Abstract

Aim. The objective of this study was to examine whether diabetes-related symptoms (e.g., fatigue, neuropathic pain, diabetes distress, and depressive symptoms) were related to sleep disturbance and sleep-related impairment in adults with type 2 diabetes while controlling for potential covariates.

Background. In people with type 2 diabetes, sleep disturbance and sleep-related impairment are common and likely associated with diabetes-related symptoms. However, limited research has investigated the predictive ability of diabetes-related symptoms on sleep.

Design. A correlational, cross-sectional design was used.

Methods. Data were collected at a large university in the Midwestern United States from September 2013 to March 2014. Multiple linear regression analyses were used to examine the relationship of diabetes-related symptoms (fatigue, neuropathic pain, distress, and depressive symptoms) to sleep disturbance and sleep-related impairment. The instruments included Patient-Reported Outcomes Measurement Information System instruments, Diabetes Symptom Checklist, and Diabetes Distress Scale.

Findings. In this study of adults with type 2 diabetes (n = 90; 52.2% female, mean age 57.4 years), gender, A1C, neuropathic pain, and fatigue were significantly related to sleep disturbance when age, diabetes duration, depressive symptoms, and distress were controlled. Those variables collectively explained 52% of the variation in sleep disturbance. Fatigue was significantly associated with sleep-related impairment when the same covariates were controlled.

Conclusion. Findings suggested that diabetes-related symptoms, including neuropathic pain and fatigue, are strongly related to sleep disturbance and sleep-related impairment in adults with type 2 diabetes, underscoring the need to include detailed assessments of neuropathic pain and fatigue when evaluating sleep.

Keywords: fatigue, neuropathy, nursing, sleep disturbance, sleep-related impairment, symptom, type 2 diabetes

SUMMARY STATEMENT

Why is this research needed?

- Sleep disturbance and sleep-related impairment are pervasive in patients with type 2 diabetes but is under-researched.
- Diabetes-related symptoms (e.g., fatigue, distress, neuropathic pain, and depressive symptoms) are common, and likely affect the sleep in patients with type 2 diabetes.
- Limited research has investigated the predictive ability of diabetes-related symptoms on sleep outcomes in patients with type 2 diabetes.

What are the key findings?

- In addition to female gender, neuropathic pain and fatigue were related to sleep disturbance in patients with type 2 diabetes.
- Fatigue was associated with sleep-related impairment in patients with type 2 diabetes, while controlling for covariates.

How should the findings be used to influence policy/practice/research/education?

- Future research investigating the sleep disturbance and sleep-related impairment should consider the possible confounding effect of neuropathic pain and fatigue, and thus include them in the assessment.
- Clinical nurses should address diabetes-related symptoms, including neuropathic pain and fatigue, in those who have sleep disturbance.
- Nursing education should emphasize the importance of effective neuropathic pain and fatigue management in reducing sleep-related problems.

INTRODUCTION

Diabetes was the seventh leading cause of death (Centers for Disease Control and Prevention, 2017). In 2015, the prevalence of diagnosed diabetes in adults (aged 18 years or older) and children (younger than age 18 years) were 9.3% and 0.18%, respectively. Approximately 95% of all cases of diabetes were type 2 diabetes (T2DM) (Centers for Disease Control and Prevention, 2017). By 2030, there will be an over 20% increase in numbers of adults with diabetes; multiple physiological and behavioral factors are considered candidates for being responsible for this increase (Shaw, Sicree, & Zimmet, 2010), among which sleep may play a role (Knutson, Spiegel, Penev, & Van Cauter, 2007). Growing evidence suggests that sleep disturbance is a risk factor for T2DM (Anothaisintawee, Reutrakul, Van Cauter, & Thakkinstian, 2016; Barone & Menna-Barreto, 2011; Reutrakul & Van Cauter, 2014; Shan *et al*., 2015). In people with established T2DM, sleep disturbance is common; prevalence estimates range from 42% to 76.8% (Gupta & Wang, 2016; Nasseri, Malek, Aghili, Valojerdi, & Khamseh, 2015; Nefs *et al*., 2015). Sleep disturbance may be related to glycemic control (Lee, Ng, & Chin, 2017; Zhu, Hershberger, Kapella, & Fritschi, 2017). Similarly, sleep-related impairment (SRI) may impair daytime functioning essential for diabetes self-care; this could result in poor glycemic control (Knutson, Ryden, Mander, & Van Cauter, 2006; Trento *et al*., 2008; Tsai *et al*., 2012). Despite the high prevalence of sleep disturbance and the adverse consequences of SRI, little is known about the specific etiological factors for them in adults with T2DM.

