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Nocturia is associated with poor sleep quality among older women in the Study of Osteoporotic Fractures

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Abstract

Objectives—1) To examine relationships between frequency of nocturia and self-reported sleep quality and objective sleep measures in older women and 2) to estimate the amount of variation in sleep measures that is specifically attributable to frequency of nocturia.

Design and Setting—Secondary, cross sectional analysis of the multicenter prospective cohort Study of Osteoporotic Fractures (SOF)

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Participants—Community-dwelling women aged ≥ 80 years

Measurements—Frequency of nocturia in the previous 12 months, Pittsburgh Sleep Quality Index sleep quality subscale, and actigraphy-measured wake after sleep onset (WASO) and total sleep time (TST).

Results—Of 1,520 participants, 25% (N=392) reported their nocturia frequency was 3–4 times/night and an additional 60% (N=917) reported their nocturia frequency was 1–2 times/night. More frequent nocturia was associated with poor sleep quality (3–4/night: 26.8% reported fairly bad or very bad sleep quality; 1–2/night: 14.7%; 0/night: 7.7%; p<.001) and longer WASO (3–4/night: 89.8 minutes; 1–2/night: 70.6; 0/night: 55.5; p<.001). In nested regression models, a nocturia frequency of 3–4/night quadrupled the odds of poor sleep quality (odds ratio: 4.26 [95% CI 1.65, 11.01]; p=.003) and was associated with a 37-minute worsening in WASO (95% CI 26.0, 49.0; p<.001). Frequency of nocturia explained an additional 6% variation in WASO, above and beyond demographic, medical/psychiatric conditions, and medication factors (ΔR^2=.06).

Conclusions—Nocturia is common among octogenarian and nonagenarian women and is independently associated with poor sleep quality and longer wake time at night. Interventions that improve nocturia may be useful in improving sleep quality and wake time at night.

Keywords

nocturia; octogenarians; nonagenarians; sleep quality

INTRODUCTION

Nocturia (defined by the International Continence Society as a complaint that the individual has to wake at night one or more times to void [1]) and sleep disturbance increase in prevalence with age.[2–5] Nocturia at least twice per night occurs in 21% of men and 27% of women ≥ 20 years and nearly half of adults 66 years and older.[6] Sleep disturbance is reported by more than half of older women.[6] Both conditions are associated with negative impact on quality of life and health.[3,7]

Prior studies have examined the relationship between nocturia and sleep disturbance. Nocturia is associated with self-reported short total sleep time in one-fifth of adults.[8] More frequent nocturia is positively associated with actigraphically-measured sleep disruption (overall wakefulness after sleep onset).[9] Nocturia predicts worse self-reported sleep quality.[10] Despite the high prevalence of both conditions, few studies have examined the unique contribution of nocturia frequency to sleep disturbance (i.e., above and beyond demographic and other health conditions known to impact sleep).[11, 12] Few studies have systematically collected both nocturia and sleep outcomes (measured subjectively and objectively) in populations that include octogenarian and nonagenarian women,[10, 13–16] two of the fastest growing cohorts in the United States.

Data characterizing the relationship between nocturia and sleep are needed to support development of treatment programs for these co-occurring conditions. Current clinical practice guidelines typically target treatments for nocturia[17, 18] or sleep disturbance,[19] but

seldom address both conditions together. Determining the relative impact of nocturia on self-reported and objectively measured sleep outcomes can help optimize treatment strategies.

The Study of Osteoporotic Fractures (SOF) includes validated measures of both sleep and self-reported nocturia frequency. Using these robust data, we sought to determine the relative impact of more frequent nocturia (i.e., above and beyond demographic and other health conditions known to impact sleep) on self-reported and objectively measured sleep outcomes among older women.

