% (95% CI 30.8–37.5%) of men aged 40–59 and 51.5% (95% CI 43.0–59.9%) of men aged 60 years and older reported urinating two or more times per night. For women, 33.6% (95% CI 28.0–39.1%) of those aged 20–39, 37.0% (95% CI 31.4–42.6%) of those aged 40–59 and 45.4% (95% CI 40.3–50.4%) of those aged 60 years and older reported urinating two or more times per night. A significant increasing trend was observed among men aged 40 to 59 years old ( $p = 0.007$ ) and an 8.4% (95% CI 3.6–13.3%) increase from 2005–2006 to 2015–2016 cycle was observed. In addition, a marginally significant increasing trend was observed among women in the same age group ( $p = 0.06$ ) and there was a 3.2% (95% CI – 3.4 to 9.7%) increase since 2005–2006 cycle. In contrast, a significant decreasing trend was observed for women who were 60 years and older ( $p = 0.032$ ) and the difference between 2005–2006 and 2015–2016 cycle was – 5.6% (95% CI – 1.6 to 0.5%).

Similarly, after multivariable adjustment, significantly higher prevalence of urinating two and more times per night was observed in both men and women among non-Hispanic black, Hispanic, obese and people with urinary incontinence. Compared to non-Hispanic-white, the OR for non-Hispanic black men was 1.73 (95% CI 1.53–1.96); for non-Hispanic black women, 2.36 (95% CI 2.13–2.61); for Hispanic men 1.12 (95% CI 1.00–1.25) and for Hispanic women, 1.19 (95% CI 1.05–1.34). Compared to people with BMI less than 25 kg/m<sup>2</sup>, the OR for obese men was 1.25 (95% CI 1.08–1.45) and for obese women was 1.18 (95% CI 1.05–1.31). The OR for men with urinary incontinence was 10.5 (95% CI 8.87–12.6) and 4.01 (95% CI 3.60–4.47) for men without. Physically active participants were less likely to have ≥ 2 nocturia episode per night compared with inactive participants [OR: men, 0.86 95% CI (0.78–0.96); women, 0.80 95% CI (0.74–0.88)]. Family poverty ratio and education attainment were both negatively associated with urinating two or more times per night (both  $p < 0.001$ ).

**Table 1** Characteristics of the US adults  $\geq 20$  years from the NHANES 2015–2016

	Gender		<i>p</i> value
	Men	Women	
No	2747	2972	
Weighted <i>N</i>	112,732,652	121,774,734	
Age, years	47.3	48.6	0.037
Age group, %			
20–39 years	37.3	35.2	0.073
40–59 years	36.4	35.4	
$\geq 60$ years	26.4	29.4	
Race/ethnicity, %			
Non-Hispanic white	64.4	63.4	0.010
Non-Hispanic black	10.5	12.1	
Hispanic	15.7	14.9	
Other	9.4	9.6	
Family poverty ratio			
$< 1$	20.4	22.6	$< 0.001$
1 to $< 2$	17.8	19.6	
2 to $< 4$	25.2	26.5	
$\geq 4$	36.6	31.3	
Educational attainment			
$<$ High school (grades 0–12)	16.1	13.0	$< 0.001$
High school graduate/general equivalency diploma)	22.0	19.7	
$>$ High school (some college or above)	62.0	67.3	
Weight status, %			
$< 25$ kg/m <sup>2</sup>	25.1	31.0	$< 0.001$
25 to $< 30$ kg/m <sup>2</sup>	36.8	27.4	
$\geq 30$ kg/m <sup>2</sup>	38.1	41.6	
Leisure-time physical activity <sup>a</sup>			
Active	57.1	53.3	0.06
Urinary leakage <sup>b</sup>			
Frequent	19.8	38.9	$< 0.001$
Nocturia, times/night			
0	35.5	30.0	0.003
1	37.7	42.4	
2	15.8	18.3	
3	7.7	7.3	
4	1.9	2.9	
$\geq 5$	1.4	1.1	