Background

Sleep is a fundamental human need but has been under-researched in people with T2DM. Sleep disturbance is individuals' subjective perceptions of their sleep quality and related sleep problems. Sleep-related impairment (SRI) is another important but distinct construct, defined as individuals' perceptions of functional impairments during wakefulness associated with sleep problems (PROMIS, 2017a). Individual sleep requirements and characteristics change across the lifespan and vary in relationship to age, gender, and physical activity (PA) levels. Age has been associated with sleep measured objectively and subjectively (Dillon *et al*., 2014; Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Ramtahal *et al*., 2015). Gender differences in sleep outcomes are common; women report more sleep disturbance than men (Arber, Bote, & Meadows, 2009; Smagula, Stone, Fabio, & Cauley, 2016). Women with T2DM have a higher risk for sleep disturbance (Gupta & Wang, 2016). A bidirectional association has been suggested between PA and sleep; habitual PA may reduce sleep disturbance (Sherrill, Kotchou, & Quan, 1998), while sleep restriction may decrease the amount and intensity of PA (Bromley, Booth III, Kilkus, Imperial, & Penev, 2012). Additionally, greater daily PA is associated temporally with less sleep time; and prior-day sleep quality can affect next-day PA (Lambiase, Gabriel, Kuller, & Matthews, 2013). A recent meta-analysis also demonstrated a beneficial effect of regular PA on sleep (Kredlow, Capozzoli, Hearon, Calkins, & Otto, 2015).

Diabetes-related symptoms are common (e.g., fatigue, neuropathic pain, diabetes distress, and depressive symptoms). For instance, the prevalence of distress and depressive symptoms in people with T2DM was 36% (Perrin, Davies, Robertson, Snoek, & Khunti, 2017) and 56.1%

(Sun et al., 2016), respectively. Those symptoms are typically self-reported. Self-reported symptoms are the patients' interpretation of physical and psychological indicators of their health, and subjective symptom assessments are commonly used when objective measures are unavailable (Patrick, Guyatt, & Acquadro, 2008). Importantly, clinical outcome measures (e.g., laboratory tests) have minimal immediate relevance to the daily functioning of patients with chronic diseases, including diabetes. Patients' self-reported perceptions of changes in symptoms may be an additional method for evaluating treatment effectiveness (Cella *et al.*, 2010). Diabetes-related symptoms likely affect sleep in people with diabetes. Although a prior study (Gupta & Wang, 2016) has investigated factors related to sleep disorders in adults with T2DM, little is known regarding the predictive ability of self-reported diabetes-related symptoms on sleep outcomes.

THE STUDY

Aim

The aim of this study was to examine whether diabetes-related symptoms (i.e., fatigue, neuropathic pain, diabetes distress, and depressive symptoms) were related to sleep disturbance and SRI in adults with T2DM while controlling for potential covariates (i.e., age, gender, and PA).

Design

This was a secondary analysis using a correlational, cross-sectional design.

Participants

The primary study examined temporal associations among real-time PA, glucose levels, and fatigue in adults with T2DM. A total of 91 adults aged 45 years or over with T2DM for

greater than one year were recruited by convenience sampling. Exclusion criteria were conditions limiting their ability to perform a 6-minute walk test; fibromyalgia; kidney disease; and current cancer therapy or not out of remission for at least one year.

Data collection

Participants were recruited through online postings, flyers, and word of mouth. Data were collected at a large urban university in the Midwestern United States from September 2013 to March 2014. The primary study consisted of three visits, and baseline data used in this study were collected at the first visit.

Ethical considerations

The study was approved by the University of Illinois at Chicago Institutional Review Board. Potential participants were given a detailed explanation of the study by the research team and then given time to read through the consent and ask questions. Written, informed consent was obtained from those who agreed to participate prior to data collection. Participants were informed of their right to withdraw at any phase of the study and given copies of the signed consent form.

Data analysis

Stata 13.0 (StataCorp LP, College Station, Texas) was used for statistical analysis. Prior to data analysis, missing data and assumptions underlying different statistical analyses were checked. Descriptive statistics [n (%) or $\bar{x}$ (SD)] were examined. Independent *t*-tests were used to compare differences between two groups. Pearson correlation analyses were conducted to examine the bivariate relationships between continuous variables (e.g., diabetes-related symptoms and sleep parameters). Pairwise deletion was used due to the small

number of missing data (< 1%), and multiple regression models were run. The outcome variables were (1) sleep disturbance and (2) SRI. The explanatory variables were biobehavioral factors (age, gender, A1C, and diabetes duration) and diabetes-related symptoms (neuropathic pain, fatigue, diabetes distress, and depressive symptoms). The final regression models were based on the literature and bivariate correlations. Preliminary analysis indicated one case as an outlier, and it was excluded from the analysis. Thus, the final analysis included data from 90 participants.

Validity and reliability

Biobehavioral factors

Age, gender, and diabetes duration were assessed using a questionnaire developed by the investigators. Height and weight were measured using a wall-mounted stadiometer and upright, balanced scale. Waist circumference was measured using a non-elastic tape measure using established protocols (McArdle, Katch, & Katch, 2001). The index of central obesity (ICO) was used to quantify central obesity. The ICO is the ratio of waist circumference to height and provides an additional measure of central obesity rather than waist circumference alone (Parikh, Joshi, Menon, & Shah, 2007). Habitual PA was measured using the Stanford Brief Activity Survey (SBAS). The SBAS is composed of two items that evaluate habitual PA at work and during leisure time throughout the day during the past year. The SBAS can be used to classify adults into five PA intensity categories: inactive, light, moderate, hard, and very hard (Taylor-Piliae et al., 2006). The SBAS was tested among 1,010 adults with various conditions (e.g., hypertension, diabetes, and obesity). SBAS classification at moderate or greater intensity had a sensitivity of 0.73 and specificity of 0.61 to detect national PA

recommendations of 150 min/week of moderate or greater intensity activity using Physical Activity Recall minutes (Taylor-Piliae et al., 2006). Adequate test-retest reliability of the SBAS in healthy older adults was also reported (Taylor-Piliae et al., 2010).