METHODS

SOF overall study

SOF enrolled 9,704 community-dwelling women aged ≥ 65 years between 1986 and 1988 from sites located in four states. An additional 662 African American women were added between 1996 and 1998. All data were collected according to a common protocol, and data collectors were centrally trained. Women unable to walk without assistance or with bilateral hip replacements at the initial assessment were excluded. Follow-up visits were conducted regularly, including a ninth study visit (in 2006 and 2008) that was conducted 20 years after baseline among the remaining 2,368 participants from three of the original four sites (one site omitted due to logistical site issues). Of the 2,368 participants, 1,534 women participated in a clinic visit interview, and of this subset, 1,520 participants responded to a question about nocturia that was administered during the interview. These data were supplemented with additional data from an ancillary SOF sleep-related study (also performed at the ninth study visit, but only at two of the three sites) that was conducted among participants who were not too frail and who agreed to participate in the ancillary study (N=856). For our secondary, cross-sectional analyses, the analytic sample for bivariate analyses examining the nocturia-subjective sleep quality relationship included all participants with nocturia data (N=1,520), and the analytic sample for bivariate analyses examining the nocturia-objective sleep relationship included the participants with nocturia data and objective sleep data (N=826). The analytic sample for multivariable analyses included complete cases (i.e., participants with complete data for nocturia, subjective sleep, and comorbidity variables; N=673). Institutional Review Boards at each site approved the study. Written informed consent was obtained from each participant.

Conceptual model

Sleep disturbance has many meanings, but is often equated with insomnia (i.e., difficulty falling or staying asleep).[20] As such, we adapted the 3-P model,[21] a framework for chronic insomnia disorder (see Figure 1). This adapted model posits that predisposing and precipitating factors lead to acute sleep disturbance, and perpetuating factors reinforce the poor sleep habits that then lead to chronic sleep disturbance. Sleep disturbance is associated with outcomes such as increased risk of falls[22] and mortality.[7] Non-pharmacological therapies such as cognitive-behavioral therapy for insomnia (CBT-I) act upon those perpetuating factors. For example, sleep restriction, which entails reducing the excessive time-in-bed (a common occurrence in insomnia) thereby improving sleep efficiency, is one of the core components of CBT-I.[23] Because nocturia may both precipitate poor sleep and

perpetuate insomnia (awakenings associated with nocturia may themselves be perpetuating factors), interventions that target nocturia may potentially improve sleep.[24]

Measures

Main predictor—Nocturia: Frequency of nocturia was assessed using an item adapted from other large epidemiologic studies of community-dwelling older women.[25] Participants were asked, "During the past 12 months, on a typical night, how many times do you get up to go to the bathroom to empty your bladder (from the time you go to sleep until you wake up in the morning)?"; response options included 0, 1–2, 3–4, or 5 or more times/night.[1] Relative to participants in the 9th examination who did not provide nocturia data (N = 848), participants with nocturia data (N=1520) were younger (87.6 years vs. 88.8 years, p<.001) more likely to be non-white (12.0% vs. 8.7%, p=.015), and less likely to have a stroke diagnosis (13.2% vs. 19.8%, p<.001), osteoarthritis (43.4% vs. 51.0%, p<.001), Parkinson Disease (1.1% vs. 3.3%, p<.001), or heart failure (12.2% vs. 15.8%, p=.016), but without differences in depression (p=.803), body mass index (p=.688), diabetes (p=.310), atherosclerotic disease (p=.289), chronic lung disease (p=.540), difficulty sleeping due to bad dreams (p=.148), pain (p=.755), or heartburn (p=.121), number of restless legs symptoms (p=.305), or sedating medication or nonprescription sleep aid use (p=.369).

Main outcomes—Self-reported sleep quality: Self-reported sleep quality was assessed with a single item: "During the past month, how would you rate your sleep quality overall" (response options: very good, fairly good, fairly bad, very bad)[26] (this item was not on the same page as the nocturia item in the questionnaire). This item constitutes the sleep quality subscale of the Pittsburgh Sleep Quality Index (PSQI). The total PSQI score was not used in this analysis because the Medication and Daytime Dysfunction subscales have low subscale-total correlations in the SOF sample.[27] In the SOF sample, the sleep quality subscale is correlated with the total PSQI score (r=0.62), which, in turn, is weakly correlated with actigraphically-measured WASO (Spearman's r=0.14, p<.001) and is uncorrelated with TST (Spearman's r=−0.02, p=.34),[27] suggesting that the sleep quality subscale provides somewhat unique information about sleep that is different from actigraphically-measured data. Given the distribution of responses across categories ("very good" [N=446]; "fairly good" [N=810]; "fairly bad" [N=198]; "very bad" [N=57]), we elected to combine the former two and latter two categories in our analyses.

