

Assessing the burden of nocturia in the workplace: the associations between nocturnal voiding, subjective well-being, work engagement and productivity

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Aims: Nocturia (getting up at night to urinate, where each urination being followed by sleep or intention to sleep) is a bothersome symptom with potentially negative consequences for individual health and daytime functioning. This study assessed the burden of nocturia in the workplace by investigating associations between nocturia and subjective well-being, work engagement and productivity.

Methods: Using large-scale international workplace survey data, the associations between nocturia, subjective well-being (SWB), work engagement (Utrecht Work Engagement Scale, UWES-9) and productivity (Work Productivity and Impairment Index, WPAI) were assessed. Bivariate and multivariate regression analysis was used with adjustment for a large set of confounding factors, including sleep duration and sleep quality.

Results: Across a study sample of 92,129 observations, aged 18 to 70, an average of 10% of the survey population reported ≥ 2 nocturnal voids (generally considered clinically significant nocturia), with prevalence of nocturia increasing with age. Individuals with nocturia reported a 35.7% ($p < 0.001$) higher relative sleep disturbance score and were 10.5 percentage points ($p < 0.001$) more likely to report short sleep. Adjusted for covariates, nocturia was associated with a 3.5% ($p < 0.001$) lower relative SWB score and a 2% ($p < 0.001$) lower relative UWES-9 work engagement score. Nocturia was associated with a 3.9 percentage points ($p < 0.001$) higher work impairment due to absenteeism and presenteeism (WPAI). Adjusting additionally for sleep disturbance and sleep duration reduced the magnitude of the estimated effects, suggesting a key role for poor sleep in explaining the relationship between nocturia and the outcomes (SWB, UWES-9, WPAI) assessed.

Conclusions: A key contribution of this study is the assessment of the association between nocturia and a range of work performance outcomes in a sizeable study using validated instruments to measure work engagement and productivity. The study highlights the importance of taking sleep into account when assessing the relationship between nocturia and associated outcomes.

Keywords: Nocturia, Sleep, WPAI, UWES-9, Subjective Well-being, GLM.

Introduction

Waking up at night to go to the bathroom interrupts sleep. The more frequent the nocturnal voids, the more ‘bothersome’ it becomes for individuals [1]. The International Continence Society (ICS) defines frequent night-time bathroom visits as *nocturia*, a lower urinary tract symptom (LUTS) [2]. Evidence suggests that less than two nocturnal voids are usually not regarded as having clinically significant nocturia that warrants a diagnostic or clinical investigation or treatment [3,4]. In this study, therefore, we use the frequently applied definition of nocturia as the need to urinate at least twice during the night (e.g. [5]).

There are different etiologies of nocturia caused by different factors. Amongst the most common are a large urine volume produced during the night (Nocturnal Polyuria), as well as an overactive bladder (OAB) or benign prostatic obstruction (BPO) [3,6,7]. Nocturia is relatively common, affecting on average up to 20% of the overall population, with prevalence increasing with age [3]. There also tends to be a higher prevalence in young women than young men, which is reversed with older age [3,8].

Nocturia has been associated with adverse health consequences such as increased risk for depression, cardiovascular disease, reduced quality of life, poor sleep, increased mortality risk and – in older individuals – a higher risk of injury through falls [9]. However, often people are reluctant to report nocturia until it becomes unbearable and substantially affecting their

quality of life [10]. Due largely to the complaint of disrupted sleep, the consequences of nocturia extend to the daytime, and specifically the workplace, as well. Nocturia has been associated with daytime fatigue, cognitive impairment and lower workplace productivity, measured through work impairment due to absenteeism and/or presenteeism [8]. However, quantitative analysis linking work performance outcomes and nocturia is very limited.

The objectives of this observational study are, therefore, to assess the associations between nocturia and performance at work, including work engagement, productivity and subjective well-being. While a few studies have quantitatively linked nocturia with productivity and subjective well-being [11,12], the interpretation of their findings is limited due to the inability to consistently control for variables that relate to nocturia and work performance simultaneously. These include, among others, comorbidities, lifestyle factors and sleep. Specifically, the inclusion of sleep as a covariate in the analysis is important given that sleep is known to be associated with nocturia as well as work performance and subjective well-being [13,14]. To address these limitations, we examined nocturia as a factor of workplace performance using large international cross-sectional workplace survey data of working age men and women, and statistically controlling for a host of covariates that may confound associations, including sleep duration and quality.

Methods

Study design

This cross-sectional observational study combined two unique datasets that linked employer-employee data: (i) Vitality UK's *Britain's Healthiest Workplace (BHW) Survey*,¹ covering the

¹ <https://www.rand.org/randeurope/research/projects/britains-healthiest-workplace.html>

United Kingdom, and (ii) AIA's *Asian Healthiest Workplace (AHW) Survey*,² covering Australia, Malaysia, Hong Kong, Thailand, Singapore and Sri Lanka.

Both cross-sectional internet-based workplace surveys were administered by organizations to their workforces. The surveys' goal was to collect information across many aspects of health and well-being, and broadly ask similar sets of question, across the seven different countries. Organizational participation in the surveys was advertised in national newspapers and in networks (e.g. client base of insurance and benefits companies) and was open to most organizations with 20 or more employees. Questionnaires were translated from English into local languages by professional translators local to the countries for which each survey was conducted. To provide a translation closely resembling the original survey instrument, the translators were aware of the concepts the questionnaire intended to measure. For the survey instruments where a validated translation was available (e.g. Work Productivity and Impairment Index, Utrecht Work Engagement Scale, Kessler Psychological Distress Scale), the language-specific instrument was applied.

Organizations, and their employees, voluntarily participated. The surveys support employees to understand their health and well-being via a personalized individual report whilst providing a comprehensive aggregated report to organizations to support their well-being strategies and improvement for productivity. At the level of each participating organization, participation among employees was encouraged through emails, newsletters and direct engagement with human resource (HR) managers. Employees were surveyed with over 100 questions related to demographic factors (e.g. age, gender, education, income), lifestyle behavior (e.g. nutrition, smoking habits, physical activity, sleep behavior), health factors (e.g.

² <https://www.rand.org/randeurope/research/projects/asia-s-healthiest-workplace.html>

mental and physical health indicators, chronic and musculoskeletal conditions), subjective well-being as well as measures including workplace engagement and productivity.