Glycemic control

A1C was measured using the A1CNow+™ (Bayer Healthcare, Indianapolis, IN). The A1CNow+™ is a point-of-care analyzer that requires only 5 μL of whole blood and can provide results within five minutes. A1CNow+™ is National Glycohemoglobin Standardization Program-certified and has been widely used as a substitute for high-performance liquid chromatography, due to its high efficiency and portability. Results obtained from the A1CNow+™ have been found equivalent to laboratory-based methods (Bode, Irvin, Pierce, Allen, & Clark, 2007).

Self-reported sleep, fatigue, and depressive symptoms

We used the Patient-Reported Outcomes Measurement Information System (PROMIS) to measure self-reported sleep, fatigue, and depressive symptoms (Cella *et al*., 2007). In this study, the computerized adaptive testing (CAT) version for each symptom was used. Use of CAT allows for more precise estimates of each person's score for each domain and usually includes four to seven items. Participants respond to one item per tablet computer screen, and selection of the next item is guided by the previous response. Measurement precision is calculated for each unique location along the continuum of a domain. Thus, the subject burden is low, and high measurement precision is achieved because each participant responds to only a small set of individually tailored items. PROMIS measures are reported as

standardized *t* scores, with a mean of 50 and standard deviation of 10 that references the U.S. population. A higher score indicates more of the measured symptom (PROMIS, 2017b).

Sleep

The sleep item bank in PROMIS assesses sleep disturbance and SRI. Sleep disturbance evaluates one's perceived difficulties in getting to sleep or staying asleep, as well as perceptions of the adequacy of sleep. It does not provide subjective estimates of sleep quantities (i.e., sleep duration, time to fall asleep, and the amount of wakefulness during sleep). Sleep-related impairment measures perceptions of alertness, sleepiness, and tiredness during waking hours and perceived functional impairment related to sleep problems. The PROMIS sleep measures have demonstrated higher measurement precision compared with commonly used sleep instruments (Yu *et al*., 2012). The validity of the instrument is supported by significant correlation with SF-36 measures (Nerenz *et al*., 2011).

Fatigue and depressive symptoms

Fatigue and depressive symptoms over the past seven days were evaluated using PROMIS. The fatigue item bank assesses the experience of self-reported symptoms of fatigue (frequency, duration, and intensity), ranging from mild subjective feelings of tiredness to an overwhelming sense of exhaustion. The physical, mental, and social impact of fatigue is also captured by PROMIS. The depression item bank assesses self-reported negative mood, views of self, social cognition, as well as decreased positive affect and engagement (e.g., loss of interest, meaning, and purpose). In a study of 143 patients with systemic sclerosis, construct validity of each CAT-administered PROMIS item bank was supported by high correlations between PROMIS domains and respective legacy measures (r = 0.61-0.82) (Khanna *et al*.,

2012). In another validation study conducted in clinic patients, PROMIS measures (including fatigue and depressive symptoms) were highly correlated with the SF-36, supporting the validity of PROMIS measures (Nerenz *et al*., 2011).

Neuropathic pain

Neuropathic pain was evaluated using the polyneuropathic pain subscale (four items) of the Diabetes Symptom Checklist-Revised (DSC-R) (Grootenhuis, Snoek, Heine, & Bouter, 1994). DSC-R consists of 34 items that measure both the occurrence and perceived burden of physical/psychological symptoms related to T2DM over the past month. The DSC-R includes eight subscales that measure the following domains: hyperglycemic, hypoglycemic, cardiovascular, polyneuropathic sensory, polyneuropathic pain, psychological fatigue, psychological/cognitive, and ophthalmologic. Each item is scored on a 5-point Likert scale from 1 = *not at all* to 5 = *extremely*. The domain score is the sum of the items within that domain; the sum of all eight domain scores results in the total score. A higher score indicates greater symptom burden. In a study consisting of more than 4,000 patients with T2DM, the overall Cronbach's α was 0.94, and the Cronbach's α for the subscale of neuropathic pain was 0.76 (Arbuckle *et al*., 2009). The respective Cronbach's αs for the overall scale and neuropathic pain subscale in this study were 0.95 and 0.83, supporting its reliability.

Diabetes distress

Diabetes distress was measured using the Diabetes Distress Scale (DDS) (Polonsky *et al*., 2005). The DDS is a self-administered scale consisting of 17 items. It measures four domains of diabetes-related emotional distress over the past month: emotional burden, physician-related distress, regimen-related distress, and diabetes-related intrapersonal distress.

Each item is rated on a 6-point Likert scale. The raw scores are transformed to a 0-to-100 scale. A higher score indicates greater distress. In a study of 683 people with diabetes (Polonsky *et al*., 2005), the Cronbach's αs for the total scale and subscales were over 0.87, indicating adequate internal consistency reliability. A significant relationship between DDS score and depression score provided evidence for its validity. The Cronbach's α of the DDS in this study was 0.94, supporting its reliability.

