Sleep Disturbance and Physical Activity in Chronic Obstructive Pulmonary Disease

BY

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Mary C. Kapella, Chair and Advisor Eileen G. Collins, Biobehavioral Health Science Laurie Quinn, Biobehavioral Health Science Ulf Bronas, Biobehavioral Health Science Chang G. Park, Health System Science Craig Horswill, Kinesiology and Nutrition This dissertation is dedicated to my family.

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LIST OF ABBREVIATIONS

| AIC | Akaike's Information Criterion |
|---------|--|
| ATS | American Thoracic Society |
| ATS-DLD | American Thoracic Society-Division of Lung Disease |
| BIC | Schwarz's Bayesian Criterion |
| CAT | Computerized Adaptive Testing |
| CBT-I | Cognitive behavioral therapy for insomnia |
| COPD | Chronic obstructive pulmonary disease |
| COPD-ED | COPD education |
| СРМ | Counts Per Minute |
| CRQ-D | Chronic Respiratory Questionnaire-Dyspnea |
| CRQ-F | Chronic Respiratory Questionnaire-Fatigue |
| FEV | Forced expiratory volume |
| FEV1% | Percentage of forced expiratory volume in 1 second |
| GOLD | Global Initiative for Chronic Obstructive Lung Disease |
| HADS | Hospital Anxiety and Depression Scale |
| IRB | Institutional Review Board |
| MET | Metabolic Equivalent for task |
| NA | Number of Awakening |
| OSA | Obstructive Sleep Apnea |
| PA | Physical activity |
| PFT | Pulmonary function tests |
| PSG | Polysomnography |

LIST OF ABBREVIATIONS (continued)

- PSQI Pittsburgh Sleep Quality Index
- RCT Randomized control trial
- SaO2 Oxygen saturation
- SD Standard deviations
- SE Sleep efficiency
- SII Sleep impairment index
- SL Sleep onset latency
- TST Total sleep time
- WASO Wake after sleep onset

SUMMARY

A study of sleep disturbance and physical activity in chronic obstructive pulmonary disease (COPD) was carried out using secondary analysis with a repeated-measure, quantitative design. The aims of this study were to identify distinct sleep patterns (sleep trajectories) over 1 week and examine impacts of sleep disturbance on next-day physical activity in people with COPD. To meet the study aims, data for 56 COPD patients with disturbed sleep were drawn from the baseline dataset of an ongoing randomized control trial (RCT) examining the efficacy of cognitive behavioral therapy for insomnia (CBT-I) and COPD education (COPD-ED) programs for people with COPD. Sleep and physical activity were measured using an accelerometer (Actiwatch-2, Philips Respironics, Murrysville, PA) over 5 days, and data cleaning for these variables was performed in adherence to professional guidelines.

In this study, participants showed worse sleep quality than the norm for healthy individuals. Two trajectories characterized each sleep variable examined, including sleep onset latency (SL), total sleep time (TST), wake after sleep onset (WASO), number of awakenings (NA), and sleep efficiency (SE). These trajectories were significantly related to self-efficacy for sleep, current smoker status, and subjective sleep disturbance.

Regarding relationships between weekly physical activity and the sleep variables, greater physical activity was related to less SL, lower NA, and less TST. Also, sleep variables had varying influences on next-day physical activity. For example, greater NA during sleep and long TST negatively influenced physical activity during the morning, and longer SL and low SE negatively influenced physical activity during the evening.

These findings provide evidence supporting the potential value of effective sleep management to promote physical activity in people with COPD.

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I. INTRODUCTION

A. Background

Around the world, Chronic obstructive pulmonary disease (COPD) has been found to increasingly cause morbidity and mortality worldwide. Currently COPD is the fourth-leading cause of death in the world (Lozano et al., 2012), and the World Health Organization has estimated that it will be the third-leading cause of death by 2020. More than 3 million people died of COPD in 2012, accounting for 6% of all deaths worldwide. Many people suffer from this disease for years and die prematurely as a result of the condition and its complications. In the United States, COPD affects 5% to 10% of the adult population (Mannino & Buist, 2007) and is already the third-leading cause of death (Xu, Murphy, Kochanek, & Bastian, 2016). COPD is a preventable and treatable disease state characterized by airflow limitation and persistent respiratory symptoms due to airway and/or alveolar abnormalities, usually caused by exposure to noxious gases or particles (Global Initiative for Chronic Obstructive Lung Disease (GOLD)., 2017). Patients with COPD commonly experience respiratory symptoms, including dyspnea, chronic cough, sputum production, and wheezing.

Physical activity in patients with COPD is important for promoting and maintaining optimal health. However, levels of physical activity in COPD patients are significantly lower than those of healthy individuals of the same age and gender (Pitta et al., 2005; Troosters et al., 2010). In addition, reduced physical activity in COPD patients has been found to lead to negative outcomes such as increased risk of hospitalization (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Katajisto, Koskela, Lindqvist, Kilpelainen, & Laitinen, 2015; Moy, Teylan, Weston, Gagnon, & Garshick, 2013), reduced quality of life (Esteban et al., 2010; Gimeno-Santos et al., 2014; Jehn et al., 2012), and increased mortality (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Loprinzi & Walker, 2016). For these reasons, physical activity is a crucial consideration for the COPD population. Substantial research on physical activity in patients with COPD has been published recently. In these studies, age and gender were shown to be the strongest determinants for physical activity (Gimeno-Santos et al., 2014), and other determinants included history of smoking and clinical characteristics such as pulmonary function, hyperinflation, dyspnea, and fatigue (Garcia-Aymerich et al., 2009; Gimeno-Santos et al., 2014; Park, Richardson, Holleman, & Larson, 2013; Tödt, Skargren, Jakobsson, Theander, & Unosson, 2015; Yu, Frei, Ter Riet, & Puhan, 2016). However, few studies have examined sleep as a determinant or correlate of physical activity in COPD patients (Hartman, Boezen, de Greef, & Ten Hacken, 2013; Parwanta, Chan-Thim, & Pepin, 2016; Spina et al., 2017). Moreover, those studies' results have been inconsistent. Thus, more research is needed to fully understand the relationship between sleep and physical activity.

Sleep disturbance, which is variously defined as waking during sleep, abnormal sleep onset or duration (Agusti et al., 2011), and poor sleep quality (Jen, Li, Owens, & Malhotra, 2016; Omachi et al., 2012), has been shown to be more severe in COPD patients than in healthy individual. More than 60% of the COPD population suffers from sleep disturbance, which has been associated with negative health outcomes such as COPD exacerbation, more emergency room visits, and increased mortality (Geiger-Brown et al., 2015; Omachi et al., 2012). Various factors have been identified as correlates of sleep disturbance in the COPD population, such as medication use, disease severity, mood, and respiratory symptoms (Budhiraja, Siddiqi, & Quan, 2015; Hartman, Prinzen, van Lummel, & Ten Hacken, 2015; McNicholas, Verbraecken, & Marin, 2013; Nunes et al., 2013; Omachi et al., 2012). Most studies have measured sleep on a single occasion using subjective self-administered questionnaires, and even when researchers have measured sleep objectively over several days, the data were summarized as population averages. Thus, it is difficult to identify longitudinal changes in sleep patterns in the COPD population and their association with other characteristics of COPD patients. Objective observation of night-to-night sleep in COPD patients over time is needed to better understand actual sleep patterns in this population and the potential benefits of sleep management.

Review of the literature revealed that longitudinal changes in sleep patterns in the COPD population have not been explored and that investigation of temporal relationships between sleep and physical activity is necessary to fully understand those relationships. Thus, the present study pursued this investigation with the long-term goal of contributing to more effective interventions for sleep management, which could be an innovative strategy for promoting physical activity in patients with COPD.

B. Research Framework and Aims of Study

The theory of unpleasant symptoms served as the conceptual framework for this study. The theory has three major concepts: influencing factors, symptoms, and performance (Lenz, Suppe, Gift, Pugh, & Miligan, 1995; Lenz, Pugh, Milligan, Gift, & Suppe, 1997). Influencing factors are those that affect the nature of the symptoms and include physiologic, psychologic, and situational factors. Symptoms consist of an individual's experiences that are "red flags" of threats to health, and performance is the impact of the symptoms on an individual's performance ability. For this study, sleep disturbance was a symptom component, and physical activity was a performance component. Dyspnea as respiratory symptom and fatigue were included as symptom components. Figure 1 provides an overview of the study's research framework.

The study had two specific aims. Aim 1 was to determine the impact of sleep disturbance on next-day physical activity in COPD patients. The hypotheses for aim 1 were as follows: (a) levels of next-day total physical activity will be negatively associated with disturbed sleep, and (b) levels of next-day hourly physical activity will be negatively associated with disturbed sleep. To identify these relationships, other symptoms such as dyspnea and fatigue were controlled for. Aim 2 was to identify distinct longitudinal sleep patterns over 1 week in COPD patients with coexisting disturbed sleep and to examine differences in participant characteristics between distinct sleep patterns will be identified for each sleep variable over 1 week, and (b) significant differences in participant characteristics will be observed between distinct sleep patterns.



Figure 1. Overview of Conceptual Schema

C. Overview of the Chapters

Chapter I serves as an introduction to the areas of interest, research framework, and specific aims of the study. The results of the study are provided as Chapters II and III and are formatted as manuscripts for submittal to peer-reviewed journals. In view of this fact, abbreviations and acronyms are defined at their first occurrence in each chapter. Chapter II, titled "Impact of Sleep Disturbance on Next-Day Physical Activity in Chronic Obstructive Pulmonary Disease," provides the results for Aim 1. This chapter examines the relationship between night-time sleep and next-day daily and hourly physical activity using mixed-effect analysis while controlling for influencing factors (age, gender, pulmonary function dyspnea, and fatigue). Chapter 3, titled "Sleep Patterns in Patients with Chronic Obstructive Pulmonary Disease," provides the results for Aim 2. This chapter identifies distinct sleep patterns in study participants over 1 week using trajectory analysis and examines differences in participant characteristics according to distinct sleep trajectories.

Appendix A presents the rationale for choosing a covariance structure matrix for the mixedeffect analysis discussed in Chapter II, and Appendix B contains the Institutional Review Board approval for the study. The principal investigator's curriculum vitae appears at the end of this dissertation.

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II. IMPACT OF SLEEP DISTURBANCE ON NEXT-DAY PHYSICAL ACTIVITY IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE

A. Introduction

Chronic obstructive pulmonary disease (COPD) is a highly prevalent chronic respiratory disease and the third-leading cause of death in the United States (Xu et al., 2016). The progressive chronic airflow limitation associated with COPD commonly has multiple extrapulmonary effects and comorbidities that are associated with physical inactivity (Watz et al., 2014). Physical activity levels in patients with COPD are remarkably lower than those of healthy individuals (Pitta et al., 2005; Troosters et al., 2010); moreover, in COPD patients, lower physical activity is recognized as a strong predictor for negative health outcomes such as hospitalization (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Katajisto et al., 2015; Moy et al., 2013) and mortality (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Loprinzi & Walker, 2016). For these reasons, there is growing interest in the determinants of physical activity (Gimeno-Santos et al., 2014; Watz et al., 2014; Yu et al., 2016) in the COPD population and in strategies to increase COPD patients' participation in physical activity (Watz et al., 2014). In previous research involving patients with COPD, low physical activity has been related to general demographic and clinical characteristics (Garcia-Aymerich et al., 2009; Gimeno-Santos et al., 2014; Park et al., 2013; Tödt et al., 2015; Yu et al., 2016), but few studies have examined the impact of sleep on physical activity in this population (Hartman et al., 2013; Parwanta et al., 2016).