All estimates were weighted to be nationally representative

<sup>a</sup>Leisure-time physical activity level was defined by engaging in no (inactive) or any (active) moderate or vigorous recreational physical activity over the past 30 days

<sup>b</sup>Frequent urinary leakage was defined by urinary leaking more than a few times a week

## Discussion

In this study using NHANES 2005–2016 data, the prevalence of participants without nocturia was higher in men, whereas the ratio of those with nocturia  $\geq 1$  or  $\geq 2$  times was higher in women and Non-Hispanic blacks. Moreover, that the prevalence of nocturia increased with age, family poverty

ratio, and weight and decreased with increased education level. In addition, from 2005 to 2016, the secular trend in the prevalence of  $\geq 1$  nocturia episode increased in both men and women in general, which was significant among those under the age of 60 years, particularly in Non-Hispanic white and Hispanics. Finally, the prevalence of  $\geq 2$  nocturia episodes tended to increase only in men aged 40–59 years.

**Table 2** Weighted trends in nocturia among US adults ≥ 20 years, NHANES 2005–2016

Age, year	Trends in nocturia						$\beta$ (95% CI)	<i>p</i> for Trend	2015–2016 vs 2005–2006 Difference (95% CI)
	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016			
<b>Urinating ≥ 1 time/night, weighted % (95% CI)</b>									
<b>Men</b>									
20–39	<b>41.9</b> (38.3 to 45.5)	<b>44.9</b> (39.2 to 50.6)	<b>54</b> (48.6 to 59.4)	<b>50.1</b> (46.6 to 53.5)	<b>51.8</b> (48.8 to 54.8)	<b>56.8</b> (52.4 to 61.2)	2.6 (1.7 to 3.5)	<0.001	14.9 (9.5 to 20.4)
40–59	<b>60.6</b> (56.2 to 64.9)	<b>64.2</b> (58.5 to 69.9)	<b>70.3</b> (67.4 to 73.2)	<b>70.9</b> (63.9 to 77.9)	<b>69.2</b> (64.3 to 74.1)	<b>70.2</b> (65.5 to 74.9)	1.8 (0.7 to 2.9)	0.001	9.6 (3.5 to 15.7)
≥ 60	<b>81.2</b> (75.5 to 86.9)	<b>83.7</b> (81.2 to 86.1)	<b>84.4</b> (81.9 to 86.9)	<b>81.6</b> (77 to 86.2)	<b>83.9</b> (80.6 to 87.1)	<b>82.7</b> (77.9 to 87.6)	0.1 (− 0.9 to 1.2)	0.814	1.5 (− 5.7 to 8.6)