RESULTS

Participant characteristics

The participants were middle-aged to older adults aged 57.4 (8.0) years and most were women (52%). The mean duration of diabetes was 8.6 (7.1) years. The participants' mean A1C level was 7.8% and ranged from 5.0% to 13.0%, suggesting excellent to poor control. Regarding PA, 42.2% engaged in moderate or greater intensity activity. Overall, the standardized *t* scores for symptoms measured by the PROMIS bank (i.e., sleep, fatigue, and depressive symptoms) were about 50, comparable to the general U.S. population (Table 1).

Relationships among sleep, diabetes-related symptoms, and baseline characteristics

Results from independent *t*-tests suggested that women had more sleep disturbance and SRI than did men. The mean sleep disturbance scores for women and men were 54.1 and 48.8 (t = -2.9, $P < 0.01$); the mean SRI scores for women and men were 54.2 and 50.2 (t = -2.1, $P < 0.05$). People with different PA level (i.e., inactive or light intensity vs. moderate or greater intensity) did not differ in sleep disturbance and SRI ($P > 0.05$). Pearson correlation analyses indicated that age, ICO, A1C, and diabetes duration were unrelated to sleep disturbance and SRI. Depressive symptoms and neuropathic pain were positively associated with sleep

disturbance and SRI (Table 2). Additionally, there were modest associations between fatigue and sleep disturbance (r = 0.56, P < 0.01) and fatigue and SRI (r = 67, P < 0.01).

Variables related to sleep

Results of the final regression models are shown in Table 3. In the first model, 52% of the variation in sleep disturbance was collectively explained by the eight variables (F = 10.67, P < 0.001). Gender, A1C, fatigue, and neuropathic pain were significantly related to sleep disturbance. Female gender (β = 0.18, P = 0.04); fatigue (β = 0.31, P < 0.01); and neuropathic pain (β = 0.37, P < 0.01) were positively related to sleep disturbance; while A1C was negatively related to sleep disturbance (β = -0.19, P = 0.04). Similarly, 52% of the variation in SRI was collectively explained by the eight factors (F = 10.60, P < 0.001). However, only fatigue was significantly associated with SRI (β = 0.52, P < 0.01).

DISCUSSION

The aim of this study was to examine whether diabetes-related symptoms were related to sleep disturbance and SRI in people with T2DM. Although studies have been conducted exploring factors related to sleep in the general population, this study was among the first that addressed the associations between diabetes-related symptoms and sleep in adults with T2DM. Findings suggested that being female, neuropathic pain, and fatigue were related to sleep disturbance, even after controlling for covariates such as age, diabetes duration, depressive symptoms, and distress. Similarly, higher fatigue was associated with more SRI.

Our bivariate analyses indicated that gender, fatigue, diabetes distress, depressive symptoms, and neuropathic pain were significantly related to both sleep disturbance and SRI. It can be argued that the similar correlation patterns may be due to the high correlation

between sleep disturbance and SRI (r = 0.72). However, sleep disturbance and SRI are distinct constructs, which was further confirmed by close examination of the regression models. In the regression model for sleep disturbance, we found that female gender, more neuropathic pain, lower A1C, and higher fatigue were significantly related to more sleep disturbance. In the model for SRI, only fatigue was a significant factor.

Consistent with the literature, our findings supported that females experienced more sleep disturbance than their male counterparts. In a study where sleep disturbance in people with T2DM was measured by the Pittsburgh Sleep Quality Index (PSQI), sleep disturbance was related to being female (OR = 2.72, 95% 1.42-5.20) (Nefs *et al*., 2015). In another study, females were at a higher risk for sleep disturbance (OR = 1.72, $P < 0.05$) (Gupta & Wang, 2016). In our analysis, being female was related to a 3.27-unit increase (regression coefficient = 3.27) in the sleep disturbance score measured by PROMIS. Also, we found that pain was significantly related to sleep disturbance in adults with T2DM, consistent with the findings in Lamond *et al*.'s study (Lamond, Tiggemann, & Dawson, 2000): pain was positively related to both sleep onset and maintenance problems, which are the main characteristics of sleep disturbance (r = 0.40 and 0.33, $P < 0.01$). Our analysis further illustrated the strength of neuropathic pain in predicting sleep disturbance: a one-unit increase in neuropathic pain score was related to a 3.07-unit increase (regression coefficient = 3.07) in sleep disturbance. In the bivariate analysis, A1C was not related to sleep disturbance; however, it was negatively related to sleep disturbance in the regression model. Further examination indicated that A1C was positively related to gender (r = 0.27, P = 0.01) and neuropathic pain (r = 0.38, $P < 0.01$), which suggests that interactions between A1C and gender or neuropathic pain might explain

the spurious significance of A1C in the regression model. Notably, the statistical significance might not be clinically significant (i.e., a 1% increase in A1C was related to a 0.81-unit decrease in sleep disturbance measured on a 100-point scale).