Objective sleep measures: Participants wore wrist actigraphs[28] (SleepWatch-O, Ambulatory Monitoring, Inc, Ardsley, New York) for a minimum of 3 days (median time=3.48 days) and completed sleep diaries. Actigraphy data were sent to the SOF Coordinating Center, where trained staff used the Action W-2 software algorithm and sleep diaries to edit the data. Prior analyses of SOF actigraphy data showed high interscorer reliability.[29] Actigraphy data collected in proportional integration mode (which in the SOF cohort corresponds better to polysomnography[28]) were scored according to the University of California, San Diego scoring algorithm.[30, 31] Mean minutes of sleep in-bed (i.e., total sleep time; TST), mean minutes awake after sleep onset in-bed (i.e., WASO), and mean time-in-bed (TIB) were computed and assessed as objective outcomes. Actigraphy was performed as part of the ancillary sleep-related study (described above).

Covariates—Medical/psychiatric comorbidities that may impact sleep[32]: Participants were asked to respond "yes," "no," or "don't know" to the questions on whether a healthcare provider had ever told them that they had the following conditions: stroke, diabetes, Alzheimer's disease or dementia, heart failure, chronic lung disease, osteoarthritis, Parkinson's disease, myocardial infarction, coronary artery disease, coronary artery disease requiring angioplasty or stenting, and peripheral vascular disease. The number of restless legs syndrome (RLS) symptoms (based upon diagnostic criteria for RLS) endorsed by each participant was summarized in a composite variable (response options for each item: yes, no, don't know; composite variable range 0–4 "yes" responses).[33] Depression was assessed with the 15-item Geriatric Depression Scale.[34] For nightmares, pain, and heartburn, participants were asked whether they had trouble sleeping in the past month due to the condition (response options: not during past month, < 1x/week, 1–2x/week, ≥3x/week).[26]

Sedating medication use: Prescription medications were inventoried at a specified appointment. Participants also completed a questionnaire about the use of specific nonprescription medications. Data from these sources were used to develop a binary composite variable representing use of any of the following medications for sleep: benzodiazepines; antiepileptics; trazodone; tricyclic antidepressants; nonbenzodiazepine, nonbarbituate sedative hypnotic (e.g., eszopiclone); or over the counter sleeping medication. Frequency of medication use was assessed with the Pittsburgh Sleep Quality Index (PSQI) item: "During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?" (response options: Not during the past month, < 1x/week, 1–2x/week, ≥3x/week).[26]

Body mass index (BMI): Body weight (kg) and height (meters) were measured using standard procedures to obtain BMI (kg/m^2).

Statistical analyses

Stata/SE 13.1 (StataCorp, College Station, Texas) was used for all statistical analyses.

Descriptive statistics were used to characterize the sample.

Self-reported sleep—Bivariate analyses using Pearson's chi-squared test examined associations between frequency of nocturia and self-reported poor sleep quality. Multivariable analyses using nested regression (Stata *nestreg* command) examined whether frequency of nocturia significantly added to the model's ability to predict the probability of poor sleep quality. We assessed effect size (odds ratios and predicted margins for self-reported sleep) of the nocturia variable in the full model.

Objectively-measured sleep—Bivariate analyses using one-way analysis of variance (ANOVA) examined relationships between frequency of nocturia and objectively-measured sleep. Multivariable analyses using two nested regressions (Stata *nestreg* command) examined whether frequency of nocturia significantly added to the model's ability to explain the variation in WASO and TST. The degree of improvement in model fit was assessed by the ΔR^2. We assessed effect sizes (B) of the nocturia variable in the full models. In post-hoc

analyses, we examined the nocturia-TIB relationship, using one-way ANOVA and nested regression.