<b>Women</b>									
20–39	<b>59.3</b> (55.4 to 63.3)	<b>57</b> (50.5 to 63.5)	<b>64.4</b> (59.1 to 69.8)	<b>65.3</b> (61.3 to 69.2)	<b>67.1</b> (62.7 to 71.6)	<b>68.9</b> (63.9 to 73.8)	2.2 (1.2 to 3.3)	<0.001	9.5 (3.5 to 15.5)
40–59	<b>70.1</b> (65.1 to 75)	<b>70.2</b> (68.1 to 72.4)	<b>75.1</b> (70.7 to 79.6)	<b>76</b> (71.5 to 80.5)	<b>75.3</b> (72 to 78.6)	<b>74.3</b> (69.8 to 78.8)	1.1 (0.1 to 2.0)	0.032	4.2 (− 2.2 to 10.6)
≥ 60	<b>81.8</b> (77.1 to 86.5)	<b>83.3</b> (80.7 to 85.9)	<b>83</b> (80.9 to 85.2)	<b>83.2</b> (79 to 87.4)	<b>80.6</b> (77.5 to 83.7)	<b>84.7</b> (81.1 to 88.3)	0.2 (− 0.6 to 1.0)	0.640	2.9 (− 2.7 to 8.5)
<b>Urinating ≥ 2 times/night, weighted % (95% CI)</b>									
<b>Men</b>									
20–39	<b>19.7</b> (16.1 to 23.3)	<b>20.6</b> (16.8 to 24.4)	<b>22.4</b> (19.2 to 25.6)	<b>20.5</b> (15.7 to 25.3)	<b>18.6</b> (14.9 to 22.3)	<b>24.3</b> (19.6 to 28.9)	0.4 (− 0.5 to 1.3)	0.338	4.6 (− 1.0 to 10.2)
40–59	<b>25.7</b> (22 to 29.4)	<b>30.8</b> (25.3 to 36.2)	<b>28.9</b> (24.9 to 32.9)	<b>30.5</b> (25.6 to 35.4)	<b>31</b> (26.6 to 35.5)	<b>34.2</b> (30.8 to 37.5)	1.3 (0.4 to 2.2)	0.007	8.4 (3.6 to 13.3)
≥ 60	<b>47.6</b> (43.1 to 52)	<b>53.1</b> (49.3 to 56.9)	<b>49.9</b> (45.9 to 53.9)	<b>45.9</b> (40.6 to 51.1)	<b>44.2</b> (37.7 to 50.7)	<b>51.5</b> (43 to 59.9)	− 0.3 (− 1.8 to 1.2)	0.719	3.9 (− 5.3 to 13.1)
<b>Women</b>									
20–39	<b>32</b> (28.7 to 35.3)	<b>28.8</b> (24.6 to 32.9)	<b>32.4</b> (28.9 to 35.9)	<b>34.5</b> (29.7 to 39.4)	<b>33.2</b> (28.8 to 37.7)	<b>33.6</b> (28 to 39.1)	0.7 (− 0.4 to 1.7)	0.203	1.5 (− 4.7 to 7.7)
40–59	<b>33.8</b> (29.9 to 37.8)	<b>33.4</b> (29.3 to 37.6)	<b>35.6</b> (31.1 to 40.2)	<b>40.6</b> (36 to 45.2)	<b>38.9</b> (33.2 to 44.5)	<b>37</b> (31.4 to 42.6)	1.1 (− 0.1 to 2.2)	0.060	3.2 (− 3.4 to 9.7)
≥ 60	<b>50.9</b> (47.1 to 54.7)	<b>46.8</b> (42.6 to 51.1)	<b>49.2</b> (46.8 to 51.6)	<b>43.8</b> (38.7 to 48.9)	<b>44.2</b> (39.0 to 49.5)	<b>45.4</b> (40.3 to 50.4)	− 1.1 (− 2.2 to − 0.1)	0.032	− 5.6 (− 11.6 to 0.5)