More than 60% of the COPD population suffer from sleep disturbances defined as waking during sleep, abnormal sleep onset or duration (Agusti et al., 2011), and poor sleep quality (Jen

et al., 2016; Omachi et al., 2012). Sleep disturbance in this population is known to be related to negative health outcomes such as exacerbation (Geiger-Brown et al., 2015; Omachi et al., 2012) and mortality (Agusti et al., 2011; Omachi et al., 2012). Even normal physiological responses during sleep that do not adversely affect healthy individuals can result in significant respiratory problems in COPD patients, and disturbed sleep impedes the restorative functions of the physiological process and thus poses serious personal and public health consequences (Redeker & McEnany, 2011).

Examining relationships between physical activity and sleep in COPD patients is important because physical inactivity and sleep disturbance rates are higher in this population than in healthy individuals, and both conditions are related to exacerbation and mortality. In addition, although several previous research studies have been conducted to identify relationships between physical activity and sleep, their results were inconsistent, and no study has focused on individuals with COPD and co-existing disturbed sleep.

B. Literature Review

1. Physical Activity in COPD Population

Physical activity in patients with COPD is important for promoting and maintaining optimal health, and reduced physical activity has been found to lead to negative outcomes such as increased risk of hospitalization (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Katajisto et al., 2015; Moy et al., 2013), reduced quality of life (Esteban et al., 2010; Gimeno-Santos et al., 2014; Jehn et al., 2012), and increased mortality (Garcia-Rio et al., 2012; Gimeno-Santos et al., 2014; Loprinzi & Walker, 2016). Also, several studies have found that levels of physical activity in patients with COPD are significantly lower than those of healthy individuals of the same age and gender (Pitta et al., 2005; Troosters et al., 2010). For example, Pitta et al., (2005) observed

that daily walking time in elderly patients with COPD averaged 44 minutes compared to 81 minutes in healthy elderly subjects.

In previous COPD research, low physical activity was related to general demographic characteristics such as older age (Garcia-Aymerich et al., 2009; Gimeno-Santos et al., 2014; Park et al., 2013; Yu et al., 2016), gender (Garcia-Aymerich et al., 2009; Gimeno-Santos et al., 2014; Park et al., 2013; Yu et al., 2016), and history of smoking (Gimeno-Santos et al., 2014; Park et al., 2013; Tödt et al., 2015; Yu et al., 2016) and to clinical characteristics such as pulmonary function, hyperinflation, dyspnea, and fatigue (Gimeno-Santos et al., 2014; Tödt et al., 2015; Yu et al., 2016). According to a systematic review performed to identify determinants and outcomes of physical activity, age and gender were shown to be the strongest determinants for physical activity in the COPD population (Gimeno-Santos et al., 2014). However, few studies have examined sleep as a determinant of physical activity in this population, and a better understanding of this matter is needed to evaluate sleep management as innovative strategy to improve physical activity in COPD patients.

2. Relationship Between Physical Activity and Sleep Disturbance

In the general population, sleep quality and total sleep time are increasingly recognized as important lifestyle contributors to health, as are their beneficial impacts on physical activity (Holfeld & Ruthig, 2014; Tang & Sanborn, 2014) and cardiovascular health (St-Onge et al., 2016). Sleep has long been considered to have restorative functions that conserve energy and metabolism, keep the physiological system within proper homeostatic limits, maintain host defenses, and restore physiological processes (Redeker & McEnany, 2011). In previous studies, sleep disturbances have been defined as waking during sleep, abnormal sleep onset or duration (Agusti et al., 2011), and poor sleep quality (Jen et al., 2016; Omachi et al., 2012). Sleep can be

measured subjectively or objectively based on research aims; common sleep variables include sleep architectures such as sleep onset latency (SL, minutes to fall asleep after lights out), total sleep time (TST, total sleep duration), wake after sleep onset (WASO, minutes spent awake after sleep onset), number of awakenings (NA, number of awakenings after sleep onset), sleep efficiency (SE, percent time spent asleep divided by time in bed), and fragmentation index (FI, sleep restlessness, with higher values signifying poor sleep continuity) (Lambiase, Gabriel, Kuller, & Matthews, 2013; Shrivastava, Jung, Saadat, Sirohi, & Crewson, 2014).

In recent studies, researchers have found that better sleep quality improves symptoms such as fatigue or pain, increasing the individual's capability to engage in physical activity. In three of these studies, higher self-reported sleep quality predicted increased subsequent physical activity in chronic pain patients (Tang & Sanborn, 2014) and older adults (Holfeld & Ruthig, 2014), and longer self-reported sleep duration was related to increased physical activity in older adults (Garfield, Llewellyn, & Kumari, 2016). In addition, increased daily activity count and moderate-to-vigorous physical activity was related to higher objectively measured sleep efficiency and lower sleep fragmentation in older women (Lambiase et al., 2013). In addition, in a healthy population, short sleep duration was reported to temporarily reduce next-day free-living physical activity (Schmid et al., 2009). Overall, research has conclusively demonstrated that sleep influences physical activity in the general population.

As to the COPD population, few studies have addressed the influence of sleep on physical activity, and their results have been inconsistent (Hartman et al., 2013; Parwanta et al., 2016; Spina et al., 2017). Among these studies, one found no significant relationship between self-reported sleep disturbance and objectively measured physical activity (Hartman et al., 2013). In contrast, two other studies employing objective measurement of both sleep and physical activity

revealed a significant relationship (Parwanta et al., 2016; Spina et al., 2017). One of these studies involving eight elderly patients with COPD (mean age: 77 years) as a subgroup (Parwanta et al., 2016) identified a significant relationship between sleep variables (sleep onset latency [SL], sleep efficiency [SE], wake after sleep onset [WASO], total sleep time [TST], and fragmentation index [FI]) and physical activity during the second tertile of the day (from noon to 5 p.m.). However, in a younger-old (mean age: 64) subgroup, the only significant relationship reported was between SL and physical activity during the same tertile (Parwanta et al., 2016). Another study including a large sample of participants with COPD (N=932) found that those having better sleep quality (non-fragmented sleep, better sleep efficiency, and lower time spent WASO) spent significantly more time in light (p <.01) and moderate-to-vigorous physical activity (p <.01) (Spina et al., 2017). In this study, only quantile values for sleep measures were included in the data analysis, and thus it was not possible to identify continuous changes in physical activity according to sleep variables. For example, individuals who had greater WASO (≥ 165 minutes) had lower daytime physical activity and tended to perform more moderate-to-vigorous activity than those with lower WASO (< 57 minutes).

The few previous studies of the temporal relationship between sleep and physical activity in the COPD population have had conflicting results. Consequently, more research is needed to fully understand this relationship and thus to develop effective interventions for improving physical activity.

The purpose of this study was to identify the impact of night-time sleep on next-day physical activity in individuals with COPD and co-existing disturbed sleep. The specific aims were to (a) characterize objectively measured and self-reported sleep and physical activity in people with COPD and disturbed sleep, (b) examine relationships between sleep variables and physical

activity for one week, and (c) examine the temporal relationship between sleep and next-day physical activity.

C. Method

1. Study Design and Participants

This study employed a repeated-measure, quantitative design with secondary analysis. Study data were obtained from an ongoing randomized control trial (RCT) examining the efficacy of cognitive behavioral therapy for insomnia (CBT-I) and COPD education (COPD-ED) programs for insomnia and fatigue in people with COPD (Kapella, Herdegen, Laghi, Steffen, & Carley, 2016). This study employed baseline data collected from RCT participants before the beginning of any intervention. Details on the research setting and RCT sample are provided by Kapella et al. (2016). Data were available for 62 RCT subjects recruited from October 2014 to July 2017, and data for 56 of these individuals were analyzed for this study. The inclusion and exclusion criteria applied to potential study participants were as follows.

COPD patients who met all these criteria were eligible for the study: (a) had mild to very severe COPD, with severity being defined based on the new Global Initiative for Chronic Obstructive Lung Disease (GOLD) standard; (b) were aged ≥ 45 years with no other major health problems; (c) were clinically stable without major worsening of COPD within the previous 2 month; and (d) had difficulty with initiating or maintaining sleep, waking up too early, or poor quality sleep (a Sleep Impairment Index score ≥ 10) (Edinger et al., 2004; Morin &

Barlow, 1993).

COPD patients who exhibited any of the following conditions were excluded from the study: (a) evidence of restrictive lung disease or asthma; (b) pulse oximetry (Oxygen Saturation, SaO2) readings of < 90% at rest or < 85% at night for > 5 minutes; (c) evidence of a major sleep disorder (other than insomnia), such as sleep apnea evidenced by an apnea/hypopnea index > 15, periodic limb movements with > 10 arousals per hour, or narcolepsy; (d) hypnotic medication use; (e) acute respiratory infection within the previous 2 months; (f) a potentially debilitating disease such as cancer, congestive heart failure, kidney disease, liver failure, or cirrhosis; evidence of alcohol or drug abuse; or musculoskeletal or degenerative nerve disease; (g) a self-reported current diagnosis of major depression or psychiatric disease or a Hospital Anxiety and Depression Scale (HADS) depression score > 11; or (h) current participation in pulmonary rehabilitation.

2. Measures

Physical activity and objective sleep disturbance were measured using a wrist-worn accelerometer (Actiwatch-2, Philips Respironics, Murrysville, PA) converted to data using Actiware software program (V.6.08) via a PC interface. RCT subjects were directed to wear the Actiwatch-2 device on the non-dominant wrist for 7 days. This device integrates the occurrence and magnitude of movement and stores the information as activity counts in 30-second epochs. During each 24-hour period, 2,880 epochs of activity counts were collected. The default settings of 10 immobile or mobile minutes for sleep onset or end, and activity threshold of 40.

Objective sleep disturbance was measured using variables included in the Actiware software program, including sleep onset latency (SL), wake after sleep onset (WASO), number of awakenings after sleep onset (NA), total sleep time (TST), and sleep efficiency (SE). A medium-sensitivity threshold (activity score of 40) (Kushida et al., 2001) and the scoring of the Actiware program were validated in previous studies (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992; Sadeh, Hauri, Kripke, & Lavie, 1995).