Additional analyses—Tolerance values were > 0.84 except hypnotic use (0.55) and frequency (0.54), which is above the critical threshold of 0.1,[35] suggesting that multicollinearity was minimal. In additional post-hoc analyses, we modeled WASO and poor sleep quality in a subset of participants who did not use sedating medications to assess whether the models' ability to predict the probability of self-reported poor sleep quality and explain the variation in objectively-measured WASO is different when participants who use sedating medications were excluded. Because we noted incomplete data (i.e., defined as >10% of missing values) in 6 variables, we also ran the models without these variables and compared results to the original models. Using *t*-tests, one-way ANOVA, pairwise correlation, Pearson's chi-squared/Fisher's Exact tests, we examined differences in sleep quality, WASO, TST, and TIB for cases without the 6 variables with >10% missing values and those cases with complete data.

RESULTS

Table 1 presents the sample characteristics for all participants with nocturia data (N=1520). Of the participants who had had nocturia data available (N=1,520), 60.3% reported a nocturia frequency of 1–2/night, followed by 25.8% having 3–4/night; with only 13.9% reporting 0/night. No women reported a nocturia frequency of 5 or more/night. Similar nocturia frequency patterns are noted in Table 2 for participants who had both nocturia and actigraphy data available (N=826). Overall, 83.1% of the women self-reported very good or fairly good sleep quality with 16.8% reporting very bad or fairly bad sleep quality. Among the participants who had nocturia data and actigraphy data (N=826), objectively-measured total sleep time (TST) was 426.7 (± 81.9) minutes with an average time of 73.6 (± 47.8) minutes for WASO and 531.4 minutes (± 74.5) for TIB (Table 2). Sample characteristics for subgroups are presented as supplements (Table S1 and S2), and these tables do not suggest consistently meaningful differences in patterns of associations with other variables. Compared to the subsample of participants who did not have usable actigraphy data (N=694), the subsample of participants who had both nocturia data and usable actigraphy data (N=826) was younger (87.4 vs. 87.9 years, p=.003) and less likely to have a stroke diagnosis (11.4% vs. 15.4%, p=.021), but there were no differences in other conditions (see Table S1).

Relationship between nocturia and sleep

Bivariate analyses (Table 2) found that more frequent nocturia was associated with a significantly higher prevalence of self-reported poor sleep quality (N=826). Objectively-measured WASO was approximately 34 minutes longer in women reporting nocturia frequency 3–4/night and 15.1 minutes longer in older women reporting nocturia frequency 1–2/night compared to women reporting no nocturia (N=821; p<.001) (Table 2 and Supplementary figure S4). In post-hoc bivariate analyses, more frequent nocturia was significantly associated with spending more objectively-measured TIB (N=823; 3–4/night: 553.7 [76.0]; 1–2/night: 524.8 [69.6]; 0/night: 517.8 [83.8]; F(2, 823)=13.85, p<.001).

Multivariable analyses conducted among complete cases (Table 3, see Model 1) found that nocturia frequency significantly added to the final model's ability to predict the probability of self-reported poor sleep quality, above and beyond variation explained by other variables in the model (χ^2 (2, 673)=9.84, p=.007). Nocturia frequency 3–4/night was associated with a 4.26 times higher odds of poor sleep quality compared with 0/night (odds ratio [OR] 4.26; 95% CI: 1.65, 11.01, p=.003), and nocturia frequency 1–2/night was associated with a 2.75 higher odds of poor sleep quality compared with 0/night (OR 2.75; 95% CI 1.10, 6.90, p=.031). Predicted probabilities of this model indicate that on average, we would expect 23.0% (95% CI: 17.3, 28.8), 16.8% (95% CI: 13.3, 20.4) and 8.8% (95% CI: 2.8, 14.8) of older women to report poor sleep quality if they have nocturia 3–4, 1–2, or 0 times/night, respectively.

In Model 2 (Table 3), entry of nocturia frequency explained an additional 6% in the variation in objectively-measured WASO (F(2,633)= 22.18, p<.001, $R^{2=}$.147, ΔR^2=.060) compared to a model that did not include nocturia frequency. Nocturia frequency 3–4/night was associated with 37.5 minutes longer WASO (B=37.5; 95% CI: 26.0, 49.0, p<.001) versus 0/night, and nocturia frequency 1–2/night was associated with 18.43 minutes longer WASO (B=18.4; 95% CI: 8.1, 28.7, p<001) than 0/night. In Model 3 (Table 3), however, nocturia frequency was not associated with objectively-measured TST.