The bold shown the prevalence of nocturia for each year

The prevalence of LUTS is very high in the United States as in the rest of the world, and the incidence is increasing exponentially, especially in adults after the age of 40 years. These symptoms not only cause a decrease in quality of life, but also increase morbidity. Therefore, the annual health

expenditure due to LUTS in the US is estimated at \$4 billion [8]. Nocturia is one of the most important economic burdens of urinary system symptoms. In Europe in 2014, health expenditure caused by nocturia-related hip fractures is estimated at €1.0 billion. In addition, nocturia has been

**Table 3** Weighted logistic regression models of nocturia, adjusted for sociodemographic and lifestyle characteristics, NHANES 2005–2016

	Odds ratio (95% CI)			
	Nocturia $\geq 2$ times/night		Nocturia $\geq 1$ time/night	
	Men	Women	Men	Women
Age	1.04 (1.03–1.04)	1.01 (1.01–1.01)	1.04 (1.04–1.04)	1.02 (1.02–1.02)
Race/ethnicity				
Non-Hispanic white	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Non-Hispanic black	1.73 (1.53–1.96)	2.36 (2.13–2.61)	1.50 (1.37–1.64)	1.94 (1.72–2.20)
Hispanic	1.12 (1.00–1.25)	1.19 (1.05–1.34)	0.97 (0.86–1.08)	0.98 (0.87–1.11)
Other	0.98 (0.81–1.20)	1.42 (1.21–1.68)	1.00 (0.86–1.16)	1.06 (0.89–1.27)
Family poverty ratio				
< 1	1 (reference)	1 (reference)	1 (reference)	1 (reference)
1 to < 2	0.73 (0.66–0.82)	0.80 (0.72–0.90)	0.86 (0.76–0.97)	0.91 (0.79–1.06)
2 to < 4	0.62 (0.54–0.70)	0.63 (0.56–0.70)	0.76 (0.66–0.88)	0.75 (0.66–0.85)
$\geq 4$	0.56 (0.50–0.64)	0.55 (0.48–0.62)	0.75 (0.65–0.86)	0.80 (0.71–0.91)
<i>p</i> for trend <sup>c</sup>	< 0.001	< 0.001	< 0.001	< 0.001
Educational attainment				
< High school (grades 0–12)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
High school graduate/general equivalency diploma)	0.87 (0.76–0.99)	0.77 (0.69–0.87)	0.99 (0.87–1.12)	0.84 (0.71–0.99)
> High school (some college or above)	0.65 (0.57–0.75)	0.63 (0.56–0.71)	0.79 (0.69–0.91)	0.75 (0.64–0.88)
<i>p</i> for trend <sup>c</sup>	< 0.001	< 0.001	< 0.001	0.001
Weight status, %				
< 25 kg/m <sup>2</sup>	1 (reference)	1 (reference)	1 (reference)	1 (reference)
25 to < 30 kg/m <sup>2</sup>	1.03 (0.90–1.16)	1.00 (0.89–1.13)	1.03 (0.92–1.16)	1.08 (0.97–1.21)
$\geq 30$ kg/m <sup>2</sup>	1.25 (1.08–1.45)	1.18 (1.05–1.31)	1.24 (1.10–1.41)	1.35 (1.22–1.50)
<i>p</i> for trend <sup>c</sup>	< 0.001	< 0.001	< 0.001	< 0.001
Leisure-time physical activity <sup>a</sup>				
Inactive	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Active	0.86 (0.78–0.96)	0.80 (0.74–0.88)	1.00 (0.91–1.10)	0.92 (0.84–1.01)
Urinary leakage <sup>b</sup>				
No	1 (reference)	1 (reference)	1 (reference)	1 (reference)
Frequent	10.5 (8.77–12.6)	4.01 (3.60–4.47)	5.61 (4.45–7.07)	2.54 (2.29–2.83)
Cycle				
2005–2006	1 (reference)	1 (reference)	1 (reference)	1 (reference)
2007–2008	1.22 (0.98–1.51)	0.80 (0.70–0.92)	1.16 (0.93–1.43)	0.93 (0.81–1.08)
2009–2010	1.19 (1.00–1.41)	0.92 (0.82–1.04)	1.57 (1.32–1.88)	1.18 (0.99–1.41)
2011–2012	1.06 (0.87–1.30)	0.93 (0.78–1.09)	1.42 (1.14–1.78)	1.20 (0.99–1.46)
2013–2014	1.09 (0.87–1.37)	0.89 (0.78–1.02)	1.53 (1.29–1.80)	1.18 (1.00–1.39)
2015–2016	1.33 (1.07–1.66)	0.91 (0.74–1.11)	1.58 (1.34–1.85)	1.29 (1.12–1.49)
<i>p</i> for trend <sup>c</sup>	0.16	0.81	< 0.001	< 0.001

All estimates were weighted to be nationally representative

<sup>a</sup>Leisure-time physical activity level was defined by engaging in no (inactive) or any (active) moderate or vigorous recreational physical activity over the past 30 days