The Sleep Impairment Index (SII) was used to measure subjective sleep disturbance in this study. The SII includes seven items, each rated on a 5-point scale (ranging from 0=not at all to 4=extremely), to evaluate sleep onset severity, sleep maintenance, early morning awakening problems, satisfaction with current sleep, interference with daily functioning, impairment attributed to the sleep problem, and level of distress caused by the sleep problem. Total SII scores range from 0 to 28, with higher scores indicating greater sleep disturbance. The total SII score can be interpreted as follows: absence of insomnia (0-7), sub-threshold insomnia (8-14), moderate insomnia (15-21), and severe insomnia (22-28) (Morin, Belleville, Belanger, & Ivers, 2011). In previous research, a cutoff score of 10 was considered optimal to detect subjects with insomnia in a community sample (sensitivity=86.1% and specificity=87.7%) (Morin et al., 2011). The SII's validity and reliability were demonstrated in older adults with insomnia (Bastien, Vallieres, & Morin, 2001). The instrument was reported to have good face validity and criterion validity with polysomnographic and prospective sleep diary measures (Morin et al., 2011; Smith & Trinder, 2001).

Activity counts collected from the Actiwatch-2 device were used as the measure of physical activity. After processing using the Actiware software program, activity counts were reported as counts per minute. Daily physical activity was measured as averaged physical activity counts per minute (cpm) during waking time (from awakening to bedtime), and hourly physical activity was measured as averaged physical activity cpm on an hourly basis. The intra- and inter-instrument reliability of the Actiwatch device was established using a shaker table under six different conditions of varying intensity to produce a range of accelerometer counts (Esliger & Tremblay, 2006). A previous study of the COPD population reported individual minute-by-minute correlations of Actiwatch counts with a 6-minute walk distance (r=.60) and metabolic (MET)

cost (r=0.53) (Van Remoortel et al., 2012). According to a more recent study involving adult females (Neil-Sztramko, Rafn, Gotay, & Campbell, 2017), the physical activity cpm measured using the Actiwatch-2 can be interpreted as follows: sedentary (under 145 cpm), light intensity activity (145-274 cpm), moderate intensity activity (274-597 cpm), and vigorous intensity activity (over 597 cpm).

Fatigue was assessed using the Chronic Respiratory Questionnaire-Fatigue (CRQ-F), which measures frequency and intensity of fatigue experienced in the previous 2 weeks (Guyatt, Berman, Townsend, Pugsley, & Chambers, 1987). The CRQ-F consists of four items, each scored on a 7-point Likert scale (ranging from 1=all of the time to 7=none of the time). Lower scores indicate more fatigue. The validity and reliability of the CRQ-F were demonstrated in the COPD population (Wijkstra et al., 1994). The Cronbach's alpha values for the CRQ-F were 0.78 (Wijkstra et al., 1994) and 0.88 (Reda, Kotz, Kocks, Wesseling, & van Schayck, 2010). Concurrent validity with the Clinical COPD Questionnaire was reported (r=0.58) (Reda et al., 2010).

Dyspnea was assessed using the CRQ-Dyspnea (CRQ-D) scale, which asks subjects to rate the dyspnea they experience during selected activities on a regular basis (Guyatt et al., 1987). The CRQ-D is a five-item instrument with a 7-point Likert scale (ranging from 1=extremely short of breath to 7=not at all short of breath). Lower scores indicate more severe dyspnea. The CRQ-D's reliability and validity were demonstrated in the COPD population (Reda et al., 2010). The Cronbach's alpha value for the CRQ-D was 0.99 (Reda et al., 2010), and concurrent validity with the Clinical COPD Questionnaire was reported (r=0.42). Pulmonary function tests (PFT) were performed to measure FEV₁% predicted. PFTs were administered using the Vmax Encore 22 (Viasys Healthcare Inc., Yorba Linda, CA) and in accordance with American Thoracic Society (ATS) standards (Miller et al., 2005).

3. Study Procedure

After study approval was obtained from a UIC Institutional Review Board (IRB), the data for 62 RCT subjects was accessed and subjected to a data cleaning process. To maximize the accuracy and validity of actigraphy data for sleep, the following data cleaning steps were conducted according to the Society of Behavioral Sleep Medicine manual (Ancoli-Israel et al., 2015): (1) delete times at the beginning and end of the recording when the device was not on the patient's wrist; (2) identify missing data by reviewing actigraphy scores by comparing the actigraphy log or event markers (the recording would show a flat line with no activity—i.e., activity values at 0—if the device was removed from the wrist; and (3) note abnormal or unusual movements in the recording indicating that the device malfunctioned. When unusual movement was observed in an activity log, the subject's sleep diary was also consulted to confirm the log data.

For data cleaning for physical activity, time-stamped continuous 30-second epoch physical activity data were downloaded using the Actiware software program (V.6.08) and exported into an Excel spreadsheet. The data was cleaned using the following rules: (1) non-wear time, defined as no counts for 60 minutes, was excluded; (2) individuals must have worn the device for a minimum of 10 hours for the day to be considered a valid day; and (3) individuals who did not have at least 4 valid days were excluded. As a result of the data cleaning process, six RCT subjects were excluded, and data for 56 participants were used for the study.

4. Sample Size

To determine a sufficient sample size for the study, Monte Carlo simulation was used. This computing-intensive simulation approach mimics the data generation process to evaluate properties of a test statistic or confidence interval. The Monte Carlo approach is a viable alternative when power analysis is not suitable for the complex analyses of a particular study (Landau & Stahl, 2013). Based on Monte Carlo simulation results for the proposed study, a total of 50 subjects were sufficient to test the study hypotheses (power = .87).

5. Statistical Analysis

All analyses were performed using SPSS version 24.0 (SPSS Inc., Chicago, IL), and a two-tailed p value < .05 was considered statistically significant for the analyses.

Descriptive statistics were used to calculate frequencies as percentages and means with standard deviations (SD) for sleep, physical activity, and participant characteristics. To examine the relationship between sleep disturbance and physical activity, Spearman's rank order correlations and mixed effect models were used. Study variables were examined for normal distribution, and variables that were not normally distributed were subjected to Spearman's rank order correlations in order to identify the relationship.

Mixed effect models with compound symmetry with an autoregressive correlation (AR1) matrix were used to estimate the effects of repeated-measure sleep disturbance on physical activity. This covariance structure has variance and covariance and was selected based on the best combination of fit indices with a lower Akaike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (BIC). Mixed effect models account for repeated measures and can efficiently manage unbalanced data and simultaneously estimate both effects of covariates and variance components while accounting for fixed effects of sleep variables. A mixed effect model can also accommodate a dataset with a large portion of missing data (Krueger & Tian, 2004). In this study, mixed effect models included age, gender, FEV_{1pp} , dyspnea, and fatigue as covariates because they are well-established determinants of physical activity in the COPD population (Gimeno-Santos et al., 2014). Separate models were used to test the adjusted relationship between each sleep disturbance variable and each physical activity variable.

D. Results

1. Participant Characteristics

Table I shows characteristics of the 56 study participants. Their mean age was 65 years, and 53.6% were male. More than half of the participants (64.3%) were Black, and most (64.3%) were not employed. The mean predicted percentage of forced expiratory volume in 1 second (FEV1 % predicted) was 69.4, and 60.7% of participants had moderate pulmonary function based on the GOLD standard. All participants had a history of smoking with a mean value of over 28 years, and their mean body mass index was 27.12.

2. Levels of Sleep, Physical Activity, Dyspnea, and Fatigue

Table II indicates levels of subjective and objective sleep disturbance, objectively measured physical activity using the Actiwatch-2, and self-reported dyspnea and fatigue in study participants. TST averaged 381.54 minutes (SD=73.96) among the participants, indicating adequate sleep duration, and the average SII value for sleep disturbance was 15.59 (SD=4.34), indicating moderate insomnia. In addition, mean physical activity was measured at 250.28 (SD=87.50) cpm, indicating light intensity activity during waking time. The mean levels of dyspnea and fatigue in participants were 4.90 and 3.90 (both on a range of 1 to 7), respectively.

3. Association Between Weekly Physical Activity and Sleep Disturbance

Table III displays correlations between averaged weekly values for sleep disturbance and physical activity. Greater physical activity (cpm) was negatively associated to SL (r=-.48, p <.001), NA (r=-.38, p<.01), TST (r=-.50, p <.001), and age (r=-.32, p <.05). Physical activity was not related to WASO, SE, subjective sleep disturbance, gender, predicted FEV₁%, dyspnea, and fatigue.

4. Temporal Relationship Between Sleep Disturbance and Daily and Hourly Next-Day Physical Activity

After adjusting for age, gender, predict FEV₁%, dyspnea, and fatigue, no significant relationships were observed between sleep disturbance and next-day daily physical activity (see Table IV). For next-day hourly physical activity (see Figure 2), a 1-minute increase in SL was associated with decreased afternoon physical activity (cpm) from 4 to 6 p.m (p < .05). and decreased evening physical activity from 9 to 10 p.m (p < .05). On the other hand, a 1-minute increase in WASO and a 1-unit increase in NA were associated with decreased morning physical activity from 5 to 8 a.m (p < .05). Similarly, increased TST was associated with decreased morning physical activity from midnight to noon (p < .05) and decreased afternoon physical activity from 1 to 3 p.m (p < .05). In terms of SE, a 1% increase was associated with decreased morning physical activity from 1 to 5 a.m (p < .05). and increased afternoon and evening physical activity from 5 to 7 p.m (p < .05).

E. Discussion

The results of this study indicate that sleep disturbance influences next-day physical activity in the COPD population. Although there was no significant temporal relationship between sleep variables and next-day daily physical activity, averaged 7-day sleep variables

and physical activity showed a strong correlation. Also, each sleep variables had varying influences on next-day physical activity. For example, number of awakenings during sleep and abnormal sleep duration influenced morning physical activity, and abnormal sleep onset and poor sleep quality (low SE) influenced evening physical activity.

Participants showed severe subjective sleep disturbance in this study. The mean SII score of 15.59 reflecting moderate insomnia was well above the cutoff score of 12, indicating elevated insomnia symptoms (Kaufmann et al., 2017). In terms of objective sleep disturbance variables, participants generally showed more sleep disturbance compared to subjects of previous studies. In this study, participants' mean SL was longer and TST was shorter than in an earlier study (Parwanta et al., 2016). Also, participants' SE was 76.53, which was lower than previous studies' values for a COPD population (Nunes et al., 2013; Spina et al., 2017) as well as in healthy individuals (Nunes et al., 2013) and older women (Lambiase et al., 2013). Although the causes of sleep disturbance in COPD patients are not fully understood (Nunes et al., 2013), several factors may contribute to disturbed sleep in this population. Potential factors include nocturnal hypoxemia from a combination of low baseline oxygen saturation and alterations in respiratory muscle function and ventilation and respiratory symptoms such as dyspnea, cough, and sputum production (Budhiraja et al., 2015; Nunes et al., 2013). This study's sample was extracted from an RCT involving people exhibiting COPD with disturbed sleep, and thus the extent of the participants' sleep disturbance was expected to be greater than that of COPD patients in other studies.