In a post-hoc nested regression examining the nocturia-TIB relationship (using the same models as the WASO model), nocturia frequency (final model) increased the model's R^2 by 2.4% (from 0.10 to 0.13). Nocturia frequency 3–4/night was associated with 31.1 additional minutes of objectively-measured TIB compared to 0/night (Model 4; B=31.1; 95% CI: 12.7, 49.4, p=.001), but nocturia frequency 1–2/night was not a predictor of TIB (p=.439).

Models that excluded participants who use sedating medications also showed that nocturia frequency adds to the models' ability to predict the probability of self-reported poor sleep quality (χ^2 (2, 435)=6.51, p=.039) and explains the variation in objectively-measured WASO (F(2,407)=14.06, p<.001, R^2=.164, ΔR^2=.058) (data not shown in tables). Models that excluded variables with >10% missing values yielded similar results (data available upon request).

Some actigraphic variables were associated with conditions that led to selective elimination of cases (because of > 10% of missing data) (Supplemental Table S3); however, this pattern was inconsistent among these objective, actigraphic measures of sleep. Relative to the subset of the SOF population who participated in Visit 9 but who did not have complete data for the multivariate analyses, those individuals with complete data were more likely to be younger, have lower BMI, and less likely to have a diagnosis of Alzheimer's Disease or dementia, heart failure, osteoarthritis, or Parkinson's Disease, and were less likely to be depressed, have trouble sleeping due to pain, have RLS symptoms and use sedating medication (data available upon request).

DISCUSSION

This study found that nocturia, which occurred in an overwhelming majority of older women in our study, contributes to more objectively-measured wake time at night and poor self-reported sleep quality, above and beyond other factors commonly associated with nighttime awakenings and poor sleep quality. The unique contribution of nocturia (i.e., the additional amount of variation in time awake or time in bed explained by nocturia) after accounting for demographics, medical conditions, depression, sedative medication use is modest. However, the magnitude of effect (e.g., the additional 37 minutes of wake-after-sleep-onset among participants with nocturia frequency 3–4/night compared to 0/night) has important clinical meaning. More time awake after sleep onset (mean 74 minutes versus 29 minutes) in older women doubles the odds of placement in an assisted living facility or adult foster home.[36] These results suggest that nocturia is a condition that should be targeted in combination with other conditions to improve sleep in older women.

Although the relationship between nocturia frequency and objectively-measured sleep has been studied in other adult populations, few studies have examined this relationship in individuals age 85 years or older, which is the age group with the highest levels of disability requiring long-term care.[32,37] Our wake time findings are similar to those reported by Zeitzer et al (in a sample with mean age 62 years), where a 34 minute difference in mean wake-after-sleep-onset between voiding 3 times/night versus 0 times/night was found.[9] We did not find an association between frequency of nocturia and objectively-measured total sleep time, in contrast to a study by Yu et al., which found that nocturia frequency was weakly correlated with self-reported total sleep time ($r=0.13$, $p=0.003$).[38] The lack of change in total sleep time despite increase in objective wake-after-sleep-onset may be explained by an increase in time-in-bed and consequent reduction in sleep efficiency (i.e., [total sleep time]/[time-in-bed]), which suggests that women attempt to “make up” for loss of sleep by spending more time in bed, a compensatory strategy that can worsen insomnia.[1, 2, 5, 10, 21, 39–41]

These findings suggest that interventions to improve sleep in older women should address nocturia. The observed increase in time-in-bed at night and worsening of sleep efficiency (data not shown) among women with more frequent nocturia in our study could be targeted with behavioral strategies, especially since older women are more vulnerable to the side effects of drug therapies often used to treat nocturia.[17, 1842] A brief behavioral treatment for chronic insomnia in older adults reduced objectively-measured wake after sleep onset from 57.28 minutes pretreatment to 46.62 minutes posttreatment (Δ−10.65 minutes behavioral treatment versus Δ−1.54 minutes information control; Cohen d=.69).[43] A pilot study of a multicomponent intervention for nocturia in men found that including treatment for sleep disturbance reduces both nocturia episodes and the time to return to sleep after an awakening.[24] An integrated, multicomponent approach to the evaluation and treatment of nocturia could have additive benefits and further improve outcomes related to lower urinary tract symptoms and sleep quality. At the very least, each patient with sleep complaints should be asked about nocturia frequency.