All survey participants provided electronic written consent for anonymized usage of their records for research purposes as required. The data anonymization and usage comply with the General Data Protection Regulation (GDPR). The Ethics Committee at the data collecting organization RAND Europe has reviewed and approved the data collection and research plan. Furthermore, as part of their scientific affiliation with RAND Europe, the University of Cambridge (United Kingdom) reviewed ethical considerations for the BHW survey, and the National University of Malaysia provided ethics approval for the AHW survey.

Study population

In the statistical analysis, for both the BHW and AHW surveys, two annual waves for the years 2017 and 2018 were included with a total number of responses of 93,432. Excluding responses with missing data and pregnant female respondents, the final data sample consisted of 92,179 responses, covering employed individuals aged 18 to 70. Figure S.1 illustrates the criteria for inclusion in the study samples. About 38% of total respondents included were from the AHW survey and 62% from the BHW survey.

The average response rates among employees in participating organizations was between 33% (BHW) and 41% (AHW), which were broadly in-line with response rates for similar type of surveys [15]. The mean respondent age was 35 in AHW and 39 in BHW. Furthermore, about 60% of respondents in the AHW survey were female, compared to 50% in the BHW survey.

Measures and survey instruments

Sociodemographic and general health characteristics

Based on the existing literature on nocturia [3,16,17], and the information available in the AHW and BHW surveys, the analyses included the following sociodemographic variables: age, gender, ethnicity, education, income, irregular working hours (e.g. night shifts), marital status and children (aged ≤ 18) living in the same household. Furthermore included were the following health characteristics: body mass index (BMI), smoking status (current smoker), physical inactivity (performing less than 150 mins per week), excessive salt intake (adding regularly more than a pinch of salt to a meal), excessive alcohol consumption (drinking more than 14 alcohol units of 10 ml/8mg per unit), and comorbid clinically diagnosed health conditions (cancer, asthma, heart disease, kidney disease, diabetes, hypertension). A description of these sociodemographic and health variables is provided in Table S.1.

Mental health was assessed through the Kessler Psychological Distress Scale [18,19]. The six-item scale is a simple measure of psychological distress, involving six questions (each with a five-level response scale from 0 to 4) about different emotional states. In line with previous research, a dichotomous variable was generated taking the value one if the overall Kessler score is above 13, which is generally applied as the threshold of medium to severe psychological distress and anxiety [20].

Nocturia and sleep measures

Focusing on nocturia, the survey questions were based on related medical studies and applied standard scales collected from voiding diaries, sleep diaries, and patient-report outcomes on sleep quality [21-23]. For example, both surveys included a question on the number of times the individual reports waking at night to visit the bathroom (*“How often do you usually get up during the night to go to the bathroom?”*).

Questions regarding sleep quality included self-reported measures drawn from the Pittsburgh Sleep Quality Index (PSQI; [24]): (*“During the last seven days, how would you rate your sleep quality?”*; 0 very poor – 4 very good). This was followed by three additional questions, on a five-point scale (0 not at all – 4 very much) based on the. These assess, during the last seven days, whether: (1) the sleep was refreshing; (2) the individual had a problem with sleep; or (3) had difficulties falling asleep. Each of the four sleep-quality items have been recoded so that higher values represent a lower sleep quality. Following the approach taken in previous research (e.g., [25]), a summary measure of sleep disturbance was created by summing the four items into a single composite score ranging from 0 to 16, with a larger score corresponding to higher sleep disturbance.

As an additional measure for sleep quality, respondents were asked about the first uninterrupted sleep period (FUSP) measured in hours. As nocturnal voiding often occurs within the first two to three hours of sleep onset, potentially negatively affecting stages 3 and 4 of restorative non-rapid eye movement (NREM) sleep, a shorter FUSP is thought to be an indicator of lower quality sleep. In addition, the level of tiredness or fatigue during wake time was assessed on a five-point scale (0 rarely ever – 4 almost every day), with a larger score corresponding to higher levels of fatigue. Lastly, sleep duration was assessed through the average number of hours of sleep per night, which was coded into three binary sleep duration variables (≤ 6 hours; 6 to 9 hours; ≥ 9 hours) measuring short, normal and long sleep duration.

Subjective well-being (SWB)

The AHW and BHW surveys included a question regarding the overall subjective well-being (SWB) of an individual, representing a standard measure applied in numerous studies on SWB [26] (*“How satisfied are you with your life nowadays?”*; 0 not at all – 10 completely). A higher score corresponds to a higher level of SWB.

Utrecht Work Engagement Scale (UWES)

Work engagement was assessed using the short 9-item Utrecht Work Engagement Scale (UWES-9), which includes three dimensions of work engagement: vigor, dedication, and absorption [27]. The nine questions related to the scale were measured on a 7-point Likert scale (0 *never* - 6 *always*). The total 9-item score as indicator for work engagement was used, ranging from 0 to 54, with a larger score corresponding to a larger level of work engagement.

Work Productivity and Activity Impairment (WPAI).

Productivity was assessed using the Work Productivity and Activity Impairment Questionnaire (WPAI). The WPAI is a tool to quantify productivity loss by measuring the effect on work productivity of general health and symptom severity [28]. The instrument consists of six questions with a recall time frame of seven days. The questions asked the respondent about the number of hours missed from work; the number of hours worked; and the degree to which the respondent feels that a health problem has affected productivity while at work and their ability to do daily activities other than work. WPAI outcomes were expressed as impairment percentages, either due to absenteeism or presenteeism or both, where higher percentages indicate greater impairment and lower productivity.

Statistical analysis

Three types of analyses were conducted. First, descriptive analyses were performed on the overall prevalence of clinically significant nocturia (≥ 2 nocturnal voids) across the two sample populations (BHW, AHW) by age and stratified further by gender. Chi-square tests were used to assess significant differences in the prevalence of nocturia within age groups across different sample populations. Furthermore, the prevalence of nocturia across the age distribution was plotted using a semi-parametric local polynomial estimation with Epanechnikov kernel and bandwidth of 5.

Second, we descriptively compared the non-nocturia and nocturia survey populations (0-1 vs. ≥ 2 nocturnal voids) with respect to sociodemographic and health characteristics, sleep quality and sleep duration, as well outcomes of interest (SWB, UWES-9, WPAI). Chi-square tests were used to assess significant differences in categorical variables and Mann-Whitney tests to assess differences in continuous variables.