In this study, significant relationships were observed between objective sleep variables averaged over the week and averaged physical activity. Greater sleep disturbance, including higher SL, higher NA, and increased TST, was correlated with reduced mean physical activity over the week, a trend similar to those observed by Spina et al. (2017) in 987 COPD patients; however, Spina et al. identified a significant temporal relationship between sleep variables and next-day daily physical activity, whereas no significant relationship was found in the present study. There are two possible reasons for this difference. First, although demographic characteristics, including age and gender ratio, were similar in the studies, there were differences in the sleep-related characteristics involved. In Spina et al.'s study (2017), participants were not screened for sleep-related disorders such as obstructive sleep apnea (OSA), and the researchers examined only objective sleep disturbance. In contrast, under the present study's inclusion criteria, the participants recruited were individuals who self-reported sleep disturbance but had no other sleep-related disorder. Also, for data analysis, Spina et al. excluded participants who did not have regularly distributed sleep during night-time or who had < 4 hours of time in bed, whereas the present study did not exclude individuals based on such sleep quality characteristics. In addition, the covariates used to examine relationships differed between the two studies. Thus, differences in both participant characteristics and analytical procedures may explain the differing results of the two studies.

This study provided new information about when during the day sleep variables influence individuals' levels of physical activity by examining the relationship between each sleep variable and hourly averaged physical activity. Each sleep variable was significantly related to a different period of next-day physical activity. First, increased SL was related to decreased afternoon activity. Previous studies have not explored this relationship on an hourly basis, and no significant relationship between SL and daily physical activity was reported in older women (Lambiase et al., 2013) or in the COPD population (Parwanta et al., 2016). In the typical circadian sleep rhythm, the urge to sleep is greatest at night and shows a small mid-
day increase. The need for sleep grows during the waking hours and is satisfied during sleep. Difficulties in falling asleep reflected by increased SL leave people with lower TST, which contributes to the circadian dip in the afternoon. Further investigation is required to more definitively link the SL and afternoon physical activity in COPD population.

In addition, low sleep quality such as increased WASO and NA during sleep was related to lower physical activity during the morning. In this study, WASO and NA respectively reflect how long participants were awake after sleep onset and how many times participants awoke during sleep. The WASO and NA results correspond to those of previous studies that identified relationships between sleep fragmentation and physical activity in older women (Lambiase et al., 2013) and the COPD population (Spina et al., 2017). In this study, WASO and NA were significantly associated with reduced physical activity in morning time (from 5 to 8 a.m.); this time period was closely related to sleep offset time (5:39 a.m. \pm 0.57 hour) in COPD patients in a previous study (Nunes et al., 2013). Thus, frequent awakening during sleep may cause fatigue or sleepiness at the sleep offset, which can in turn lead to delay in getting out of bed and decreased physical activity in the morning time. The present study did not explore the "morningness-eveningness" preference of participants, which reflects the sleep-wake pattern of the circadian rhythm (Matuzaki et al., 2014) and could affect the relationship between sleep and physical activity.

TST was also related to reduced physical activity during the morning. This finding was expected because those having longer sleep duration would be expected to wake up later and thus to perform less morning physical activity. However, increased TST was also related to decreased afternoon physical activity, a finding in line with previous research indicating that as TST increased, daily physical activity levels decreased (Spina et al., 2017). Longer TST may indicate prior sleep deprivation, medical conditions, or effects of medications (Shrivastava et al., 2014). However, longer TST is an important predictor of both higher mortality (Heslop, Smith, Metcalfe, Macleod, & Hart, 2002) and increased levels of systematic inflammation factors such as CRP and interleukin-6 (Irwin, Olmstead, & Carroll, 2016) in general population. For all these reasons, education about adequate sleep duration in patients with COPD is warranted to improve physical activity as well as longitudinal health outcome.

SE, defined herein as percent time spent asleep divided by time in bed, was related to lower physical activity during night-time (i.e., from 2 to 4 a.m.) and increased physical activity in the evening. These findings are consistent with previous studies' findings that SE was positively associated with increased next-day daily physical activity in older adults and the COPD population (Spina et al., 2017). SE values provide an overall sense of how well an individual sleep, and higher values indicate good sleep quality. Well-rested people may feel more energetic and be more likely to engage in afternoon physical activity. Interestingly, negative associations were observed between SE and night-time physical activity, indicating that people with good SE do not wake up frequently during the night and thus perform little activity at that time.

Finally, the predicted FEV_1 % and subjective sleep disturbance measured using the SII showed no correlation with physical activity in this study. As to pulmonary function, COPD severity in the study population was relatively mild according to the GOLD standard, and thus participants may not have experienced much dyspnea during physical activity. The lack of correlation between physical activity and SII scores in the present study was similar to the results of a previous study that examined the relationship between self-reported sleep

disturbance and objectively measured physical activity in COPD patients (Hartman et al., 2013). Notably, however, the present study was the first to examine the relationship between both subjective and objective sleep measures and physical activity in the COPD population. This being said, only cross-sectional correlations between subjective sleep and physical activity were examined. Future studies should examine temporal relationships between subjective sleep and objective physical activity to determine whether subjective or objective sleep has more influence on physical activity.

The findings of this study have clinical implications for patients with COPD in terms of improving their physical activity. The findings suggest that physical activity in the COPD population could be enhanced by applying tailored interventions that emphasize sleep management. Current strategies for promoting physical activity in COPD patients tend to focus on performance during day-time hours. However, sleep management strategies such as cognitive behavioral therapy and medication may be effective in engaging COPD patients in more physical activity throughout the day. With respect to future research, additional research is needed to further explore the relationship between night-time sleep variable and physical activity and how each variable influence different time point physical activity in COPD population. On a more general level, sleep is a frequently ignored aspect of research protocols (McNicholas et al., 2013), but the results of the present study indicate that sleep disturbance should be assessed and emphasized in physical activity research concerning the COPD population (Spina et al., 2017).

This study has three limitations that should be acknowledged. First, because data cleaning was performed by only one person, some bias may have been present. Second, the study sample was extracted from an RCT involving COPD patients in the Chicago area reporting subjective sleep disturbance. Thus, the findings of the present study may have limited

generalizability. Finally, this study used averaged activity counts per minute as the physical activity measure and did not examine relationships between sleep and different degrees of physical activity such as light, moderate, and vigorous intensities. These relationships merit future investigation, as they may provide important clues to means of increasing physical activity in COPD patients.

F. Conclusion

This study is unique because it identified relationships between night-time sleep variables and next-day hourly physical activity that revealed when sleep significantly affects physical activity during the day. Moreover, the results suggest that sleep impairment is an important factor influencing next-day physical activity. Therefore, sleep management should be considered during development of interventions to improve physical activity in the COPD population. Given that sleep variables influence next-day physical activity in the COPD population with coexisting disturbed sleep at various times of day, a sleep management approach could address various aspects of sleep such as duration, latency, and wakening. To support this approach, further research is needed to identify the specific mechanisms underlying the sleep-physical activity relationship.

G. References

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Table I

Participants Characteristics

| | | (N=56) | |
|--------------------------------|-------------|-----------|--|
| | Mean | N (%) | |
| Age | 65.15±7.79 | | |
| Gender | | | |
| Male | | 30 (53.6) | |
| Female | | 26 (46.4) | |
| Race | | | |
| White | | 17(30.4) | |
| Black | | 36(64.3) | |
| Asian | | 1 (1.8) | |
| American Indian or Alaskan | | 2 (3.6) | |
| Working Status | | | |
| Not working | | 46 (82.1) | |
| Working (Part time, full time) | | 8 (14.3) | |
| Housewife | | 2 (3.6) | |
| FEV1 % predicted | 69.45±20.09 | | |
| ≥80 (Mild) | | 14 (25.0) | |
| 50 to <80 (Moderate) | | 34 (60.7) | |
| 30 to <50 (severe) | | 6 (10.7) | |
| < 30 (Very Severe) | | 2 (3.6) | |
| Smoking (pack/year) | 28.53±25.01 | | |
| BMI | 27.12±6.00 | | |

Table II

| | | (N=56) |
|--|--------|--------|
| | Mean | SD |
| Objective Sleep Disturbance | | |
| Sleep onset latency (min) | 30.86 | 22.81 |
| Wake after sleep onset (min) | 61.62 | 21.63 |
| Number of awakenings after sleep onset | 37.93 | 12.55 |
| Total sleep time (min) | 381.51 | 73.96 |
| Sleep efficiency (%) | 76.53 | 9.70 |
| Subjective Sleep Disturbance | | |
| Sleep impairment index | 15.59 | 4.34 |
| Physical Activity (cpm) | 250.28 | 87.50 |
| Dyspnea | 4.90 | 1.50 |
| Fatigue | 3.90 | 1.03 |
| Note com=count per minute | | |

Levels of Sleep, Physical Activity, Dyspnea, and Fatigue of the Participants

Note. cpm=count per minute

Table III

Association Between Weekly Physical Activity and Sleep Disturbance

(N=56)

| | SL | WASO | NA | TST | SE | SII | Age | Gender | FEV _{1pp} | Dyspnea | Fatigue | |
|----|------|------|-----|------|-----|-----|-----|--------|--------------------|---------|---------|--|
| PA | 48** | 06 | 38* | 50** | .12 | 14 | 32* | .02 | .03 | .20 | .20 | |

Note. PA=physical activity; SL=sleep onset latency; WASO=wake after sleep onset; NA= number of awakenings after sleep onset; TST= total sleep time; SE=sleep efficiency; SII=Sleep impairment index; FEV_{1pp} = predicted percentage of forced expiratory volume in 1 second. *p < .01, *p < .001

Table IV

Temporal Relationship Between Sleep Disturbance and Next-Day Daily Physical Activity

| | | | | (N=56) |
|--|----------|------|-------|--------|
| | Estimate | SE | t | р |
| Sleep onset latency (min) | -0.08 | 0.08 | -1.04 | .300 |
| Wake after sleep onset (min) | 0.01 | 0.08 | 0.08 | .938 |
| Number of awakenings after sleep onset | -0.05 | 0.19 | -0.27 | .791 |
| Total sleep time (min) | 0.01 | 0.02 | 0.26 | .799 |
| Sleep efficiency (%) | 0.15 | 0.28 | 0.54 | .594 |

Covariates: age, gender, predicted FEV₁%, dyspnea, fatigue



Figure 2. Temporal Relationship between Sleep Disturbance and Hourly Physical Activity SL=sleep onset latency; WASO=wake after sleep onset; NA= number of awakenings after sleep onset; TST= total sleep time; SE=sleep efficiency. Covariates: age, gender, predicted FEV₁%, dyspnea, fatigue

III. SLEEP PATTERNS IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

A. Introduction

Chronic obstructive pulmonary disease (COPD) is a highly prevalent chronic respiratory disease and the third-leading cause of death in the United States. In the COPD population, sleep disturbance is a common complaint; more than 60% of patients with COPD suffer from sleep disturbances (Agusti et al., 2011; Jen et al., 2016) defined as waking during sleep, abnormal sleep onset or duration (Agusti et al., 2011), and poor sleep quality (Jen et al., 2016; Omachi et al., 2012). Sleep disturbance in the COPD population is known to be related to negative health outcomes such as impaired quality of life (Nunes et al., 2009), exacerbation (Geiger-Brown et al., 2015; Omachi et al., 2012), and even mortality (Agusti et al., 2011; Omachi et al., 2012).