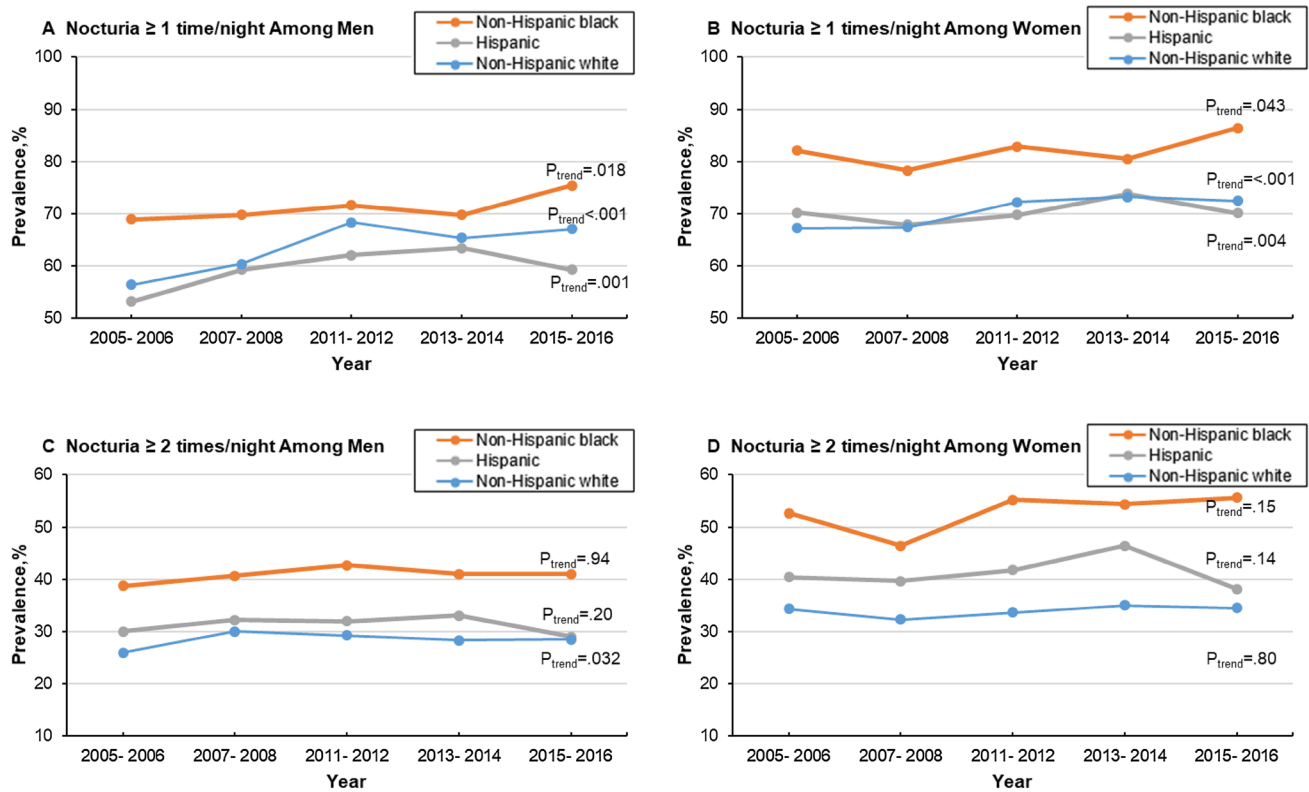
<sup>b</sup>Frequent urinary leakage was defined by urinary leaking more than a few times a week

<sup>c</sup>*p* value for trend was only provided for ordinal variables

reported to indirectly cause a cost of about €29.0 billion, leading to reduced work productivity [9]. In the United States, annual direct costs resulting from nocturia-related falls were estimated at around \$1.5 billion and the indirect costs were

estimated at \$61 billion in 2014 [9]. In the present study, it is important in many ways that  $\geq 1$  nocturia episode in individuals under 60 years of age, and  $\geq 2$  nocturia episodes in men between 40–59 years of age were on an upward trend





**Fig. 1** Weighted trends in nocturia among the US adults  $\geq 20$  years according to race/ethnicity, NHANES 2005–2016

between 2005 and 2016. First, the increase in the frequency of nocturia in these age groups may lead to an increase in health expenditures by reducing the productivity of the people who are actively working [9]. Second, a population-based epidemiologic study demonstrated a significant association between nocturia and depression in both men and women, which was stronger in those  $< 50$  years of age [10]. This suggests that in the US, nocturia should be considered in the prevention of depression and negative outcomes due to depression, which is one of the most important and increasing health problems of today [11–13]. Third, in a study conducted using NHANES data to investigate the effect of nocturia on mortality risk, it was reported that  $\geq 2$  nocturia episodes increased the risk of mortality by 1.54 times in men and 1.28 times in women. However, interestingly, the magnitude of the nocturia and mortality association was greater in those younger than 65 years with attenuated associations in the 65 years or older age group. There was a significant trend in increased risk of death due to increased night void events [4].