Strengths of this study include the multicenter sample and advanced age of the participants. Limitations include a lack of data on the directionality of the nocturia frequency and the nighttime awakenings (i.e., did awakenings from sleep precede the recognition of the need to void or did the awakenings occur because of the need to void). Data on nocturia frequency were not collected on the same nights that actigraphy data were collected. Recall bias may limit the validity of the nocturia frequency item. The lack of men in the sample and our finding that participants with nocturia and actigraphy data were younger and healthier limit the generalizability of our findings to an older and less healthy population (e.g., older women with a stroke diagnosis). Because the data on the nocturia variable were collected in the context of pre-specified categorical responses (i.e., 0, 1–2, 3–4, 5+) that combined one and two voids per night into a single category, we were unable to analyze our data using a threshold of two voids per night, which is commonly used to define clinically-significant nocturia,[2] thereby limiting comparison of our results with other studies. Our estimates may be biased due to the high percentage of missing data for variables such as sedating medication use, diagnosis of heart disease, and diagnosis of Alzheimer's Disease. In the model predicting poor sleep quality, we observed a wide confidence interval for odds ratio for nocturia frequency 3–4/night, which suggests less certainty about the estimate.

In conclusion, our data suggest that nocturia is common among octogenarian and nonagenarian women and is associated with poor self-reported sleep quality and longer objectively-measured wake time at night. Our findings support the need for sleep intervention studies to include measurement and treatment of nocturia as part of a multicomponent approach to address sleep disturbance in older adults.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Personal Relationship	None

Author Contributions:

Role	Author
Study concept and design	Fung, Vaughan, Markland, Huang, Mitchell, Bliwise, Ancoli-Israel, Redline, Alessi, Stone
Acquisition of subjects and/or data	Ancoli-Israel, Redline, Stone
Analysis and interpretation of data	Fung, Vaughan, Markland, Huang, Mitchell, Bliwise, Ancoli-Israel, Redline, Alessi, Stone
Preparation of manuscript	Fung, Vaughan, Markland, Huang, Mitchell, Bliwise, Ancoli-Israel, Redline, Alessi, Stone

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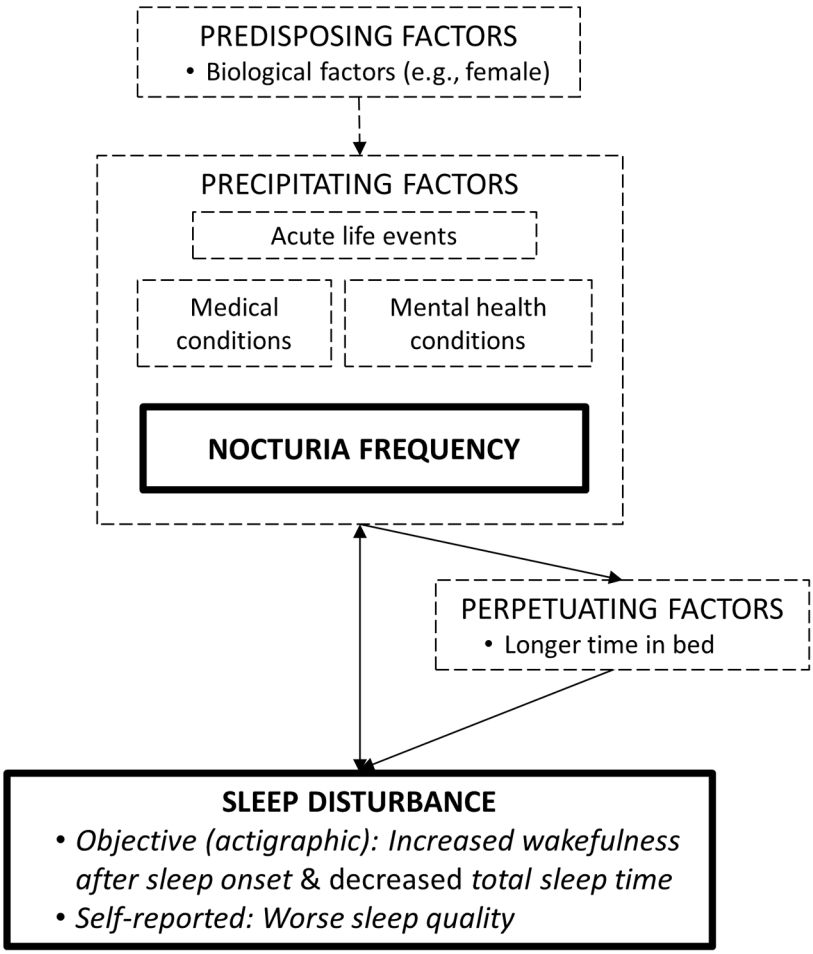