Studies examining the relationship between sleep disturbance and A1C have been inconsistent. In one study (Nefs *et al*., 2015), A1C was not related to sleep disturbance as measured by the PSQI while controlling covariates. In other studies (Knutson *et al*., 2006; Knutson, Van Cauter, Zee, Liu, & Lauderdale, 2011; Mahmood *et al*., 2013; Osonoi *et al*., 2015), sleep quality was related to A1C or fasting glucose in the bivariate analysis; however, the relationship became non-significant after adjusting for covariates (e.g., age, gender, and complications). Surprisingly, in our study, the association between fatigue and sleep disturbance was moderate ($r = 0.56$); a one-unit increase in fatigue was associated with a 0.35-unit increase in sleep disturbance, after controlling for covariates. Although the causality between sleep disturbance and fatigue is unclear, the evidence is emerging supporting the significant relationship, particularly in people with cancer (Carpenter *et al*., 2004; Ho, Rohan, Parent, Tager, & McKinley, 2015). Limited research has examined the relationship between sleep disturbance and fatigue in people with T2DM. Sleep disturbance assessed by PSQI has been positively related to fatigue ($r = 0.58$, $P = 0.002$) (Cuellar & Ratcliffe, 2008), which is consistent with our findings. In one study (Nefs *et al.*, 2015), T2DM patients with poor sleep quality (PSQI > 5) reported more fatigue; however, fatigue was not significantly related to sleep after controlling for covariates.

Although diabetes distress and depressive symptoms were related to sleep disturbance in the bivariate correlation analyses, the associations became non-significant in the regression

model. In this analysis, neuropathic pain was significantly related to diabetes distress (r = 0.34) and depression (r = 0.34). These moderate correlations indicate that neuropathic pain may have confounded the correlations between sleep and psychological factors, including depressive symptoms and diabetes distress. Indeed, one study showed that the significant association between sleep quality and diabetes distress became non-significant after controlling for covariates (Nefs *et al.*, 2015). Similarly, in another study, the relationship between diabetes severity and sleep disturbance was almost entirely mediated by pain and nocturia rather than psychological factors such as emotional adjustment (Lamond *et al.*, 2000). In geriatric patients with T2DM (Öztürk *et al.*, 2015), neuropathy was related to poor sleep quality (OR = 1.36, 95% CI 0.03-2.69) and depression (OR = 2.91, 95% CI 0.61-5.21), further supporting the potential confounding effect of neuropathic pain.

In the regression model for SRI, only fatigue was significantly associated with SRI after controlling for covariates. A one-unit increase in fatigue was related to a 0.57-unit increase in SRI. In this model, neuropathic pain was not significant. SRI evaluates perceived functional impairment related to sleep problems during wake time, rather than impairment during sleep. Although pain could disturb nocturnal sleep, it may not exert a significant impact on daytime functional impairment. The significance might be due to the high correlation between sleep disturbance and SRI, which suggests that these two constructs overlapped and shared same variances. It is also possible that sleep disturbance mediated the relationship between fatigue and SRI. Studies evaluating the relationship between SRI and fatigue are limited, so there are no specific data to which we can refer.

Limitations

In the present study, we found significant information on the relationship between diabetes-related symptoms and sleep in adults with T2DM. Nevertheless, findings need to be interpreted in the context of limitations. This report is a secondary analysis of data from a cross-sectional study. Thus, causality cannot be determined, especially in the relationship between fatigue and sleep. The sample size was not determined *a priori*. It is possible that the sample size was not large enough to capture the relationships between variables of interest. Depressive symptoms, fatigue, sleep disturbance, and SRI might be interrelated. A path analysis would better elucidate their relationships. However, the small sample size precluded us from gaining more insight into the moderating and mediating effects. Additionally, we only recruited participants aged 45 or over, so the generalizability of our findings is limited to this population. Data of primary constructs were self-reported, particularly sleep measures, which could introduce recall bias. An objective measure of sleep, such as the use of actigraphy, would provide a different perspective regarding the relationship between diabetes-related symptoms and sleep in T2DM. Although we controlled several covariates in the regression analyses, it is possible that we have missed some confounding variables (e.g., daytime sleepiness), which need to be explored in future studies.

CONCLUSION

Building upon previous studies, we contributed to current knowledge about the relationship between diabetes-related symptoms and sleep. We found that, in addition to female gender, higher levels of fatigue and neuropathic pain strongly related to more sleep disturbance in adults with T2DM. Fatigue was also associated with SRI when controlling for covariates.

In light of the study limitations, more research is needed to determine the causality between sleep and fatigue. Future studies using a more representative sample should be designed to increase the generalizability of the findings to a wider population. Objective measures of sleep (e.g., actigraphy) are becoming more feasible and can provide sleep measures including total sleep time and time spent awake after sleep onset. A combination of objective and subjective sleep measures is needed in future research to provide a richer delineation of sleep problems and related factors in people with T2DM.

The findings have important nursing implications. According to the most recent American Diabetes Guidelines(American Diabetes Association, 2017), sleep assessment should be included in all medical evaluations of patients with diabetes. Thus, in clinical practice, nurses should pay extra attention to females when conducting sleep-related assessments. A comprehensive sleep evaluation should also include diabetes-related symptoms such as neuropathic pain and fatigue. Nursing education for patients with diabetes should emphasize the importance of effective neuropathic pain management in order for the sleep disturbance to be prevented or ameliorated. Fatigue in itself is a complex and debilitating symptom. Clinical nurses are recommended to learn methods for fatigue management so that the sleep problems could be improved. Evidence indicates that aerobic-resistance exercise can significantly decrease fatigue (Tomas-Carus *et al*., 2016). Therefore, nurses may encourage the patients to engage in regular physical activity to reduce their fatigue.