Third, we used multivariate generalized linear models (GLMs) to assess the difference between outcomes (SWB, UWES-9, WPAI) for individuals with clinically significant nocturia and individuals without clinically relevant nocturia symptoms. All multivariate regression models were adjusted for sociodemographic and health characteristics. We also performed separate regression analyses which additionally adjusted for the sleep disturbance score and dummy variables for short and long sleep duration as additional covariates. We specified a Gaussian distribution, with identity link, in the GLMs for normally distributed outcomes (SWB, UWES-9). Furthermore, we specified a negative binomial distribution with log-link for outcomes with skewed distributions (WPAI). To mitigate the potential issue of employer selection bias into the AHW and BHW surveys, we included company identifier dummy variables in all GLMs and therefore only exploit variation across employees within the different organizations participating. All GLMs further included dummy variables for the week, month and year of the survey response given. For pooled regression analyses, based on the combined BHW and AHW samples, country dummy variables were included. We report Bonferroni corrected adjusted means, differences to the adjusted means across nocturia sub-groups, confidence intervals and p values.

For all analyses statistical significance was assessed at a significance level of 0.05 and all statistical analyses were conducted in STATA 16.

Results

Survey participants and nocturia prevalence

Table 1 reports that across both samples, 9.5% (BHW) and 10.2% (AHW) of respondents report clinically significant nocturia (i.e., ≥ 2 nocturnal voids), but some significant differences are observed within age groups between the samples when stratified by gender. Across most age groups, nocturia prevalence among women tends to be higher than for men and prevalence is increasing with age (Figure 1).

Table 2 reports that individuals with nocturia exhibit lower income and are more likely to work irregular hours. Furthermore, nocturia is associated with obesity, comorbid chronic health conditions (asthma, heart disease, kidney disease, diabetes, hypertension) and higher levels of psychological distress and anxiety.

Bivariate associations between nocturia and sleep

Clinically significant nocturia is positively associated with short and long sleep duration, as well as lower sleep quality (Table 3). On average, individuals reporting two or more nocturnal voids are 10.5 percentage points ($p < 0.001$) more likely to be short sleepers (BHW: 13.2 percentage points; AHW: 5.5 percentage points) and 0.3 percentage points ($p < 0.001$) more likely to be long sleepers (BHW: 0.2 percentage points [$p=0.0287$]; AHW: 0.5 percentage points [$p<0.001$]). The mean sleep disturbance score is 1.5 ($p < 0.001$) higher among individuals with nocturia (BHW: 1.6 [$p<0.001$]; AHW: 1.3 [$p<0.001$]), corresponding to a 35.7% ($= 1.5/4.2$) higher relative sleep disturbance score. The mean reported FUSP is 1 hour ($p < 0.001$) shorter, (BHW: 1.3 hours [$p<0.001$]; AHW: 0.7 hours [$p<0.001$]). Furthermore, individuals with nocturia report on average a 0.2 ($p < 0.001$) higher daytime fatigue score (BHW: 0.3 [$p<0.001$]; AHW: 0.1 [$p<0.001$]), corresponding to a 6.9% ($= 0.2/2.9$) higher relative score.

Nocturia and associated outcomes (SWB, UWES-9, WPAI)

Bivariate associations

Table 4 reports that, without adjusting for covariates, clinically significant nocturia is associated with lower subjective well-being and work engagement and higher levels of work impairment due to absenteeism and/or presenteeism. On average, individuals reporting two or more nocturnal voids report a -0.4 ($p < 0.001$) lower SWB score (BHW: -0.4 [$p < 0.001$]; AHW: -0.2 [$p < 0.001$]) than individuals reporting less nocturnal voids. This corresponds to a 5.8% (= -0.4/6.9) lower relative SWB score. In terms of work engagement, the UWES-9 score is -0.7 lower ($p < 0.001$) among individuals with nocturia (BHW: -1.0 [$p < 0.001$]; AHW: -0.2 [$p = 0.132$]), corresponding to a 2.1% (= -0.7/32.9) lower relative UWES-9 score. Unadjusted for covariates, total work impairment is 5.8 percentage points (pp) ($p < 0.001$) higher for individuals with nocturia (BHW: 5.9 pp [$p < 0.001$]; AHW: 5.4 pp [$p < 0.001$]).

Associations adjusted for socio-demographic and health characteristics, and sleep.

Table 5 reports the associations between nocturia and SWB, UWES-9 and WPAI outcomes adjusted for confounding factors. Adjusted for sociodemographic and health characteristics, the SWB score is on average -0.238 ($p < 0.001$) lower for individuals with nocturia (BHW: -0.243 [$p < 0.001$]; AHW: -0.212 [$p < 0.001$]), corresponding to a -3.5% (= -0.238/6.9) lower relative SWB score. Adjusting additionally for sleep disturbance, short, and long sleep duration reduces the magnitude of the relative difference in the SWB score to -0.031 ($p = 0.103$), rendering it to be statistically insignificant (BHW: -0.036 [$p = 0.140$]; AHW: -0.014 [$p = 0.655$]).

The adjusted UWES-9 score is -0.657 ($p < 0.001$) lower for individuals with nocturia (BHW: -0.636 [$p < 0.001$]; AHW: -0.662 [$p < 0.001$]), which corresponds to about a -2% (= -0.657/32.9) lower relative UWES-9 score. Adjusting additionally for sleep disturbance, short,

and long sleep duration reduces the magnitude of the relative difference in the UWES-9 score to -0.073 ($p=0.448$) (BHW: -0.051 [$p=0.694$]; AHW: -0.092 [$p=0.494$]).

Similar to the findings for the SWB and UWES-9 scores, adjusting for covariates reduces the magnitude of the relative difference in WPAI. Total work impairment due to absenteeism and presenteeism is 3.9 percentage points ($p<0.001$) higher in the pooled sample (BHW: 3.4 percentage points [$p<0.001$]; AHW: 4.3 percentage points [$p<0.01$]) when adjusted for sociodemographic and health characteristics. Adjusting additionally for the sleep disturbance score and the short and long sleep duration dummy variables, the magnitude of the relative difference in total work impairment reduces further to 1.8 percentage points ($p<0.001$) for individuals with nocturia (BHW: 1.6 percentage points [$p<0.001$]; AHW: 1.9 percentage points [$p<0.001$]). Thus, assuming a 35-hour working week, a full-time employed individual with nocturia loses weekly on average about 0.6 ($= 0.018 \times 35$) hours of work more than an individual reporting less than two nocturnal voids.