Sleep quality and duration are increasingly recognized as important lifestyle contributors to health (St-Onge et al., 2016). Daily sleep interacts with various lifestyle factors and may or may not change over a week's time, depending on the individual. Understanding night-to-night sleep patterns is important to be able to provide appropriate medical and nursing care to promote sleep quality, so much so that these patterns have been recommended as a measure for identifying regularity and variability of sleep behaviors in behavioral insomnia treatment (Riedel & Lichstein, 2001).

In previous research, disease severity, mood (Budhiraja et al., 2015; McNicholas et al., 2013), and respiratory symptoms (such as sputum production, cough, and dyspnea) have been shown to be predictors of sleep disturbance in the COPD population (Budhiraja et al., 2015). In most of these COPD studies, sleep has been measured on one occasion, typically using

subjective self-administered questionnaires (Chang et al., 2016; Geiger-Brown et al., 2015; Hartman et al., 2015; Omachi et al., 2012) but sometimes using objective laboratory-based polysomnography (McSharry, Ryan, Calverley, Edwards, & McNicholas, 2012; Valipour, Lavie, Lothaller, Mikulic, & Burghuber, 2011). A few studies (Budhiraja et al., 2012; Nunes et al., 2013) have measured sleep over several days, but the data were summarized as population averages, making it difficult to identify night-to-night sleep patterns. Thus, limited information is available on longitudinal changes in sleep patterns in the COPD population and their association with other characteristics of COPD patients.

Group-based trajectory modeling, also known as trajectory analysis, simultaneously estimates patterns over time and identifies subgroups of individuals with similar trajectories that might otherwise go unobserved (Nagin, 2005). Such modeling employs the trajectory group as a statistical device for approximating the unknown distribution of trajectories across participants using the maximum likelihood approach. This method has been used to identify patterns of symptoms or physical activity in various populations, but to my knowledge, this technique has not been used to characterize sleep patterns in the COPD population.

B. Literature Review

A strong physiological basis exists for COPD patients' poor sleep quality (Jen et al., 2016). During sleep, central respiratory control and lung mechanics are reduced, and although this does not have an adverse effect in the healthy population, it may result in significant hypoxemia and hypercapnia in patients with COPD (McNicholas et al., 2013). Also, coughing is typically suppressed during sleep, resulting in mucus plugging and hypersecretion that reduce nocturnal gas exchange and severely affect COPD patients (Jen et al., 2016). Previous studies have revealed that COPD patients suffer more severe sleep disturbance than healthy individuals. Nunes et al. (2013) measured sleep variables using an actigraphy device (Monologger, Ambulatory Monitoring Inc., NY, USA) for at least 5 days and reported that COPD patients (n=26) showed increased sleep latency and wake after sleep onset and reduced sleep time and sleep efficiency compared to healthy controls (n=15). In his study, mean total sleep time in COPD patients was 280 minutes and mean sleep latency was 39.49 minutes, indicating severe sleep impairment based on previous research. In the study of Budhiraja et al. (2012), sleep was measured for 7 days using a motion logger (Actiwatch, Ambulatory Monitoring Inc., Ardsley, NY). In their study, insomnia disorder was highly prevalent in COPD patients; mean sleep time was 379.5 minutes in patients with insomnia and 448.8 minutes in those without insomnia. In addition, Budhiraja et al. observed significant differences in sleep efficiency and wake after sleep onset between COPD patients with and without insomnia.

Sleep disturbance has been associated with negative health outcomes in COPD patients (Geiger-Brown et al., 2015; Omachi et al., 2012). In the study of Geiger-Brown et al. (2015), sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI), and poor sleepers (PSQI score > 5) had greater COPD exacerbation rates than good sleepers (PSQI score \geq 5). In their longitudinal study, Omachi et al. (2012) found that self-reported sleep disturbance longitudinally predicted COPD exacerbation, respiratory-related emergency service use, and mortality.

Various factors have been reported as correlates of sleep disturbance in the COPD population. For example, medication use, disease severity, and mood have been associated with sleep disturbance in COPD patients (Budhiraja et al., 2015; McNicholas et al., 2013). In addition, respiratory symptoms such as sputum production (Hartman et al., 2015), cough (Omachi et al.,

2012), and dyspnea (Nunes et al., 2013; Omachi et al., 2012) are known to be related to sleep disturbance in this population (Budhiraja et al., 2015). Because most studies measured sleep on one occasion using subjective self-administered questionnaires, and because the few studies that measured sleep objectively over several days summarized their data as population averages, it was difficult to identify daily changes in sleep patterns. Thus, limited information is available on longitudinal changes in sleep patterns in the COPD population and their association with other characteristics of COPD patients.

Consequently, the aims of this exploratory study were to (a) apply trajectory analysis to characterize changes in sleep patterns in COPD patients with co-existing sleep disturbance over a 7-day period and (b) identify patient characteristics associated with sleep patterns.

C. Method

1. Study Design and Setting

This study used secondary data analysis with a repeated-measure, quantitative design. Study data were obtained from an ongoing randomized control trial (RCT) examining the efficacy of cognitive behavioral therapy for insomnia (CBT-I) and COPD education (COPD-ED) programs for insomnia and fatigue in COPD patients (Kapella et al., 2016). The setting for the study was the University of Illinois at Chicago (UIC), College of Nursing, Center for Narcolepsy, Sleep, and Health Research.

2. Participants

Study data were extracted from a baseline dataset for RCT subjects who received no intervention. This study included participants with mild-to-severe COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) standard who reported difficulty initiating or maintaining sleep, waking up too early, or poor-quality sleep. The study excluded individuals having other major health problems or evidence of a major sleep disorder other than insomnia, such as sleep apnea, narcolepsy, or periodic limb movements with > 10 arousals per hour. Details on the research setting and RCT sample were provided by Kapella et al. (2016). Among the 62 eligible RCT subjects recruited from October 2014 to July 2017, the present study included 56 participants who wore the Actiwatch-2 device on their non-dominant wrist for at least 22 hours per day over at least 5 consecutive days (four weekdays and either Saturday or Sunday).

3. Measurements

Daily sleep variables were assessed using the wrist-worn Actiwatch-2 accelerometer (Philips Respironics, Murrysville, PA). The Actiwatch-2 device integrates occurrence and magnitude of movement and stores the information as activity counts in 30-second epochs. For this study, collected Actiwatch-2 data was converted to Actigraph data using the Actiware software program (V.6.08) via a PC interface. To maximize the accuracy and validity of actigraphy data for sleep, the following data cleaning steps were conducted according to the Society of Behavioral Sleep Medicine manual (Ancoli-Israel et al., 2015): (1) delete times at the beginning and end of the recording when the device was not on the patient's wrist; (2) identify missing data by reviewing actigraphy scores by comparing the actigraphy log or event markers (the recording would show a flat line with no activity—i.e., activity values at 0—if the device was removed from the wrist; and (3) note abnormal or unusual movements in the recording indicating that the device malfunctioned. Each epoch of data from the Actiwatch-2 device was assessed as "wake" or "sleep" based on whether or not the activity score exceeded a set threshold in the software program. In this study, the valid medium-sensitivity threshold (an activity score of 40) was used.(Kushida et al., 2001) Among the actigraph data, the daily sleep variables

assessed for this study were sleep onset latency (SL, minutes to fall asleep after lights out), wake after sleep onset (WASO, minutes spent awake after sleep onset), number of awakenings after sleep onset (NA), total sleep time (TST), and sleep efficiency (SE, percentage of time spent asleep divided by time in bed). Scoring of actigraph data with standardized computer algorithms is a reliable and valid method comparable to polysomnography, which is the gold standard for sleep measurement.(Cole et al., 1992; Sadeh et al., 1995)

Self-report sleep disturbance was measured using the Sleep Impairment Index (SII). The SII includes seven items, each rated on a 5-point scale (ranging from 0=not at all to 4=extremely), to evaluate sleep onset severity, sleep maintenance, early morning awakening problems, satisfaction with current sleep, interference with daily functioning, impairment attributed to the sleep problem, and level of distress caused by the sleep problem. Total SII scores range from 0 to 28, with higher scores indicating greater sleep disturbance. The total SII score can be interpreted as follows: absence of insomnia (0-7), sub-threshold insomnia (8-14), moderate insomnia (15-21), and severe insomnia (22-28) (Morin et al., 2011). Morin et al. (2011) reported that a cutoff score of 10 was considered optimal to detect subjects with insomnia in a community sample (sensitivity=86.1% and specificity=87.7%). The SII's validity and reliability were demonstrated in older adults with insomnia (Bastien et al., 2001). The instrument was reported to have good face validity and criterion validity with polysomnographic and prospective sleep diary measures (Smith & Trinder, 2001). Cronbach's alpha in this study was 0.80.

Self-efficacy for sleep. Confident for managing sleep was measured using the Self-Efficacy Scale for sleep (SES) (Lacks, 1987) which asks their confidence in falling asleep, staying asleep and obtaining refreshing sleep. The SES includes nine items, each rated on 5-point scale (not confident at all to very confident). Total scores range from 9 to 45, with a higher score for

greater confidence to managing sleep. The Cronbach's alpha value for the SES was 0.86 (Edinger & Sampson, 2003).

Fatigue was assessed using the Chronic Respiratory Questionnaire-Fatigue (CRQ-F), which measures frequency and intensity of fatigue experienced in the previous 2 weeks (Guyatt et al., 1987). The CRQ-F consists of four items, each scored on a 7-point Likert scale (ranging from 1=all of the time to 7=none of the time). Lower scores indicate more fatigue. The validity and reliability of the CRQ-F were demonstrated in the COPD population (Wijkstra et al., 1994). The Cronbach's alpha values for the CRQ-F were 0.78 (Wijkstra et al., 1994) and 0.88 (Reda et al., 2010). Concurrent validity with the Clinical COPD Questionnaire was reported (r=0.58) (Reda et al., 2010).

Dyspnea was assessed using the CRQ-Dyspnea (CRQ-D) scale, which asks subjects to rate the dyspnea they experience during selected activities on a regular basis (Guyatt et al., 1987). The CRQ-D is a five-item instrument with a 7-point Likert scale (ranging from 1=extremely short of breath to 7=not at all short of breath). Lower scores indicate more severe dyspnea. The CRQ-D's reliability and validity were demonstrated in the COPD population (Reda et al., 2010). The Cronbach's alpha value for the CRQ-D was 0.99 (Reda et al., 2010), and concurrent validity with the Clinical COPD Questionnaire was reported (r=0.42).

Depression and Anxiety. Depression and anxiety were assessed using the PROMIS selfreport depression and anxiety scale, computerized adaptive testing (CAT) version. The PROMIS item bank was established by researchers of the National Institutes of Health, who used item response theory to develop subjective measures with a high level of interval measurement precision approaching that of physiological instruments. Subjects respond to one item per tablet computer screen, and selection of the next item is guided by the subject's response to a previously administered item. T-scores from CAT, rescales the raw score into a standardized score with a mean of 50 and SD of 10, were used for depression and anxiety. CAT has been found to be appropriate for the general adult population and adults with chronic health conditions.