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References

American Diabetes Association. (2017). Comprehensive medical evaluation and assessment of comorbidities. In Standards of Medical Care in Diabetes - 2017. *Diabetes Care, 40 (Suppl. 1)*, S25-S43. doi: 10.2337/dc17-S006

Anothaisintawee, T., Reutrakul, S., Van Cauter, E., & Thakkinstian, A. (2016). Sleep disturbances compared to traditional risk factors for diabetes development: Systematic review and meta-analysis. *Sleep Medicine Reviews, 30*, 11-24. doi: 10.1016/j.smrv.2015.10.002

Arber, S., Bote, M., & Meadows, R. (2009). Gender and socio-economic patterning of self-reported sleep problems in Britain. *Social Science & Medicine, 68*(2), 281-289. doi: 10.1016/j.socscimed.2008.10.016

Arbuckle, R. A., Humphrey, L., Vardeva, K., Arondekar, B., Danten-Viala MSc, M., Scott, J. A., & Snoek, F. J. (2009). Psychometric evaluation of the Diabetes Symptom Checklist-Revised (DSC-R): A measure of symptom distress. *Value in Health, 12*(8), 1168-1175. doi: 10.1111/j.1524-4733.2009.00571.x

Barone, M. T., & Menna-Barreto, L. (2011). Diabetes and sleep: A complex cause-and-effect relationship. *Diabetes Research and Clinical Practice, 91*(2), 129-137. doi: 10.1016/j.diabres.2010.07.011

Bode, B. W., Irvin, B. R., Pierce, J. A., Allen, M., & Clark, A. L. (2007). Advances in hemoglobin A1c point of care technology. *Journal of Diabetes Science and Technology, 1*(3), 405-411. doi: 10.1177/193229680700100314

Bromley, L. E., Booth III, J. N., Kilkus, J. M., Imperial, J. G., & Penev, P. D. (2012). Sleep restriction decreases the physical activity of adults at risk for type 2 diabetes. *Sleep, 35*(7), 977-984. doi: 10.5665/sleep.1964

Carpenter, J. S., Elam, J. L., Ridner, S. H., Carney, P. H., Cherry, G. J., & Cucullu, H. L. (2004). Sleep, fatigue, and depressive symptoms in breast cancer survivors and matched healthy women experiencing hot flashes. *Oncology Nursing Forum, 31*(3), 591-598. doi: 10.1188/04.ONF.591-598

Cella, D., Riley, W., Stone, A., Rothrock, N., Reeve, B., Yount, S., . . . Choi, S. E. (2010). The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. *Journal of Clinical Epidemiology, 63*(11), 1179-1194. doi: 10.1016/j.jclinepi.2010.04.011

Cella, D., Yount, S., Rothrock, N., Gershon, R., Cook, K., Reeve, B., . . . Rose, M. (2007). The Patient-Reported Outcomes Measurement Information System (PROMIS): Progress of an NIH Roadmap cooperative group during its first two years. *Medical Care, 45*(5 Suppl 1), S3-11. doi: 10.1097/01.mlr.0000258615.42478.55

Centers for Disease Control and Prevention. (2017). National Diabetes Statistics Report, 2017 (Vol. 2016). Atlanta, GA: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services.

Cuellar, N. G., & Ratcliffe, S. J. (2008). A comparison of glycemic control, sleep, fatigue, and depression in type 2 diabetes with and without restless legs syndrome. *Journal of Clinical Sleep Medicine, 4*(1), 50-56.

Dillon, H. R., Lichstein, K. L., Dautovich, N. D., Taylor, D. J., Riedel, B. W., & Bush, A. J. (2014). Variability in self-reported normal sleep across the adult age span. *The Journals of Gerontology Series B, 70*(1), 46-56. doi: 10.1093/geronb/gbu035

Grootenhuis, P. A., Snoek, F. J., Heine, R. J., & Bouter, L. M. (1994). Development of a type 2 diabetes symptom checklist: A measure of symptom severity. *Diabetic Medicine, 11*(3), 253-261.

Gupta, S., & Wang, Z. (2016). Predictors of sleep disorders among patients with type 2 diabetes mellitus. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 10*(4), 213-220. doi: 10.1016/j.dsx.2016.06.009

Ho, S.-Y., Rohan, K. J., Parent, J., Tager, F. A., & McKinley, P. S. (2015). A longitudinal study of depression, fatigue, and sleep disturbances as a symptom cluster in women with breast cancer. *Journal of Pain and Symptom Management, 49*(4), 707-715. doi: 10.1016/j.jpainsymman.2014.09.009

Khanna, D., Maranian, P., Rothrock, N., Cella, D., Gershon, R., Khanna, P. P., . . . Bechtel, A. (2012). Feasibility and construct validity of PROMIS and “legacy” instruments in an academic scleroderma clinic. *Value in Health, 15*(1), 128-134. doi: 10.1016/j.jval.2011.08.006