Distinguishing the associations between nocturia and total work impairment by different age groups reveals that the relative magnitude of the effect is larger for younger individuals than for older individuals with nocturia (Table S.2). For the pooled sample, individuals aged 18 to 30 report on average a 2.8 percentage points ($p < 0.001$) higher total work impairment (BHW: 3 percentage points [$p=0.002$]; AHW: 2.5 percentage points [$p=0.04$]). In contrast, individuals aged 50 to 70 report on average a 0.9 percentage points ($p=0.012$) higher total work impairment than individuals in the same age group without nocturia (BHW: 0.8 percentage points [$p=0.042$]; AHW: 1.3 percentage points [$p=0.062$]).

Discussion

This study directly contributes to the emerging evidence that examines nocturia as a symptom with adverse implications not only for the elderly (e.g. age 65 or above) but with potentially

also negative consequences for young and middle-aged individuals in terms of lower subjective well-being and performance at work. Except for a few studies, such as the Finnish National Nocturia and Overactive Bladder Study [1,17] and the Boston Area Community Health Survey [29], there is limited evidence from population-based studies of all ages and both genders on the effects of nocturia.

To the best of our knowledge, the combined international workplace survey data used in this study represents the largest observational survey data on nocturia in employed non-patient populations. The findings of the study underscore the prevalence and importance of nocturia, and a key contribution is the assessment of the association between nocturia and a range of work performance outcomes using validated instruments to measure work engagement and productivity. The strength of this study is the demonstration that these negative consequences persist even after adjusting for many relevant covariates, highlighting the importance of taking poor sleep into account when assessing the relationship between nocturia and associated outcomes. Especially the calculations of work impairment due to absenteeism and presenteeism are relevant for future calculations of the economic burden of nocturia.

Previous studies assessing the association between nocturia and work impairment using the WPAI instrument reported 8 to 39 percentage points higher relative total work impairment for individuals with clinically significant nocturia compared to individuals without nocturia symptoms [11,12]. However, these studies were limited to very small sample sizes or the inability to adjust the analysis for confounding factors. A novel finding of this study is that nocturia is indeed associated with a statistically significantly higher work impairment due to absenteeism and presenteeism, even after controlling for many sociodemographic and health characteristics, but the estimated magnitude of the associations is substantially lower than previous estimates. For instance, the analyses conducted in this study suggest that after

adjusting for sociodemographic and health characteristics total work impairment for individuals with nocturia is on average 3.9 percentage points larger, with some variation across the two regional data samples (BHW: 3.4 percentage points; AHW: 4.3 percentage points). The relative magnitude of these associations tends to be larger for younger individuals (e.g. aged 18 to 30) than for older individuals (e.g. aged 50 to 70). In addition to the association with work impairment, there is evidence that nocturia is associated with lower subjective well-being (SWB score) and lower work engagement (UWES-9 score).

Another novel aspect of this study is the ability to adjust for poor sleep as confounding factor in the analysis. With the exception of a few studies [8,30], other studies have failed to address the potential confounding factor of sleep, which is critical due to the known association between nocturia and sleep disruption. It is well documented that poor sleep is associated with adverse effects on work performance and subjective well-being [13] and the findings of the multivariate regressions performed in this study indeed suggest that the association between nocturia, well-being and productivity outcomes might be best understood as reflecting the effects of poor sleep. That is, the magnitude of the associations between nocturia, the SWB score, UWES-9 score and work impairment (WPAI) were substantially reduced by adjusting for sleep disturbance and sleep duration in the regression models, suggesting that sleep is a key underlying factor in the relationship between nocturia and the outcome variables examined.

However, the bidirectional relationship between sleep and nocturia cannot be causally established with the nature of the observational cross-sectional data. For instance, disrupted sleep could be caused by other factors such as sleep apnea, which contributes to sleep fragmentation, and has been associated with nocturia episodes and increased urine production [31,32]. Some descriptive evidence has suggested that poor sleep quality could be a predictor of nocturia, but longitudinal data also supports the reverse direction; that nocturnal voiding is strongly predictive of poor sleep quality [33]. Overall, while this study cannot fully tease apart

the directionality of the relationship between nocturia and poor sleep, which is an important area for future research, the empirical evidence presented in this study suggests that poor sleep likely plays a major role for the bidirectional relationship between nocturia and associated outcomes.

Overall, the nocturia prevalence in this non-patient population data corresponds to the population prevalence of two or more nocturnal voids suggested in previous studies [3], with about 10% of the employed population across seven countries in our study sample experiencing the impact of nocturia. Our findings further suggest that the prevalence of nocturia may vary across different geographies, age and gender groups, which should be considered, and adjusted for, when analyzing the potential consequences of nocturia in future research. The descriptive results (Table 2) on the sociodemographic and health characteristics associated with nocturia (e.g., income, irregular working hours, BMI, comorbid chronic health conditions) are in line with a comprehensive review of studies which have looked at correlates for nocturia [16] and is aligned with the recent consensus paper from the ICS on the diagnosis and treatment of nocturia [34].

Limitations

The present survey data and analysis has several strengths, such as the large sample size and comprehensive collection of data on sociodemographic and health characteristics, as well as measures of poor sleep, allowing an in-depth investigation of the association between nocturia and a variety of outcomes. Other strengths are its relevance and geographical scope due to coverage of different regions such as the United Kingdom, Asia and Australia, reflecting diversity and potentially different views on nocturia, sleep, subjective well-being and work performance. However, there are some limitations to the empirical approach.

First, it is important to stress that all data is self-reported. This creates potential for the under-reporting of the real prevalence of certain lifestyle habits – such as smoking or alcohol

consumption – or for overstating others, as physical activity for instance. Furthermore, while efforts have been made to linguistically and culturally adapt the questionnaires when translating them into local languages, it is important to highlight that due to the translation the validity of some of the survey measures used may not be guaranteed.

Second, as we define the nocturia population based on the self-reported frequency of nocturnal bathroom visits, the main variable in the analysis may be subject to inaccuracies since it has not been clinically diagnosed by a health professional and no bladder diary has been used to diagnose nocturia (e.g. as recommended by [2]). Furthermore, the nocturia variable used in the analysis does not allow for a differentiation of possible etiologies of nocturia (e.g. nocturnal polyuria or low bladder capacity, or other conditions where it is present). However, in contrast to nocturia-specific patient surveys, this study focused on the associations between nocturia, poor sleep and outcomes such as subjective well-being, work engagement and productivity, and the survey data covers a broad array of health and workplace topics, and thus would probably not be subject to response bias based on nocturia itself.