Participants' age, gender, and employment status were measured using the American Thoracic Society-Division of Lung Disease (ATS-DLD) respiratory questionnaire (Guyatt et al., 1987). In addition, pulmonary function tests (PFT) were performed to measure COPD severity. PFTs were administered using the Vmax Encore 22 (Viasys Healthcare Inc., Yorba Linda, CA) in adherence to ATS standards (Miller et al., 2005).

4. Statistical Analysis

Descriptive statistics (means, standard deviations, and percentages) were used to describe participant characteristics. Group-based trajectory analysis in STATA TRAJ (Jones & Nagin, 2012; Jones & Nagin, 2013) was used to identify sleep patterns across the 7-day period. Groupbased trajectory modeling is a type of finite mixture modeling that extends growth curve modeling for distinct subgroups, allowing the shape of the trajectories to vary across the subgroups. This type of group-based trajectory model is useful for exploring previously unrecognized but distinct patterns and identifying meaningful but unknown (or unmeasurable) homogeneous subpopulations (trajectory classes). Group-based trajectory analysis handles missing data by fitting the model using maximum likelihood estimation, generating asymptotically unbiased parameter estimates assuming the data are missing at random (D. S. Nagin & Odgers, 2010).

In this study, a separate censored normal trajectory model was estimated for each of five measures of daily sleep (SL, TST, WASO, NA, and SE). For each measure, model selection

involved iterative estimation of (a) the number of trajectory groups and (b) the shape of each trajectory group based on both statistical and non-statistical considerations. Statistical criteria for ascertaining the best fitting model included two log-likelihood statistics (Akaike's Information Criterion [AIC] and Bayesian Information Criterion [BIC]). Smaller AIC and BIC values indicate a better model. After distinct trajectory groups were identified, a χ^2 -test and t-test were performed to compare groups in terms of participant characteristics. Data analysis was performed using STATA 14.0 software (StataCorp, College Station, TX, USA), and a p-value < .05 was considered statistically significant.

D. Results

1. Participant Characteristics

The mean age of the 56 study participants was 65 years, and more than half of the participants (53.6%) were male. Most participants were black (64.3%) and unemployed (82.1%). The mean predicted percentage of forced expiratory volume in 1 second (FEV1 %) was 69.4, and 60.7% of participants had moderate pulmonary function (50 to <80) based on the GOLD standard. All participants had a history of smoking, with a mean duration of over 28 years. Their mean self-reported sleep disturbance on the SII was 15.6, and their mean self-efficacy for sleep on the SES was 23.9. Their mean levels of dyspnea and fatigue on the CRQ-D and CRQ-F were 4.9 and 3.9, and their mean scores for depression and anxiety on PROMIS were 53.6 and .58.9, respectively (see Table V).

2. Weekly Sleep Characteristics

Table VI shows weekly sleep variable characteristics for the study participants. The mean SL was longest on Tuesday (40.6 ± 61.4 minutes) and shortest on Wednesday (27.0 ± 32.2 minutes), and WASO was longest on Friday (66.9 ± 59.1 minutes) and shortest on Wednesday (56.6 ± 31.8

minutes). NA was highest on Wednesday (39.1 ± 20.0 times) and lowest on Sunday (34.2 ± 12.9 times), whereas TST was longest on Sunday (391 ± 99.5 minutes) and shortest on Saturday (372.9 ± 123.5 minutes). Finally, SE was lowest on Tuesday and Saturday ($76.8\pm14.0\%$) and highest on Wednesday ($80.0\pm9.6\%$).

3. Sleep Trajectories

Figure 3 shows a graphic representation of sleep trajectories for all the sleep variables. For SL, two participant groups were identified as "short SL" (Group 1) and "long SL" (Group 2). SL Group 1 (76.1%) showed continuously lower SL levels from Monday through Sunday, while SL Group 2 (23.9%) showed an inclining SL pattern during the week. For TST, two groups were labeled as "long TST" (Group 1) and "short TST" (Group 2). TST Group 1 (53.3%) showed longer TST throughout the week than TST Group 2 (46.7%). For WASO, two groups were identified as "lower WASO" (Group 1) and "curved WASO" (Group 2). WASO Group 1 (92.2%) showed continuously lower WASO during the week, but WASO Group 2 (7.8%) showed continuous WASO decline from Monday through Thursday and then an incline for the rest of the week. For NA, two groups were labeled as "low NA" (Group 1) and "high NA" (Group 2). NA Group 1 (67.0%) showed continuously lower NA through Friday and then a modest incline for the rest of the week, whereas NA in Group 2 (33.0%) was continuously high (over 40). Finally, for SE, two groups were identified as "high SE" (Group 1) and "low SE" (Group 2). SE Group 1 (76.8%) showed a declining SE pattern throughout the week, with Sunday having the lowest SE; in contrast, SE Group 2 (23.2%) showed good sleep quality (high SE) throughout the week.

4. Differences in Trajectory Group Characteristics

Table VII presents differences in trajectory group characteristics. In the SL groups, significant differences were observed in current smoker and self-efficacy for sleep scores. In the long SL group (Group 2), 72.7% of participants were current smokers compared to 38.8% in the short SL group (Group 1); with regard to self-efficacy for sleep, the mean score of the long SL group (Group 2) was significantly lower than that of the short SL group (Group 1). In the TST groups, there was a significant difference in mean age; in the long TST group (Group 1), the mean participant age was 68 years, which was significantly higher than the 61.8 years of the short TST group (Group 2) (p < .05). In the NA groups, significant differences were found in self-efficacy for sleep and subjective sleep disturbance. The mean self-efficacy for sleep score was 20.3 for the high NA group (Group 2), which was significantly lower than 25.0 for the low NA group (Group 1) ($p \le 0.05$), and the mean subjective sleep disturbance score for the high NA group (Group 2) was significantly higher than that for the low NA group (Group 1) (p < .05). No significant differences in characteristics were observed in the SE groups or in the WASO groups. No significant differences in dyspnea, fatigue, depression, and anxiety were observed between groups.

E. Discussion

To my knowledge, this study was the first to apply group-based trajectory analysis to identify sleep patterns over the week in the COPD population. Previous studies employed averaged values for sleep variables collected over several days using an actigraph device or onenight measurements of sleep variables using polysomnography (PSG). Despite their respective merits, both of these methods make it difficult to detect night-to-night patterns in sleep characteristics. In this study, sleep patterns were examined over 7 days to provide new and more detailed information on sleep characteristics and thus to contribute to development of more

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effective sleep interventions for COPD patients. The study findings offer two principal insights into sleep patterns among such patients. First, sleep patterns were found to follow two distinct trajectories, such as low and high or short and long, for each variable. And second, these patterns were significantly related to self-efficacy for sleep, current smoker status, and subjective sleep disturbance.

Regarding the two SL trajectories found in this study, more than half of the participants were included in the short SL group. The estimated SL value in the short SL group was stable at about 30 minutes across the week but was three times longer than the values found in healthy individuals (Natale, Plazzi, & Martoni, 2009; Nunes et al., 2013) and a general insomnia group (Natale et al., 2009) in previous studies. The other trajectory group, referred to as long SL, exhibited a longer SL value across the week than the short SL group, and the mean daily value in the long SL group tended to show greater fluctuation, indicating that their sleep pattern was irregular. Several reasons for longer sleep onset time have been reported in previous studies, including use of media and occurrence of night-time symptoms. However, COPD patients experiencing longer SL on a continuous basis require special attention from clinicians to avoid reduced QOL or other negative health outcomes. As discussed below, this study revealed a significant difference in self-efficacy for sleep between the two SL groups, but further research is needed to identify factors influencing long SL in order to productively alter individuals' sleep patterns.

As to TST, trajectory analysis revealed two distinct sleep patterns—short TST and long TST—and the mean age of the long TST group was higher than that of the short TST group. In general, total sleep time declines with age (Cooke & Ancoli-Israel, 2011), but the present study's results indicated the opposite. Parwanta et al. (2016) also reported that TST was longer in younger-old COPD patients (i.e., those aged from 65 to 76 years) than in older-old COPD patients (i.e., those aged 77 years and above). In addition, Nunes et al. (2013) found no correlation between age and TST in either a COPD or healthy population. The associations between older age and longer TST found in both Parwanta et al.'s and the present study may be due to study-specific participant characteristics or COPD-related characteristics. Further studies are needed to clarify the relationship between TST and age in the COPD population as well as to identify particular mechanisms or factors of this relationship that could be exploited to promote their sleep quality.

With regard to awakening during sleep, the short NA group showed a lower and more stable pattern than the high NA group throughout the week. The two significant differences in participant characteristics observed between the two NA groups involved self-efficacy for sleep and levels of subjective sleep disturbance measured as SII scores. Although the study design did not allow identification of causal relationships between self-efficacy for sleep and NA, the findings suggest that increasing confidence for sleep may be a productive strategy for improving objective sleep quality and reducing subjective sleep disturbance in the COPD population. Regarding subjective sleep disturbance, only NA among the objective sleep variables showed a significant difference between the two groups. Thus, the number of times that COPD patients wake during the night appears to significantly influence their recognition of their sleep disturbance.

In the WASO and SE groups, two distinct patterns were found for each variable, but no significant differences in participant characteristics were found between the respective groups. For WASO, the low WASO group, which included 92.2% of the participants, showed a stable WASO time of about 60 minutes that was lower than the curved WASO group's and the 96

minutes found in other COPD studies (Budhiraja et al., 2012; Nunes et al., 2013). However, the lower WASO time exceeded the 18 minutes previously observed for healthy individuals (Natalie et al., 2008). In contrast, the curved WASO group consisting of about 7.8% of participants exhibited fluctuations in WASO during the week that followed a distinct curve and a WASO time longer than that reported in other studies (Budhiraja et al., 2012; Nunes et al., 2013). For SE, 24.2% of participants fell into the low SE group, which showed a declining pattern from about 70% to 60% from Wednesday to Sunday. Given these findings, SE in this group was lower than that previously measured in other COPD populations (Budhiraja et al., 2012; Nunes et al., 2013; Spina et al., 2017) and in healthy individuals (Nunes et al., 2013). Both the curved WASO and low SE groups showed irregular and problematic sleep patterns calling for special attention from clinicians because irregular and unpredictable sleep is a source of frustration and distress to insomnia sufferers (Carey, Moul, Pilkonis, Germain, & Buysse, 2005). The participants exhibiting these patterns tended to be male, to have lower pulmonary function and lower selfefficacy for sleep, and to display more severe subjective sleep disturbance than the low WASO group and high SE group, but no significant differences in demographic or disease-related characteristics were found between the respective groups. Further studies are needed to identify and confirm factors influencing these groups across the week in order to accumulate the detailed information required to improve such individuals' sleep quality. In addition, further sleep research that extends to 2 or more weeks is needed to confirm the WASO and SE patterns identified.