Figure 1.
Conceptual model describing nocturia-sleep disturbance relationship

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Table 1

Sample characteristics for cases with nocturia frequency data (N = 1,520)

		Nocturia frequency				
Variable	**Total % or Mean (SD)**	**0/night % or Mean (SD)**	**1–2/night % or Mean (SD)**	**3–4/night % or Mean (SD)**	**N**	**P value[a]**
Age	87.6 (2.9)	88.1 (3.0)	87.6 (2.9)	87.6 (3.0)	1459[b]	.037
White	88.0	13.6	61.1	25.3	1338	.285
BMI (range 18.4–36.6)	26.2 (3.9)	26.3 (4.0)	26.1(3.9)	26.4 (4.1)	1363	.463
Stroke	13.2	15.0	56.5	28.5	200	.485
Diabetes	15.0	14.1	52.0	33.9	227	.007
Alzheimer disease/dementia	4.3	36.2	60.3	3.5	58	<.001
Atherosclerotic disease[c]	23.1	11.3	60.8	27.8	309	.292
Heart failure/enlarged heart	12.2	17.8	57.3	24.9	185	.236
Chronic lung disease	11.0	10.2	57.8	31.9	166	.100
Osteoarthritis	43.4	13.6	60.4	25.8	657	.180
Parkinson's disease	1.1	33.3	60.0	6.7	15	.040
GDS-15[d] (range 0–13)	2.6 (2.4)	2.5 (2.6)	2.4 (2.3)	3.0 (2.7)	1476	<.001
Bad dreams[e]						.027
Not during past month	83.1	14.7	59.4	25.9	1256	
< 1/week	10.5	5.7	70.4	23.9	159	
1–2/week	4.7	18.3	53.5	28.2	71	
≥3/week	1.7	7.7	61.5	30.8	26	
Pain[e]						.004
Not during past month	64.0	15.6	61.0	23.4	967	
< 1/week	11.2	12.4	63.3	24.3	169	
1–2/week	11.3	11.7	56.1	32.2	171	
≥3/week	13.5	7.8	58.3	33.8	204	
Heartburn[e]						.624
Not during past month	86.4	14.2	59.9	25.9	1306	
< 1/week	8.5	11.6	62.8	25.6	129	
1–2/week	3.5	7.6	69.8	22.6	53	

		Nocturia frequency				
Variable	**Total % or Mean (SD)**	**0/night % or Mean (SD)**	**1–2/night % or Mean (SD)**	**3–4/night % or Mean (SD)**	**N**	**P value[a]**
≥3/week	1.6	16.7	50.0	33.3	24	
Restless legs symptoms (#)						.080
0	73.0	16.1	59.7	24.2	590	
1	0.3	0.0	50.0	50.0	2	
2	2.0	11.8	70.6	17.7	17	
3	5.5	11.4	63.6	25.0	44	
4	19.2	6.5	63.2	30.3	155	
Sedating medication use	30.5	14.3	60.7	25.1	407	.832
Frequency of hypnotic use						.692
Not during past month	72.1	14.2	60.6	25.1	1090	
<1/week	7.8	11.9	61.9	26.3	118	
1–2/week	4.3	7.7	61.5	30.8	65	
≥3/week	15.8	14.7	57.6	27.7	238	

BMI=body mass index.