Third, SWB is measured using a single question. While this question has been used in many studies to assess the overall life satisfaction of an individual, it is important to highlight that SWB is indeed a complex construct which may not be measured adequately with one single item. Using other SWB tools such as the BBC-SWB scale or the Well-Being Scale (WeBS) would provide a more nuanced analysis on the association between nocturia and SWB.

Fourth, the sleep disturbance summary measure used in the analysis is partly based on validated sleep instruments such as the PSQI and consistent with the Patient-Reported Outcome Measurement Information System (PROMIS) sleep disturbance instruments [35]. However, it is important to highlight that the summary measure itself is not validated and hence the psychometric properties to measure sleep quality are not guaranteed.

Fifth, the response rates are average for organizational surveys conducted online, however, a larger response rate would have been generally beneficial. Furthermore, due to the internet-based data collection, there is a risk that respondents to both surveys were generally younger and more tech-savvy than the patient sample populations in previous nocturia research. It is also important to highlight that this survey data covers only employed individuals and findings of the study may not be directly applied to people currently not in the workforce.

Sixth, when interpreting the results, caution should be applied with regards to causality. Our statistical regression models capture associations and not necessarily causation. Whilst each multivariate regression model adjusts for a large set of covariates, there is a possibility that reverse causality is an issue. For instance, when we examine the association between nocturia and sleep, it is not a priori clear in which direction this relationship holds [33].

Finally, even though the data and the regression analysis include corrections for many potential confounders, we may have overlooked some underlying comorbidities and lifestyle factors.

Conclusion

Given nocturia's potential negative consequences on sleep and daytime functioning, understanding the consequences of nocturia in younger populations, especially those in the working-age is important from a wider societal point of view, as it not only negatively affects individuals' quality of life but potentially also has negative ramifications for their performance at work. The findings of this study emphasize that nocturia is a debilitating symptom that affects a broad age range in the population, including working adults. These findings highlight the considerable individual and societal burden of nocturia, and future research is encouraged to assess the economic burden of the nocturia-related work performance impairment.

Transparency

This study was funded by Ferring Pharmaceuticals.

Declaration of financial/other interest

Fredrik L. Andersson is an employee of International PharmaScience Center, Ferring Pharmaceuticals A/S, Copenhagen, Denmark; Teodor Burtea is an employee of Ferring International Center S.A., Saint-Prex, Switzerland. The other authors declare no financial interest.

Author contributions

MH, FLA, TB, MW, CvS conceptualized the study. MH conducted the statistical analysis. EY and WT advised and reviewed the analysis. All authors reviewed the final manuscript.

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Table 1. Prevalence of clinically significant nocturia (≥ 2 nocturnal voids) by age and gender, without adjustment

Age group	All			Female			Male								
	BHW sample		AHW sample	BHW sample		AHW sample	BHW sample		AHW sample	Significance (1 vs. 2)					
	%	n	%	n	%	n	%	n	%	n	p value				
All ages	9.5	57,631	10.2	34,548	<0.001	10.6	28,193	10.4	20,574	0.486	8.5	29,438	10.0	13,974	<0.001
18-30	6.5	16,483	8.9	12,414	<0.001	7.5	8,724	9.4	7,888	<0.001	5.4	7,759	8.0	4,526	<0.001
31-40	7.5	15,911	10.3	12,354	<0.001	8.5	7,724	10.5	7,253	<0.001	6.6	8,187	10.0	5,101	<0.001
41-50	9.8	14,057	10.0	6,897	0.593	10.7	6,667	9.7	3,904	0.096	8.9	7,390	10.4	2,993	0.018
51-70	16.3	11,180	15.7	2,883	0.444	18.7	5,078	16.1	1,529	0.021	14.4	6,102	15.4	1,354	0.361

Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey.

Note. Chi-square tests were used for comparisons of percentages.

Table 2. Sociodemographic, health and lifestyle characteristics by number of reported nocturnal voids (0-1 vs. ≥ 2), without adjustment.

	BHW sample					AHW sample				
	1. Nocturnal voids: 0-1; N = 52,159		2.Nocturnal voids: ≥ 2 ; N = 5,472		Significance (1 vs. 2)	1. Nocturnal voids: 0-1; N = 31,023		2. Nocturnal voids: ≥ 2 ; N = 3,525		Significance (1 vs. 2)
	%	n	%	n	p values	%	n	%	n	p values
Ethnicity										
White	91.1	47,501	91.4	5,001	0.423	10.6	3,275	10.3	364	0.677
Asian	1.4	712	2.2	118	<0.001	87.0	27,005	86.6	3,053	0.459
Black	4.3	2,229	3.5	193	0.008	0.0	0	0.0	0	
Other	3.3	1,717	2.9	160	0.145	2.4	743	3.1	108	0.015
Education										
Completed primary education	9.4	4,919	15.1	827	<0.001	18.9	5,852	20.1	710	0.066
Completed secondary education	31.5	16,424	37.4	2,049	<0.001	16.0	4,961	16.1	568	0.880
Completed tertiary education	59.1	30,816	47.4	2,596	<0.001	65.1	20,210	63.7	2,247	0.103
Family background										
Child younger than 18	27.1	14,148	22.0	1,204	<0.001	29.1	9,030	29.6	1,042	0.568
Married or cohabitating	65.2	34,000	67.1	3,673	0.004	51.7	16,044	54.6	1,924	<0.001
Income										
Below median income	34.9	18,220	39.8	2,180	<0.001	35.8	11,109	40.9	1,442	<0.001
Job										
Working irregular hours	14.2	7,431	19.6	1,070	<0.001	18.1	5,615	23.5	828	<0.001
BMI										
Normal (BMI ≥ 18.5 to < 25)	46.9	24,447	35.6	1,946	<0.001	54.4	16,864	45.6	1,608	<0.001
Underweight (BMI < 18.5)	1.5	785	1.4	76	0.501	7.0	2,183	5.2	184	<0.001
Overweight (BMI ≥ 25 to < 30)	34.3	17,916	35.4	1,938	0.116	25.5	7,898	28.7	1,010	<0.001
Obese (BMI ≥ 30)	17.3	9,011	27.6	1,513	<0.001	13.1	4,078	20.5	722	<0.001
Smoking status										
Current smoker	10.4	5,400	11.1	609	0.072	9.2	2,867	10.9	384	<0.001
Alcohol use										
Excessive consumption	29.7	15,484	29.9	1,636	0.739	3.4	1,067	4.6	162	<0.001
Physical activity										
Less than 150 mins/week	32.5	16,949	38.6	2,113	<0.001	32.1	9,971	36.9	1,302	<0.001
Nutrition										
Excessive salt intake	4.2	2,202	4.3	236	0.734	17.7	5,505	21.7	764	<0.001
Comorbidities										
Asthma	7.8	4,043	10.9	599	<0.001	5.2	1,610	6.8	239	<0.001
Heart disease	1.1	551	2.8	153	<0.001	1.0	295	2.1	75	<0.001
Kidney disease	0.5	286	1.5	83	<0.001	0.5	169	1.1	40	<0.001
Cancer	0.4	219	1.0	54	<0.001	0.3	95	0.7	23	<0.001