Knutson, K. L., Ryden, A. M., Mander, B. A., & Van Cauter, E. (2006). Role of sleep duration and quality in the risk and severity of type 2 diabetes mellitus. *Archives of Internal Medicine, 166*(16), 1768-1774. doi: 10.1001/archinte.166.16.1768

Knutson, K. L., Spiegel, K., Penev, P., & Van Cauter, E. (2007). The metabolic consequences of sleep deprivation. *Sleep Medicine Reviews, 11*(3), 163-178. doi: 10.1016/j.smrv.2007.01.002

Knutson, K. L., Van Cauter, E., Zee, P., Liu, K., & Lauderdale, D. S. (2011). Cross-sectional associations between measures of sleep and markers of glucose metabolism among subjects with and without diabetes: The Coronary Artery Risk Development in Young Adults (CARDIA) Sleep Study. *Diabetes Care, 34*(5), 1171-1176. doi: 10.2337/dc10-1962

Kredlow, M. A., Capozzoli, M. C., Hearon, B. A., Calkins, A. W., & Otto, M. W. (2015). The effects of physical activity on sleep: A meta-analytic review. *Journal of Behavioral Medicine, 38*(3), 427-449.

Lambiase, M. J., Gabriel, K. P., Kuller, L. H., & Matthews, K. A. (2013). Temporal relationships between physical activity and sleep in older women. *Medicine and Science in Sports and Exercise, 45*(12), 2362-2368. doi: 10.1249/MSS.0b013e31829e4cea

Lamond, N., Tiggemann, M., & Dawson, D. (2000). Factors predicting sleep disruption in Type 2 diabetes. *Sleep, 23*(3), 415-416.

Lee, S. W., Ng, K. Y., & Chin, W. K. (2017). The impact of sleep amount and sleep quality on glycemic control in type 2 diabetes: A systematic review and meta-analysis. *Sleep Medicine Reviews, 31*, 91-101. doi: 10.1016/j.smrv.2016.02.001

Mahmood, W. A. W., Yusoff, M. S. D., Behan, L. A., Di Perna, A., Tun, T. K., McDermott, J., & Sreenan, S. (2013). Association between sleep disruption and levels of lipids in

Caucasians with type 2 diabetes. *International Journal of Endocrinology, 2013*, 1-8. doi: 10.1155/2013/341506

McArdle, W. D., Katch, F. I., & Katch, V. L. (2001). Body composition assessment. In W. D. McArdle, F. I. Katch & V. L. Katch (Eds.), *Exercise Physiology* (pp. 752-793). Philadelphia: Lippincott, Williams, and Wilkins.

Nasseri, R., Malek, M., Aghili, R., Valojerdi, A. E., & Khamseh, M. E. (2015). Disturbed sleep in type 2 diabetes mellitus independent of chronic complications, pain, and nocturia. *International Journal of Diabetes in Developing Countries, 35*(4), 454-459. doi: 10.1007/s13410-015-0314-3

Nefs, G., Donga, E., van Someren, E., Bot, M., Speight, J., & Pouwer, F. (2015). Subjective sleep impairment in adults with type 1 or type 2 diabetes: Results from Diabetes MILES—The Netherlands. *Diabetes Res Clin Pract, 109*(3), 466-475. doi: 10.1016/j.diabres.2015.07.008

Nerenz, D. R., Pietrantoni, L., Schultz, L., Obeid, L., Swartz, A., Rubinfeld, I., & Velanovich, V. (2011). PSU24: Agreement between PROMIS depression, sleep disturbance, and fatigue CAT measures and SF-36 scores in a clinical cohort. *Value Health, 14*(3), A90. doi: 10.1016/j.jval.2011.02.506

Ohayon, M. M , Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. *Sleep, 27*(7), 1255-1274. doi: 10.1093/sleep/27.7.1255

Osonoi, Y., Mita, T., Osonoi, T., Saito, M., Tamasawa, A., Nakayama, S., . . . Watada, H. (2015). Poor sleep quality is associated with increased arterial stiffness in Japanese patients with type 2 diabetes mellitus. *BMC Endocrine Disorders, 15*(29), 1-7. doi: 10.1186/s12902-015-0026-1

Öztürk, Z. A., Yesil, Y., Kuyumcu, M. E., Savas, E., Uygun, Ö., Sayıner, Z. A., & Kepekçi, Y. (2015). Association of depression and sleep quality with complications of type 2 diabetes in geriatric patients. *Aging Clinical and Experimental Research, 27*(4), 533-538. doi: 10.1007/s40520-014-0293-0

Parikh, R. M., Joshi, S. R., Menon, P. S., & Shah, N. S. (2007). Index of Central Obesity: A novel parameter. *Medical Hypotheses, 68*(6), 1272-1275. doi: 10.1016/j.mehy.2006.10.038

Patrick, D., Guyatt, G. H., & Acquadro, C. (2008). Patient-reported outcomes. In J. P. T. Higgins & S. Green (Eds.), *Cochrane handbook for systematic reviews of interventions* (1 ed., pp. 531-545). Hoboken, NJ: John Wiley & Sons Inc.