In this study, the sleep trajectories defined significantly differed in terms of self-efficacy for sleep, current smoker status, and subjective sleep disturbance. Self-efficacy, according to Bandura (1989), is peoples' belief in their ability to participate in certain behaviors needed to

promote their health, and self-efficacy for sleep refers to peoples' confidence in their ability to engage in sleep behaviors such as falling asleep, staying asleep, and obtaining refreshing sleep (Lacks, 1987). In previous research on people with insomnia, improvement of self-efficacy has been associated with successful hypnotic tapering of medication (Belleville & Morin, 2008), and high self-efficacy for undertaking sleep was one of the most significant predictors of acceptance of behavioral treatment for insomnia (Bluestein et al., 2011). Because self-efficacy for sleep is modifiable through education (Van Houdenhove, Buyse, Gabriels, & Van den Bergh, 2011), the study findings suggest that objective sleep quality in the COPD population could be increased by improving confidence for sleep. The single study known to be addressing this possibility is ongoing (Kapella et al., 2016), but improvement of self-efficacy for sleep could be a useful alternative to medication for decreasing sleep disturbance.

Two limitations of this study should be acknowledged. First, this study included only 56 participants with COPD and disturbed sleep in the Chicago area, and thus the study findings may have limited generalizability to the COPD population as a whole. Second, the cross-sectional nature of the study did not support explanation of potential causal relationships between sleep patterns and demographic and disease-related characteristics.

The study findings have several implications for future research. First, future studies should include extended study periods (2 or more weeks) to confirm sleep patterns observed during 1 week in this study. Second, future studies should also investigate determinants and outcomes for sleep trajectory groups on a longitudinal basis in order to identify causal relationships. Such studies are warranted to explore (1) the effects of improved self-efficacy on alteration of sleep patterns and (2) the long-term health outcomes associated with the altered patterns. Finally, additional research employing group-based trajectory analysis is warranted to identify distinct

sleep patterns in broad populations such as sleep apnea patients. This study included only COPD patients with co-existing disturbed sleep, but if distinct and potentially different sleep patterns could be identified in other populations, the findings would be valuable for development of targeted treatments for specific patterns or groups.

F. Conclusion

In this study of COPD patients with co-existing disturbed sleep, two trajectories characterized all the sleep variables examined, including SL, TST, WASO, NA, and SE. This study differs from other longitudinal research on sleep in its consideration of daily sleep variables for COPD patients to identify their sleep patterns. Observation of actual sleep patterns in COPD patients over time is necessary to understand their sleep variability or stability and gain insights for sleep management. More research is needed to confirm these longitudinal patterns and explore their outcomes. Furthermore, it would be worthwhile to examine self-efficacy for sleep as a potential means of improving sleep patterns in the COPD population.
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Table V

Participants Characteristics

| | | (N=56) |
|---------------------------------|-----------|-----------|
| | Mean | N (%) |
| Age | 65.2±7.8 | |
| Gender | | |
| Male | | 30 (53.6) |
| Female | | 26 (46.4) |
| Race | | |
| White | | 17(30.4) |
| Black | | 36(64.3) |
| Asian | | 1 (1.8) |
| American Indian or Alaskan | | 2 (3.6) |
| Working Status | | |
| Not working | | 46 (82.1) |
| Working (Part time, full time) | | 8 (14.3) |
| Housewife | | 2 (3.6) |
| FEV1 % predicted | 69.4±20.1 | |
| ≥80 (Mild) | | 14 (25.0) |
| 50 to <80 (Moderate) | | 34 (60.7) |
| 30 to <50 (severe) | | 6 (10.7) |
| < 30 (Very Severe) | | 2 (3.6) |
| Smoking (pack/year) | 28.5±25.0 | |
| Self-reported sleep disturbance | 15.6±4.3 | |
| Self-Efficacy for sleep | 23.9±6.5 | |
| Dyspnea | 4.8±1.6 | |
| Fatigue | 3.9±1.1 | |
| Depression | 53.6±8.7 | |
| Anxiety | 58.9±8.2 | |

Table VISleep Characteristics

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|------|-------------|-------------|-------------|-------------|-------------|-------------|------------|
| SL | 30.0±41.5 | 40.6±61.4 | 27.0±32.2 | 28.3±30.9 | 31.7±44.0 | 30.4±39.8 | 35.8±46.8 |
| WASO | 59.1±37.3 | 60.0±38.9 | 56.6±31.8 | 61.1±34.9 | 66.9±59.1 | 59.4±44.3 | 57.2±32.7 |
| NA | 38.8±19.6 | 37.2±19.0 | 39.1±20.0 | 36.3±16.2 | 38.4±23.6 | 35.8±20.3 | 34.2±12.9 |
| TST | 384.9±103.5 | 380.9±109.3 | 386.8±109.8 | 381.4±112.3 | 380.7±116.9 | 372.9±123.5 | 391.0±99.5 |
| SE | 78.5±10.2 | 76.8±12.3 | 80.0±9.6 | 77.2±12.5 | 77.3±12.3 | 76.8±14.0 | 77.1±12.0 |





Solid lines are estimated trajectories and dot symbols are observed group means at each time point

| | S | L | TS | ST | WA | ASO | N | A | S | Е |
|------------------------------|-------------|-------------|------------|-------------|------------|------------|-------------|-------------|------------|------------|
| Variables | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| v artables | (Short SL, | (Long SL, | (Long TST, | (Short TST, | (Low WASO | , (Curved | (Low NA, | (High, NA, | (High SE, | (Low SE, |
| | 76.1%) | 23.9%) | 53.3%) | 46.7%) | 92.2%) | WASO,7.8%) | 67.0%) | 33.0%) | 76.8%) | 23.2%) |
| Age | 64.9 (1.2) | 66.0 (1.9) | 68.1(1.4)* | 61.8 (1.3)* | 64.8 (1.0) | 69.7 (5.9) | 65.4(1.3) | 64.5 (1.7) | 65.8 (1.3) | 63 (1.4) |
| Male (%) | 23 (53.0) | 7 (53.0) | 14 (46.0) | 16 (61.0) | 26 (50.0) | 4 (100.0) | 18 (47.4) | 12 (66.7) | 21 (48.8) | 9 (69.2) |
| Current Smoker (%) | 14 (38.8)* | 8 (72.7)* | 11 (44.0) | 11 (50.0) | 21 (47.3) | 1 (25.0) | 15(45.5) | 7 (50.0) | 16 (44.5) | 6 (54.5) |
| FEV ₁ % predicted | 68.3 (3.2) | 73.0 (4.4) | 72.2 (3.9) | 66.3(3.6) | 70.2 (2.8) | 59.3 (6.8) | 72.1(4.5) | 64 (50.0) | 70.9 (3.3) | 64.6 (3.8) |
| Self-efficacy for Sleep | 25.0 (0.9)* | 20.3 (1.5)* | 23.5 (1.2) | 24.3(1.2) | 24.1 (0.3) | 22.0 (3.6) | 25.4 (1.0)* | 20.7 (1.3)* | 24.5 (1.0) | 22.1 (1.4) |
| SII | 15.2 (0.7) | 16.8 (0.9) | 15.8 (0.6) | 15.3 (0.8) | 15.4 (0.6) | 17.8 (1.9) | 14.7 (0.7)* | 17.4(1.0)* | 15.0 (0.7) | 17.4 (1.0) |
| Dyspnea | 4.8 (0.3) | 5.0 (0.3) | 4.9 (0.5) | 4.8 (0.3) | 4.9 (1.1) | 3.7 (0.2) | 5.1 (0.2) | 4.4 (0.4) | 4.9 (0.2) | 4.7 (0.5) |
| Fatigue | 4.0 (0.2) | 3.6 (0.2) | 3.9 (0.2) | 3.9 (0.2) | 3.9 (0.1) | 4.1 (0.3) | 4.1 (0.2) | 3.9 (0.1) | 3.9 (0.1) | 3.7 (0.3) |
| Depression | 53.3 (1.4) | 54.5 (2.1) | 52.2 (1.7) | 55.2 (1.5) | 53.3 (1.2) | 56.9 (2.7) | 52.5 (1.5) | 55.7 (1.8) | 52.7 (1.9) | 56.4 (1.8) |
| Anxiety | 59.1 (1.3) | 58.3 (2.1) | 58.1 (1.8) | 59.8 (1.8) | 58.8 (1.2) | 60.9 (3.3) | 58.3 (1.4) | 60.2 (1.7) | 58.2 (1.3) | 61.2 (1.8) |

Table VII Differences in Trajectory Group Characteristics

Note. SL=sleep onset latency; WASO=wake after sleep onset; NA= number of awakenings after sleep onset; TST= total sleep time; SE=sleep efficiency; $FEV_1\%$ = Percentage of forced expiratory volume in 1 second; SII=Sleep impairment index (Subjective sleep disturbance). *p < .5 APPENDICES

APPENDIX A

1. Total Sleep Time

| | Diagonal | CSH | AR (1) | Unstructured |
|--------------------------------------|----------|------|--------|--------------|
| -2 Restricted Log Likelihood | 3599 | 3420 | 3428 | 3329 |
| Akaike's Information Criterion (AIC) | 3613 | 3436 | 3432 | 3385 |
| Schwarz's Bayesian Criterion (BIC) | 3640 | 3466 | 3440 | 3492 |

2. Sleep Onset Latency

| | Diagonal | CSH | AR (1) | Unstructured |
|--------------------------------------|----------|------|--------|--------------|
| -2 Restricted Log Likelihood | 3596 | 3417 | 3425 | 3326 |
| Akaike's Information Criterion (AIC) | 3610 | 3433 | 3429 | 3382 |
| Schwarz's Bayesian Criterion (BIC) | 3637 | 3464 | 3437 | 3489 |

3. Sleep Efficiency

| | Diagonal | CSH | AR (1) | Unstructured |
|--------------------------------------|----------|------|--------|--------------|
| -2 Restricted Log Likelihood | 3604 | 3415 | 3424 | 3324 |
| Akaike's Information Criterion (AIC) | 3618 | 3431 | 3428 | 3380 |
| Schwarz's Bayesian Criterion (BIC) | 3644 | 3462 | 3435 | 3487 |

4. Wake After Sleep Onset (WASO)

| | Diagonal | CSH | AR (1) | Unstructured |
|--------------------------------------|----------|------|--------|--------------|
| -2 Restricted Log Likelihood | 3607 | 3418 | 3426 | 3325 |
| Akaike's Information Criterion (AIC) | 3621 | 3434 | 3430 | 3381 |
| Schwarz's Bayesian Criterion (BIC) | 3648 | 3465 | 3438 | 3489 |

5. Number of Awakening

| | Diagonal | CSH | AR (1) | Unstructured |
|--------------------------------------|----------|------|--------|--------------|
| -2 Restricted Log Likelihood | 3596 | 3416 | 3425 | 3325 |
| Akaike's Information Criterion (AIC) | 3610 | 3432 | 3429 | 3381 |
| Schwarz's Bayesian Criterion (BIC) | 3637 | 3463 | 3436 | 3488 |

APPENDIX B

UNIVERSITY OF ILLINOIS AT CHICAGO

Office for the Protection of Research Subjects (OPRS) Office of the Vice Chancellor for Research (MC 672) 203 Administrative Office Building 1737 West Polk Street Chicago, Illinois 60612-7227

Approval Notice Amendment to Research Protocol and/or Consent Document – Expedited Review UIC Amendment # 19

February 13, 2017

Mary C. Kapella, PhD, RN Biobehavioral Health Science 845 S. Damen Ave. 226 N.U.R.S., M/C 802 Chicago, IL 60612 Phone: (312) 355-3150 / Fax: (312) 996-8066

RE:

Protocol # 2013-0626

"Efficacy and Mechanisms of Behavioral Therapy for Insomnia Co-Existing with COPD"

Dear Dr. Kapella:

Members of Institutional Review Board (IRB) #3 have reviewed this amendment to your research and/or consent form under expedited procedures for minor changes to previously approved research allowed by Federal regulations [45 CFR 46.110(b)(2) and/or 21 CFR 56.110(b)(2)]. The amendment to your research was determined to be acceptable and may now be implemented.