	BHW sample					AHW sample				
	1. Nocturnal voids: 0-1; N = 52,159		2.Nocturnal voids: ≥ 2; N = 5,472		Significance (1 vs. 2)	1. Nocturnal voids: 0-1; N = 31,023		2. Nocturnal voids: ≥ 2; N = 3,525		Significance (1 vs. 2)
	%	n	%	n	p values	%	n	%	n	p values
Diabetes	1.4	717	4.7	255	<0.001	1.9	587	5.0	177	<0.001
Hypertension	4.4	2,295	10.4	568	<0.001	5.3	1,630	11.0	389	<0.001
Psychological distress	6.2	3,214	11.2	614	<0.001	7.2	2,232	10.2	358	<0.001

Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey; BMI, body mass index.

Note. Chi-square tests were used for comparisons of percentages.

Table 3. Bivariate associations between clinically significant nocturia (≥ 2 nocturnal voids) and sleep

	Pooled sample						BHW sample						AHW sample					
	1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)		1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)		1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)	
	Mean	SD	Mean	SD	Mean	p value	Mean	SD	Mean	SD	Mean	p value	Mean	SD	Mean	SD	Mean	p value
Sleep duration																		
≤ 6 hours (%)	33.0	47.0	43.5	49.6	10.5	<0.001	26.4	44.1	39.6	48.9	13.2	<0.001	44.0	49.6	49.5	50.0	5.5	<0.001
> 9 hours (%)	0.6	7.5	0.9	9.4	0.3	<0.001	0.5	7.1	0.7	8.3	0.2	0.0287	0.7	8.2	1.2	10.9	0.5	<0.001
Sleep quality																		
Sleep disturbance (score)	4.2	2.8	5.7	3.1	1.5	<0.001	4.3	2.9	5.9	3.3	1.6	<0.001	4.1	2.7	5.4	2.9	1.3	<0.001
FUSP (hours)	4.4	2	3.4	2	-1.0	<0.001	4.6	1.8	3.3	1.4	-1.3	<0.001	4.2	2.1	3.5	1.7	-0.7	<0.001
Fatigue (score)	2.9	1.1	3.1	1.2	0.2	<0.001	3.0	1.2	3.3	1.2	0.3	<0.001	2.7	1.0	2.8	1.0	0.1	<0.001

Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey; SD, Standard Deviation; FUSP, first unit of uninterrupted sleep period.

Note. Chi-square tests were used for comparisons of categorical variables (percentages) and Mann-Whitney tests for comparisons of continuous variables.

Table 4. Bivariate associations between clinically significant nocturia (≥ 2 nocturnal voids), subjective well-being, work engagement and productivity

	Pooled sample						BHW sample						AHW sample					
	1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)		1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)		1. Nocturnal voids: 0-1		2. Nocturnal voids: ≥ 2		Diff (1 vs. 2)	
	Mean	SD	Mean	SD	Mean	p value	Mean	SD	Mean	SD	Mean	p value	Mean	SD	Mean	SD	Mean	p value
Outcomes																		
SWB (score)	6.9	1.9	6.5	2.1	-0.4	<0.001	7.0	1.8	6.6	2.1	-0.4	<0.001	6.7	2.0	6.5	2.1	-0.2	<0.001
UWES-9 (score)	32.9	8.8	32.2	9.4	-0.7	<0.001	32.3	8.8	31.3	9.5	-1.0	<0.001	33.8	8.8	33.6	9.2	-0.2	0.132
WPAI																		
<i>total (%)</i>	16.9	23.2	22.7	26.5	5.8	<0.001	12.0	19.8	17.9	24.3	5.9	<0.001	25.1	26.0	30.5	27.7	5.4	<0.001
<i>absenteeism (%)</i>	1.5	6.5	2.6	8.6	1.1	<0.001	0.9	5.5	1.8	8.1	0.9	<0.001	2.5	7.8	3.7	9.3	1.3	<0.001
<i>presenteeism (%)</i>	15.4	21.3	20.1	23.9	4.7	<0.001	11.1	18.3	15.8	21.7	4.7	<0.001	22.6	24.0	26.8	25.5	4.2	<0.001

Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey; SD, Standard Deviation; FUSP, first unit of uninterrupted sleep period; SWB, subjective well-being; UWES, Utrecht Work Engagement Score; WPAI, Work Productivity and Activity impairment.

Note. Mann-Whitney tests for comparisons of continuous variables.