Finally, according to NHANES data, the prevalence of obesity, hypertension, diabetes mellitus, and sodium consumption has increased over the years. This may account for the upward trend of nocturia in the middle aged and younger aged groups, indicating that these cardiovascular risk factors are not being effectively controlled in the US [14–16].

In the present study, the prevalence of those who had nocturia for at least 1 time was more than 80% and the prevalence of those who had nocturia for at least 2 times was around 50%, but no change was observed in the nocturia prevalence trend in those  $\geq 60$  years of age. In fact, even if it seems that there is no increase in the nocturia trend over the age of 60, these rates are already very high, because serious complications such as nocturia-related hip fractures, falls and reduced functionality are more common in older subjects and often require hospitalization [9, 17, 18]. Importantly, the negative effect of nocturia on sleep outcomes seems to be stronger in adults over 65 years of age [19]. Moreover, a recent study has reported that older patients with  $\geq 2$  nocturia episodes are more likely to have geriatric syndromes such as frailty, polypharmacy, incontinence, falls, lower gait speed and lower functional capacity, which are high risk indicators for many adverse clinical events in older adults [3]. Considering that even if there is no increase in the nocturia trend in those over the age of 60, the United States older population will be 88.5 million (20% of the total population) in 2050, it is clear evidence that nocturia and related complications will be more likely in the future [20].

One of the findings of our study was that nocturia was more common in non-Hispanic blacks is consistent with

previous epidemiological studies [21]. Factors such as socioeconomic and educational status may account for some of these ethnic differences. However, Kupelian et al. found that nocturia was more common in non-Hispanic blacks even after adjusting for income and educational status [21]. Therefore, racial variations may also indicate potential genetic, lifestyle behaviors or sociocultural factors in the aetiopathogenesis of nocturia. However, future studies are needed to clarify the issue.

The main strength of the present study was the use of a large, nationally representative dataset (NHANES), which allowed for the first time an accurate secular trend of the prevalence of nocturia among US adults over time. However, the present study has some limitations. First, this was a cross-sectional study. Second, the presence of nocturia was evaluated using a validated question, but participants were not asked to complete the 3-day frequency volume charts and nocturnal polyuria. Third, any validation scale, such as overactive bladder symptom score or bladder diary was not used for nocturia evaluation. Finally, confounding factors except for BMI, such as diabetes, benign prostatic hyperplasia, drugs used were not evaluated.

In conclusion, frequent nocturia affects an important proportion of men and women of all ages in the United States and prevalence increases with age. Risk factors for nocturia include advanced age, non-Hispanic black race/ethnicity, increased family poverty ratio and weight, and low education level. During the period 2005–2016, the apparent continued increase in  $\geq 1$  nocturia episode prevalence in US adults under 60 years of age is concerning. Although there is no change in the nocturnal prevalence trend in those  $\geq 60$  years of age, the prevalence of those who have nocturia for at least 1 time was more than 80% and the prevalence of those who have nocturia for at least 2 times is around 50%. Future studies are needed to determine the reasons for these trends and high ratios. Because increased nocturia episodes can be a clinical marker of poor health status, nocturia assessment is very important for clinical practice; thus, evaluation of nocturia and nocturia frequency should be a part of patient's assessment, and impactful strategies should be implemented to reduce nocturia episodes and improve its related negative outcomes.