Perrin, N. E., Davies, M. J., Robertson, N., Snoek, F. J., & Khunti, K. (2017). The prevalence of diabetes - specific emotional distress in people with type 2 diabetes: A systematic review and met - analysis. *Diabetic Medicine*. doi: 10.1111/dme.13448

Polonsky, William H, Fisher, Lawrence, Earles, Jay, Dudl, R James, Lees, Joel, Mullan, Joseph, & Jackson, Richard A. (2005). Assessing psychosocial distress in diabetes development of the Diabetes Distress Scale. *Diabetes Care, 28*(3), 626-631.

PROMIS. (2017a). Intro to PROMIS: List of adult measures. Retrieved from http://www.healthmeasures.net/explore-measurement-systems/promis/intro-to-promis/list-of-adult-measures

PROMIS. (2017b). Patient Reported Outcomes Measurement Information System: Score & interpret. Retrieved from http://www.healthmeasures.net/score-and-interpret/about-healthmeasures-scores

Ramtahal, R., Khan, C., Maharaj-Khan, K., Nallamothu, S., Hinds, A., Dhanoo, A., . . . Lazo, M. (2015). Prevalence of self-reported sleep duration and sleep habits in type 2 diabetes patients in South Trinidad. *Journal of Epidemiology and Global Health, 5*(4), S35-S43. doi: 10.1016/j.jegh.2015.05.003

Reutrakul, S., & Van Cauter, E. (2014). Interactions between sleep, circadian function, and glucose metabolism: Implications for risk and severity of diabetes. *Annals of the New York Academy of Sciences, 1311*(1), 151-173. doi: 10.1111/nyas.12355

Shan, Z., Ma, H., Xie, M., Yan, P., Guo, Y., Bao, W., . . . Liu, Li. (2015). Sleep duration and risk of type 2 diabetes: A meta-analysis of prospective studies. *Diabetes Care, 38*(3), 529-537. doi: 10.2337/dc14-2073

Shaw, J. E., Sicree, R. A., & Zimmet, P. Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice, 87*(1), 4-14. doi: 10.1016/j.diabres.2009.10.007

Sherrill, D. L., Kotchou, K., & Quan, S. F. (1998). Association of physical activity and human sleep disorders. *Archives of Internal Medicine, 158*(17), 1894-1898. doi: 10.1001/archinte.158.17.1894

Smagula, S. F., Stone, K. L., Fabio, A., & Cauley, J. A. (2016). Risk factors for sleep disturbances in older adults: Evidence from prospective studies. *Sleep Medicine Reviews, 25*, 21-30. doi: 10.1016/j.smrv.2015.01.003

Sun, N., Lou, P., Shang, Y., Zhang, P., Wang, J., Chang, G., & Shi, C. (2016). Prevalence and determinants of depressive and anxiety symptoms in adults with type 2 diabetes in China: A cross-sectional study. *BMJ Open, 6*(8), e012540. doi: 10.1136/bmjopen-2016-012540

Taylor-Piliae, R. E., Norton, L. C., Haskell, W. L., Mahbouda, M. H., Fair, J. M., Iribarren, C., . . . Fortmann, S. P. (2006). Validation of a new brief physical activity survey among men and women aged 60–69 years. *American Journal of Epidemiology, 164*(6), 598-606. doi: 10.1093/aje/kwj248

Taylor-Piliae, R. E., Fair, J. M., Haskell, W. L., Varady, A. N., Iribarren, C., Hlatky, M. A., . . . Fortmann, S. R. (2010). Validation of the Stanford Brief Activity Survey: examining psychological factors and physical activity levels in older adults. *Journal of Physical Activity & Health, 7*(1), 87-84. doi: 10.1123/jpah.7.1.87

Tomas-Carus, P., Ortega-Alonso, A., Pietilainen, K. H., Santos, V., Gonçalves, H., Ramos, J., & Raimundo, A. (2016). A randomized controlled trial on the effects of combined aerobic-resistance exercise on muscle strength and fatigue, glycemic control and health-related quality of life of type 2 diabetes patients. *The Journal of Sports Medicine and Physical Fitness, 56*(5), 572-578.

Trento, M., Broglio, F., Riganti, F., Basile, M., Borgo, E., Kucich, C., . . . Porta, M. (2008). Sleep abnormalities in type 2 diabetes may be associated with glycemic control. *Acta Diabetologica, 45*(4), 225-229. doi: 10.1007/s00592-008-0047-6

Tsai, Y. W., Kann, N. H., Tung, T. H., Chao, Y. J., Lin, C. J., Chang, K. C., . . . Chen, J. Y. (2012). Impact of subjective sleep quality on glycemic control in type 2 diabetes mellitus. *Family Practice, 29*(1), 30-35. doi: 10.1093/fampra/cmr041

Yu, L., Buysse, D. J., Germain, A., Moul, D. E., Stover, A., Dodds, N. E., . . . Pilkonis, P. A. (2012). Development of short forms from the PROMIS sleep disturbance and sleep-related impairment item banks. *Behavioral Sleep Medicine, 10*(1), 6-24. doi: 10.1080/15402002.2012.636266

Zhu, B., Hershberger, P. E., Kapella, M. C., & Fritschi, C. (2017). The relationship between sleep disturbance and glycemic control in adults with type 2 diabetes: An integrative review. *Journal of Clinical Nursing*. doi: 10.1111/jocn.13899