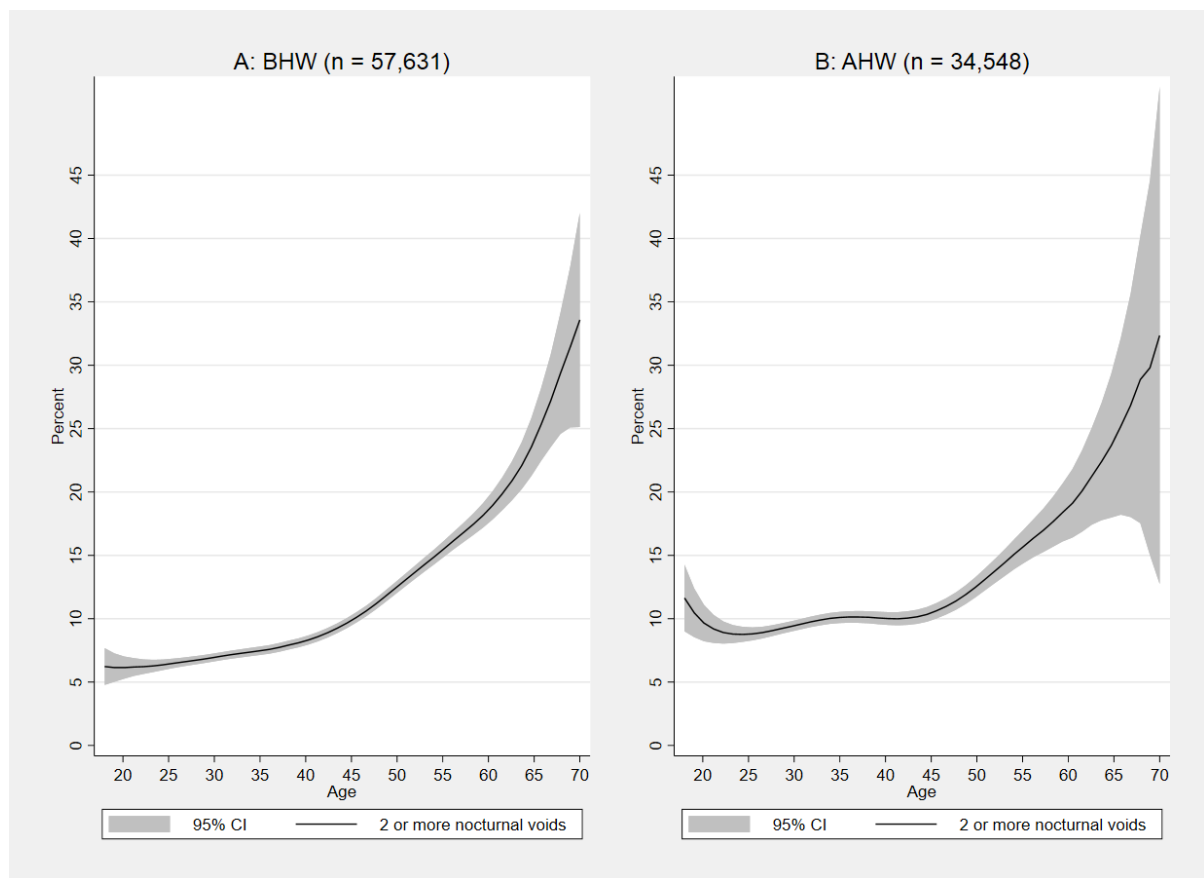
Table 5. Associations between clinically significant nocturia (≥ 2 nocturnal voids) and outcomes (SWB, UWES-9, WPAI), adjusted for sociodemographic and health characteristics and poor sleep

	Pooled sample (n=92,148)			BHW sample (n=57,612)			AHW sample (n=34,536)		
	Coefficient	95% CI	p value	Coefficient	95% CI	p value	Coefficient	95% CI	p value
Outcomes									
SWB (score)									
1. adjusted: demographics and health	-0.238	-0.278 - -0.198	<0.001	-0.243	-0.293 - -0.192	<0.001	-0.212	-0.275 - -0.149	<0.001
2. adjusted: demographics, health and sleep	-0.031	-0.068 - 0.006	0.103	-0.036	-0.083 - 0.012	0.140	-0.014	-0.074 - 0.046	0.655
UWES-9 (score)									
1. adjusted: demographics and health	-0.657	-0.845 - -0.469	<0.001	-0.636	-0.888 - -0.385	<0.001	-0.662	-0.927 - -0.398	<0.001
2. adjusted: demographics, health and sleep	-0.073	-0.115 - 0.261	0.448	-0.051	-0.202 - 0.303	0.694	-0.092	-0.171 - 0.355	0.494
WPAI									
<i>total (%)</i>									
1. adjusted: demographics and health	0.039	0.034 - 0.045	<0.001	0.034	0.028 - 0.040	<0.001	0.043	0.035 - 0.052	<0.001
2. adjusted: demographics, health and sleep	0.018	0.012 - 0.024	<0.001	0.016	0.009 - 0.023	<0.001	0.019	0.011 - 0.028	<0.001
<i>absenteeism (%)</i>									
1. adjusted: demographics and health	0.004	0.003 - 0.006	0.000	0.003	0.002 - 0.005	0.000	0.006	0.004 - 0.008	0.000
2. adjusted: demographics, health and sleep	0.003	0.002 - 0.004	0.000	0.002	0.001 - 0.004	0.000	0.004	0.002 - 0.006	0.000
<i>presenteeism (%)</i>									
1. adjusted: demographics and health	0.032	0.028 - 0.037	0.000	0.028	0.024 - 0.033	0.000	0.035	0.027 - 0.043	0.000
2. adjusted: demographics, health and sleep	0.013	0.008 - 0.017	0.000	0.011	0.007 - 0.016	0.000	0.013	0.005 - 0.021	0.002

Abbreviations. CI, confidence interval; BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey; SWB, subjective well-being; UWES, Utrecht Work Engagement Score; WPAI, Work Productivity and Activity impairment.

Note. Covariates for demographics and health include age, gender, ethnicity, education, income, working irregular hours, marital status, body mass index, smoking status, physical inactivity (less than 150 mins/week), excessive alcohol consumption (more than country-specific recommended amount), excessive salt intake (more than country-specific recommended amount), comorbid asthma, cancer, diabetes, hypertension, kidney disease, psychological distress and anxiety. Covariates for sleep include sleep disturbance score and dummy variable for short sleep. Coefficients for WPAI need to be multiplied by 100 to calculate the percentage point change in work impairment due to absenteeism and/or presenteeism.

Figure 1. Prevalence of clinically significant nocturia (≥ 2 nocturnal voids) stratified by age, without adjustment.



Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey.

Note. Plotted using a semi-parametric local polynomial estimation with Epanechnikov kernel and bandwidth of 5.