**Acknowledgements** We thank the participants and staff of the National Health and Nutrition Examination Survey.

**Funding** No.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interest.

## References

1. Everaert K, Anderson P, Wood R, Andersson FL, Holm-Larsen T (2018) Nocturia is more bothersome than daytime LUTS: results from an observational, real-life practice database including 8659 European and American LUTS patients. *Int J Clin Pract* 72(6):e13091
2. Haylen BT, de Ridder D, Freeman RM, Swift SE, Berghmans B, Lee J et al (2010) An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Neurourol Urodyn* 29(1):4–20
3. Dutoglu E, Soysal P, Smith L, Arik F, Kalan U, Kazancioglu RT et al (2019) Nocturia and its clinical implications in older women. *Arch Gerontol Geriatr* 85:103917
4. Kupelian V, Fitzgerald MP, Kaplan SA, Norgaard JP, Chiu GR, Rosen RC (2011) Association of nocturia and mortality: results from the Third National Health and Nutrition Examination Survey. *J Urol* 185(2):571–577
5. Endeshaw YW, Schwartz AV, Stone K, Caserotti P, Harris T, Smagula S et al (2016) Nocturia, insomnia symptoms and mortality among older men: the health, aging and body composition study. *J Clin Sleep Med JCSM Off Publ Am Acad Sleep Med* 12(6):789–796
6. Varilla V, Samala RV, Galindo D, Ciocon J (2011) Nocturia in the elderly: a wake-up call. *Cleve Clin J Med* 78(11):757–764
7. van Doorn B, Bosch JLHR (2012) Nocturia in older men. *Maturitas* 71(1):8–12
8. Saigal CS, Joyce G (2005) Economic costs of benign prostatic hyperplasia in the private sector. *J Urol* 173(4):1309–1313
9. Holm-Larsen T (2014) The economic impact of nocturia. *Neuro-urol Urodyn* 33(1):S10–S14
10. Kupelian V, Wei JT, O'Leary MP, Norgaard JP, Rosen RC, McKinlay JB (2012) Nocturia and quality of life: results from the Boston area community health survey. *Eur Urol* 61(1):78–84
11. Liu Y, Collins C, Wang K, Xie X, Bie R (2019) The prevalence and trend of depression among veterans in the United States. *J Affect Disord* 245:724–727
12. Greenberg PE, Fournier A-A, Sisitsky T, Pike CT, Kessler RC (2015) The economic burden of adults with major depressive disorder in the United States (2005 and 2010). *J Clin Psychiatry* 76(2):155–162
13. Furukawa S, Sakai T, Niiya T, Miyaoka H, Miyake T, Yamamoto S et al (2018) Nocturia and prevalence of depressive symptoms in Japanese adult patients with type 2 diabetes mellitus: The Dogo Study. *Can J Diabetes* 42(1):51–55
14. Moon S, Chung HS, Yu JM, Ko KJ, Choi DK, Kwon O et al (2019) The association between obesity and the nocturia in the U.S. population. *Int Neurourol J* 23(2):169–176
15. Ryu S, Frith E, Pedisic Z, Kang M, Loprinzi PD (2019) Secular trends in the association between obesity and hypertension among adults in the United States, 1999–2014. *Eur J Intern Med* 62:37–42
16. Brouillard AM, Kraja AT, Rich MW (2019) Trends in dietary sodium intake in the United States and the impact of USDA guidelines: NHANES 1999–2016. *Am J Med* 132(10):1199–1206
17. Vaughan CP, Fung CH, Huang AJ, Johnson TMN, Markland AD (2016) Differences in the association of nocturia and functional outcomes of sleep by age and gender: a cross-sectional, population-based study. *Clin Ther* 38(11):2386–2393.e1
18. Kim SY, Bang W, Kim M-S, Park B, Kim J-H, Choi HG (2017) Nocturia is associated with slipping and falling. *PLoS ONE* 12(1):e0169690



19. Oelke M, Wachter S, Drake MJ, Giannantoni A, Kirby M, Orme S et al (2017) A practical approach to the management of nocturia. *Int J Clin Pract* 71(11):e13027
20. Vincent GK, Velkof VA (2010) The next four decades the older population in the United States: 2010 to 2050. *Curr Popul Rep*, P25-1138
21. Kupelian V, Link CL, Hall SA, McKinlay JB (2009) Are racial/ethnic disparities in the prevalence of nocturia due to socioeconomic status? Results of the BACH survey. *J Urol* 181(4):1756–1763

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.