[a]Pearson’s chi-squared, Fisher’s exact test, or one-way analysis of variance comparing condition-nocturia relationships.

[b]Some participants had missing values for age, because extreme age values were recoded to missing to protect the confidentiality.

[c]Heart attack, coronary artery disease, or myocardial infarction, angioplasty, stent placement, or peripheral artery disease.

[d]GDS=Geriatric Depression Scale-15 with possible range is 0 to 15.

[e]Trouble sleeping in past month due to bad dreams, pain, or heartburn.

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Table 2

Bivariate relationships between nocturia frequency and sleep quality, wake after sleep onset (WASO), total sleep time (TST), and time-in-bed (TIB) for cases with both nocturia frequency and actigraphy data (N=826)

Variable	Total	Void 0/night N(%) or mean (SD)	Void 1–2/night N(%) or mean (SD)	Void 3–4/night N(%) or mean (SD)	χ^2 (df, N) or F(df), p value
Self-reported sleep quality	826	111 (13.4%)	500 (60.5%)	215 (26.0%)	χ^2 (2, 826)=20.2, p<.001
Good (very or fairly good)	690	102 (91.9%)	428 (85.6%)	160 (74.4%)	
Poor (very or fairly bad)	136	9 (8.1%)	72 (14.4%)	55 (25.6%)	
Actigraphy-measured wake after sleep onset (minutes)	824	55.5 (41.7)	70.6 (46.3)	89.8 (49.5)	F(2, 821)=22.4, p<.001
Actigraphy-measured total sleep time (minutes)	825	435.5 (79.8)	423.0 (82.5)	430.5 (81.1)	F(2, 822)=1.38, p=.252
Actigraphy-measured time- in-bed (minutes)	826	517.8 (83.8)	524.8 (69.6)	553.7 (76.0)	F(2,823)= 13.85, p=.024

Table 3

Parameter estimates and significance tests for nested regression models that included nocturia variables (i.e., full models that included covariates[a] and variables for nocturia frequency 1–2/night and 3–4/night for complete cases only; N = 673)

	Model 1: Self-Reported Sleep Quality		Model 2: Objective Wake After Sleep Onset (WASO)			Model 3: Objective Total Sleep Time (TST)			Model 4: Objective Time-in- Bed (TIB)		
Significance tests for overall model	χ^2 (DF)	P value	F (Df)	ΔR^2 [b]	P value	F(Df)	ΔR^2 [b]	P value	F (Df)	ΔR^2 [b]	P value
	9.84 (2)	.007	22.18 (2, 633)	.060	<.001	1.22 (2, 634)	.004	.297	8.68 (2, 635)	.024	<.001
Adjusted parameter estimates	Odds ratio (CI)	P value	B[c]	CI	P value	B[c]	CI	P value	B[c]	CI	P value
Nocturia frequency 1–2/night	2.75 (1.10, 6.90)	.031	18.43	8.12, 28.74	<.001	−14.74	−33.32, 3.84	0.120	6.47	−9.96, 22.91	.439
Nocturia frequency 3–4/night	4.26 (1.65, 11.01)	.003	37.53	26.02, 49.04	<.001	−12.81	−33.56, 7.94	.226	31.1	12.72, 49.43	.001

[a] Age, race, body mass index, dichotomous variables for stroke, diabetes, Alzheimer's disease or dementia, heart failure, chronic lung disease, osteoarthritis, Parkinson's disease, atherosclerotic disease (history of myocardial infarction, coronary artery disease, coronary artery disease requiring angioplasty or stenting, or peripheral vascular disease), polytomous variable for number of restless legs syndrome symptoms and frequency of nightmares, pain, and heartburn, Geriatric Depression Scale was entered as an interval variable, and sedating medication and frequency of use.

[b] Difference in R^2 for full model that contained nocturia frequency variables versus reduced model that did not contain nocturia frequency variables.

[c] Unstandardized regression coefficient

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