Table S.1. Sociodemographic and health characteristics variables (BHW and AHW survey)

Variable	Description
Ethnicity	1. White (1 yes - 0 no); 2. Asian (1 yes - 0 no); 3. Black (1 yes - 0 no); 4. Other (1 yes - 0 no)
Education	1. Completed primary education only (1 yes - 0 no); 2. completed secondary education (1 yes - 0 no); 3. completed tertiary education (1 yes - 0 no).
Income	Below country-specific median income (1 yes - 0 no)
Irregular hours	Working irregular working hours such as night shifts (1 yes - 0 no)
Marital status	1. Married or cohabitating (1 yes - 0 no); 2. other (1 yes - 0 no)
Children	Children under 18 living in the same household (1 yes - 0 no)
BMI	1. BMI < 18.5; (1 yes - 0 no); 2. BMI >25 to 30 (1 yes - 0 no); 3. BMI >30 (1 yes - 0 no); 4. BMI 18.5 to 25 (1 yes - 0 no)
Current smoker	Currently smoking cigarettes (1 yes - 0 no)

Variable	Description
Excessive alcohol consumption	Consumption > 14 units (8mg) per week (1 yes - 0 no)
Physical inactivity	Exercising less than 150 mins per week (1 yes - 0 no)
Excessive salt intake	Salt addition to every meal regularly more than a pinch of salt (1 yes - 0 no)
Asthma	Clinically diagnosed with Asthma within the last 12 months; (1 yes - 0 no)
Cardiovascular disease	Clinically diagnosed with Cardiovascular disease within the last 12 months; (1 yes - 0 no)
Kidney disease	Clinically diagnosed with Kidney disease within the last 12 months; (1 yes - 0 no)
Cancer	Clinically diagnosed with Cancer within the last 12 months; (1 yes - 0 no)
Diabetes	Clinically diagnosed with Diabetes within the last 12 months; (1 yes - 0 no)
Hypertension	Clinically diagnosed with Hypertension within the last 12 months; (1 yes - 0 no)

Abbreviations. BMI, body mass index.

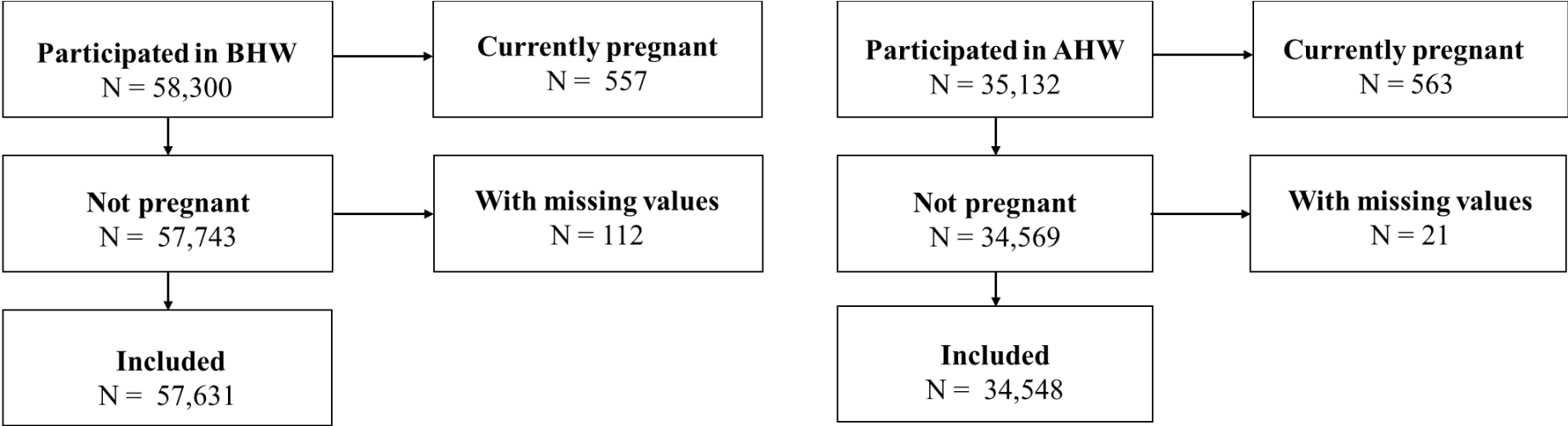
Table S.2. Associations between clinically significant nocturia (≥ 2 nocturnal voids) and total work impairment due to absenteeism and presenteeism (WPAI) adjusted for sociodemographic and health characteristics and poor sleep.

	Pooled sample				BHW sample				AHW sample			
	1. Nocturnal voids: 0-1		2. Difference to ≥ 2 voids		1. Nocturnal voids: 0-1		2. Difference to ≥ 2 voids		1. Nocturnal voids: 0-1		2. Difference to ≥ 2 voids	
	Adj. Mean	95% CI	Adj. Mean	p value	Adj. Mean	95% CI	Adj. Mean	p value	Adj. Mean	95% CI	Adj. Mean	p value
Age group												
18-30	0.186	0.185 - 0.188 n = 28,897	0.028	<0.001	0.128	0.127 - 0.130 n = 16,483	0.030	0.002	0.282	0.280 - 0.283 n = 12,414	0.025	0.004
31-40	0.110	0.109 - 0.111 n = 28,265	0.015	<0.001	0.082	0.081 - 0.083 n = 15,911	0.015	<0.001	0.174	0.172 - 0.175 n = 12,354	0.019	0.025
41-50	0.162	0.161 - 0.163 n = 20,954	0.012	0.014	0.108	0.107 - 0.109 n = 14,057	0.008	0.206	0.243	0.241 - 0.244 n = 6,897	0.018	0.012
50-70	0.081	0.079 - 0.082 n = 14,063	0.009	0.012	0.070	0.069 - 0.072 n = 11,180	0.008	0.042	0.098	0.095 - 0.100 n = 2,883	0.013	0.062

Abbreviations. BHW, Britain's Healthiest Workplace survey; AHW, Asian's Healthiest Workplace survey, WPAI, Work Productivity and Activity impairment.

Note. Mean values adjusted for age, gender, ethnicity, education, income, working irregular hours, marital status, body mass index, smoking status, physical inactivity (less than 150 mins/week), excessive alcohol consumption (more than country-specific recommended amount), excessive salt intake (more than country-specific recommended amount), comorbid asthma, cancer, diabetes, hypertension, kidney disease, psychological distress and anxiety, sleep disturbance score and dummy variable for short sleep. Adjusted means need to be multiplied by 100 to calculate the percentage point change in total work impairment due to absenteeism and presenteeism.

Figure S.1. Inclusion and exclusion criteria for sample populations



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