Please note the following information about your approved amendment:

Amendment Approval Date: February 13, 2017

Amendment:

Summary: UIC Amendment #19 received on January 26, 2017: The proposed changes involve using data collected on the Actiwatch-2 device to conduct an additional study to examine impacts of sleep disturbance on physical activity. Specific aims are (1) to describe patterns and characteristics of physical activity and sleep in patients with COPD and co-existing disturbed sleep, (2) to determine the impact of daily sleep disturbance on COPD patients' following-day physical activity, and (3) Identify determinants of physical activity in patients with COPD and co-existing disturbed sleep. One of research assistants will extract

APPENDIX B (continued)

data for 60 subjects from the dataset and then data cleaning and analysis will be performed. A separate substudy protocol was submitted.

<u>Approved Subj</u>ect Enrollment #: 300 **Performance Sites:** UIC, Edward Hines Jr., VA Hospital **Sponsor:** NIH, NINR

Research Protocol(s): a) Impacts of Sleep Disturbance on Following-day Physical Activity in COPD Population, PI: Inah Kim, MSN, RN, Protocol V1; 01/16/2017

Please note the Review History of this submission:

| Receipt Date | Submission Type | Review Process | Review Date | Review Action |
|--------------|------------------------------|-----------------------|-------------|---------------|
| 01/26/2017 | Amendment | Expedited | 02/01/2017 | Modifications |
| | | | | Required |
| 02/08/2017 | Response To Modifications | Expedited | 02/13/2017 | Approved |

Please be sure to:

 \rightarrow Use your research protocol number (2013-0626) on any documents or correspondence with the IRB concerning your research protocol.

 \rightarrow Review and comply with all requirements on the guidance,

"UIC Investigator Responsibilities, Protection of Human Research Subjects" (http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)

Please note that the UIC IRB #3 has the right to ask further questions, seek additional information, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS at (312) 996-1711 or me at (312) 413-3788. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Rachel Olech, B.A., CIP Assistant Director, IRB # 3 Office for the Protection of Research Subjects

Enclosure(s): None

cc: Mariann R. Piano, Biobehavioral Health Science, M/C 802

VITA

| | V A A Z X |
|-------------------|---|
| NAME | Inah Kim |
| Education | |
| 2018 | Ph.D. Nursing Science University of Illinois at Chicago, Chicago, Illinois |
| 2014 | Master of Science Degree in Nursing Pusan National University, Pusan, Korea |
| 2010 | Bachelor of Science Degree in Nursing Pusan National University, Pusan, Korea |
| RESEARCH EXPERIEN | CE |
| 2017 | Research Assistant "Multivariable Closed-Loop Technologies for Physically Active Young Adults with Type 1 Diabetes" Laurie Quinn (PI), R01DK085611 |
| 2015-2016 | Research Assistant "Strength Training to Enhance Early Recovery after Stem Cell Transplantation" Eileen Hacker (PI), American Cancer Society, RSG-13-054-01-PCSM |
| 2010 | Research Assistant "The Effects of Nurse-Physician Partnership on Treatment of Chronic Obstructive Pulmonary Disease" Haejung Lee (PI), National Research Foundation of Korea (NRF) (2009- 0088833) |

TEACHING EXPERIENCE

| Teaching Assistant, College of Nursing |
|---|
| University of Illinois at Chicago, Chicago, Illinois |
| Lecturer, Seminars for Nursing Excellence Summer Lecture Series |
| University of Illinois at Chicago, Chicago, Illinois |
| Clinical instructor for vising Korean undergraduate students |
| University of Illinois at Chicago, Chicago, Illinois |
| |

PROFESSIONAL EXPERIENCE

 2011-2013 Staff Nurse, Cardiothoracic Surgical Unit Pusan National University Hospital
 2014 Staff Nurse, Orthopedic Unit Sungsam Hospital

HONORS/AWARDS/SCHOLARSHIP

2016 W. E. Van Doren Scholarship Fund College of Nursing, University of Illinois at Chicago

| 2016 | Dean Joan L. Shaver Scholarship Fund |
|------|--|
| | College of Nursing, University of Illinois at Chicago |
| 2016 | Gertrude Hess Nursing Scholarship |
| | College of Nursing, University of Illinois at Chicago |
| 2016 | Virginia M. Ohlson Scholarship Award |
| | College of Nursing, University of Illinois at Chicago |
| 2011 | Outstanding Leader Award |
| | Korean Red Cross, Pusan National University |
| 2011 | Outstanding Nursing Student Award |
| | Korea Sigma Theta Tau Society, Pusan National University |
| | |

FUNDED RESEARCH GRANTS

| College of Nursing PhD Student Research Awards | 3/31/17-12/15/17 |
|--|------------------|
| "Sleep disturbance and physical activity in COPD" | |
| Direct Expenses: \$500 | |
| Sigma Theta Tau International Alpha Lambda Chapter Award | 3/31/17-12/15/17 |
| "Sleep disturbance and physical activity in COPD" | |
| Direct Expenses: \$1000 | |

PUBLICATIONS

Articles

- Kim, I., Hacker, E., Ferrans, C. E., Horswill, C., Park, C., & Kapella, M. (2017). Evaluation of fatigability measurement: Integrative review. *Geriatric Nursing*. https://doi.org/10.1016/j.gerinurse.2017.05.014
- Hacker, E. D., Kim, I., Park, C., & Peters, T. (2017). Real-time Fatigue and Free-Living Physical Activity in Hematopoietic Stem Cell Transplantation Cancer Survivors and Healthy Controls: A Preliminary Examination of the Temporal, Dynamic Relationship. *Cancer nursing*, 40(4), 259-268.
- Kim, I., & Lee, H. (2014). Effects of a Progressive Walking Program on Physical Activity, Exercise Tolerance, Recovery, and Post-Operative Complications in Patients with a Lung Resection. *Journal of Korean Academic Nursing*, 44(4), 381-390. doi: 10.4040/jkan.2014.44.4.381.
- Lee, H., Boo, S., Lim, Y., Kim, S., & **Kim, I.** (2014). Accuracy of Inhaler Use in Patients with COPD. *Clinical Nursing Research*, *23*(5), 560-574. doi: 10.1177/1054773813498269.
- Lee, H., Yoon, J., Kim, I., & Jeong, Y. (2013). The Role of Personal Resources and Coping Strategies on Depression and Anxiety in Patients with Chronic Obstructive Pulmonary Disease. *Heart and Lung*, 42, 473-479. doi: 10.1016/j.hrtlng.2013.07.009
- Choi, E., Lee, H., **Kim, I**., Lim, Y., Lee, M., & Kim, M. (2011). Delirium Assessment Ability of Clinical Nurses. *Journal of Korean Gerontological Nursing*, *13*(3), 233-241.
- Lee, H., **Kim, I.**, Lim, Y., Jung, H., & Park, H. (2011). Depression and Sleep Disturbance in Patients with Chronic Obstructive Pulmonary Disease. *Geriatric Nursing*, *32*(6), 408-417. doi: 10.1016/j.gerinurse.2011.08.002

Abstract

Kim, I, Park, C., Vispute, S., Collins, E., & Kapella, M. (2017). 1021 Sleep Disturbance And Physical Activity In Copd Patients Based On Nhanes 2005–2006 Data. Sleep. 40 (Abstract Supplement): A380. doi: 10.1093/sleepj/zsx050.1020.

PRESENTATIONS

- Kim, I., Hacker, E. D., & Park, C. (2016 Sep.). Evaluation of the Dynamic Relationship between Real-Time Fatigue and Free-Living Physical Activity. Podium presentation at 2016 State of the Science Congress on Nursing Research: Determinants of Health in September, Washington, DC.
- Hacker, E. D, Collins, E., Park, C., Rondelli, D., Peters, T., & Kim, I. (2016, March). Frailty Assessment Prior to Hematopoietic Stem Cell Transplantation. Poster presentation at Midwest Nursing Research Society (MNRS) 40th Annual Research Conference, Milwaukee, Wisconsin.
- **Kim, I.**, Lee, H., & Yoon, J. (2013, Oct.). The mediating role of coping strategies on the relation between personal resources and depression and anxiety in old patients with COPD. Oral presentation at the 3rd World Academy of Nursing Science, Seoul, Korea.
- Lee, H., Lim, Y., Kim, S., & Kim, I. (2013, June). Factors affecting life satisfaction among patients with chronic obstructive pulmonary disease. Poster session presented at The 20th International Association of Gerontology Geriatrics (IAGG) World Congress of Gerontology and Geriatrics, Seoul, Korea.
- Lee, H., Lim, Y., **Kim, I.,** & Kim, S. (2012, July). Personal resources and psychological responses of patients with COPD. Poster session presented at Sigma Theta Tau International 23rd International Nursing Research Congress, Brisbane, Australia.
- Lim, Y., Lee, H., Kim, S., & Kim, I. (2012, Aug.). Do patients with COPD use inhalers correctly? Poster session presented at Sigma Theta Tau International 23rd International Nursing Research Congress, Brisbane, Australia.
- Lim, Y., Lee, H., Kim, I., Park, H. (2011, Oct.). Characteristics related to drop-out and attendance of telephone-based intervention among patients with COPD. Poster session presented at The 8th International Nursing Conference (INC): Nursing education-New paradigm for global environment, Seoul, Korea.
- Lee, H., Jung, Y., Lim, Y., **Kim, I.** (2011, Nov.). Factors affecting levels of anxiety and depression in patients with COPD. Poster session presented at the 64th Annual Scientific Meeting of the Gerontological Society of America (GSA), Boston, MA, USA.

PROFESSIONAL AFFILIATIONS

| 2017-Present | Sleep Research Society |
|--------------|---|
| 2017-Present | Sigma Theta Tau International Honor Society of Nurses |
| 2016-Present | The Council for the Advancement of Nursing |
| 2015-Present | Midwest Nursing Research Society |
| 2010-Present | Korean Nurse Association |
| | |