Exploring the Causes, Magnitude, and Implications of Discrepancies in Objective and Subjective Sleep Measures in Women in the Menopause Transition and Postmenopause

In Hye Park

A dissertation

Submitted in partial fulfillment of the

Requirement for the degree of

Doctor of Philosophy

University of Washington

2024

Reading Committee:

Kerry Reding, Chair

Eeeseung Byun

Teresa Ward

Program Authorized to Offer Degree:

School of Nursing

University of Washington

Abstract

Exploring the Causes, Magnitude, and Implications of Discrepancies in Objective and Subjective Sleep Measures in Women in the Menopause Transition and Postmenopause

In Hye Park

Chair of the Supervisory Committee

Kerry Reding

Department of Biobehavioral Nursing and Health Informatics

Over half of women undergoing the menopausal transition (MT) or postmenopause (PM) experience significant sleep disturbances due to aging, hormonal changes, hot flashes, and night sweats. These issues can severely affect mental health, daily functioning, and overall quality of life. Poor sleep quality during these stages is linked to increased risks of anxiety, depression, and reduced productivity. Accurate assessment of sleep is vital but challenging, as subjective tools like questionnaires often differ from objective methods such as polysomnography (PSG) and actigraphy. However, discrepancies between subjective and objective measures highlight the need for combined approaches to capture the full complexity of sleep disturbances in MT and PM. Despite growing research, the unique sleep challenges faced by women in these stages remain underexplored, emphasizing the importance of targeted studies to inform effective interventions—a gap this dissertation aims to address.

This dissertation investigates the discrepancies between subjective and objective sleep assessments in menopausal and postmenopausal women, offering critical insights into how physiological, psychological, and stress-related factors contribute to sleep disturbances. By examining these issues through subjective and objective measures, it emphasizes the need for nuanced approaches in both research and clinical practice, structured around three main topics (Chapters 2, 3, and 4). Chapter 2 reviews 16 studies (2010–2022) that highlight consistent patterns of subjective sleep assessments overestimating total sleep time (TST) and sleep onset latency (SOL) while reporting more nighttime awakenings (WASO) compared to objective measures like PSG and actigraphy. These discrepancies arise as subjective measures reflect personal perceptions—often influenced by menopausal symptoms such as vasomotor symptoms (VMS) and heightened emotional sensitivity—while objective tools provide a more precise account of physiological sleep patterns. This chapter underscores the importance of integrating both methods to capture the multifaceted nature of sleep disturbances, laying the foundation for targeted clinical interventions. Chapter 3 explores how insomnia amplifies the misalignment between subjective and objective sleep measures. Using data from the Finding Lasting Answers for Symptoms and Health (MsFLASH) research network, it examines key sleep parameters (TST, SOL, WASO, and sleep efficiency [SE]) across actigraphy, PSQI, and sleep diaries. Results show that women with insomnia experience greater perceptual discrepancies, often overestimating TST and SE while underestimating SOL and WASO compared to objective data. These biases are more pronounced in PSQI scores, likely due to recall errors inherent in retrospective reporting. The findings highlight insomnia's role in altering sleep perception through mechanisms such as heightened cortical activation and impaired sensory processing, emphasizing the need for combined assessment methods to accurately evaluate sleep in menopausal populations.

Chapter 4 investigates how VMS and stress influence discrepancies in sleep assessment. Using MsFLASH data, the study evaluates SOL, TST, WASO, and SE through actigraphy, PSQI, and sleep diaries, while also considering perceived stress and physiological stress via nighttime salivary cortisol. Results reveal that VMS contributes significantly to overestimations of SOL and WASO and underestimations of TST and SE in subjective reports, particularly PSQI, highlighting the impact of symptom-driven perceptual biases. While perceived stress affected SOL discrepancies, physiological stress (cortisol) showed no consistent relationship, questioning its reliability as a stress marker in sleep studies. This chapter advocates for integrating actigraphy with sleep diaries for a more accurate depiction of sleep patterns in women with VMS and stress, cautioning against overreliance on PSQI for nuanced sleep assessments. This research highlights the interplay between menopausal symptoms and sleep perception, advocating for multifaceted assessment strategies to enhance clinical practices. This dissertation underscores the importance of adopting a comprehensive, multi-method approach to evaluating sleep disturbances in menopausal and postmenopausal women. By exploring the discrepancies between subjective and objective sleep evaluations, it reveals the shortcomings of relying solely on single-method assessments to understand the intricate interaction between physiological and perceptual elements of sleep. Factors such as VMS, insomnia, and stress play a significant role in shaping these discrepancies, emphasizing the value of dual-method approaches that combine objective measurements with subjective accounts.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This doctoral journey would not have been possible without the unwavering support and encouragement of so many incredible individuals. The past few years, particularly during the COVID-19 pandemic and through personal health challenges, have been a time of significant change and difficulty. However, it was the collective help and kindness of those around me that enabled me to navigate this long and challenging path.

First and foremost, I extend my deepest gratitude to my dissertation committee members for their encouragement and guidance. I am especially thankful to my committee chair, Dr. Kerry Reding, for her thoughtful mentorship and kindness. I am equally grateful to Dr. Eeeseung Byun and Dr. Teresa Ward for their steadfast support and willingness to join my committee when changes were needed. Their cooperation and commitment to my journey were invaluable, and I am truly appreciative of their guidance throughout this process.

I would also like to express my heartfelt thanks to Dr. Diana Buchanan and Dr. Nancy Woods, who served as my previous committee chair and member, respectively, and whose guidance was instrumental in shaping my dissertation proposal and broader research vision.

I am deeply grateful to the MsFLASH Network for granting me access to their well-established datasets, which formed the foundation of my dissertation. Their resources provided a remarkable opportunity to contribute to meaningful research in this field.

The University of Washington School of Nursing has been an exceptional environment for my academic growth. Serving as a teaching assistant for various graduate and undergraduate courses not only advanced my insight as a nursing educator and researcher but also enriched my perspective on health and nursing education.

I am also profoundly thankful for the financial support I received through scholarships, including the Robert L. and Catherine M. Zesbaugh Scholarship Fund, the David & Pauline

Pfeiffer Endowed Fund, and the Hester McLaws Dissertation Grant. These scholarships greatly eased my financial burden and allowed me to focus on my academic progress.

To my PhD nursing cohort and fellow doctoral students, I extend my heartfelt thanks. Their encouragement, camaraderie, and willingness to share knowledge, philosophies, and perspectives have been an invaluable resource throughout my doctoral studies.

I would like to give special thanks to Ms. Betsy Mau, and Ms. Emma Lorenzo for their friendly advice and practical support with academic administration, financial matters, and other logistical challenges. Their help ensured a smoother journey through my program.

Finally, and most importantly, I would like to thank my family—my mom, dad, younger brother, and my husband. Their endless encouragement, love, and unwavering support have been my greatest source of strength during this meaningful milestone. Without them, this profound academic pursuit would not have been possible.

CHAPTER 1. Introduction

Sleep disturbances are a common and significant health concern for women during the menopausal transition (MT) and postmenopausal (PM) stages, with an estimated 40% to 60% of this population reporting sleep-related issues (Kravitz & Joffe, 2011; Makara-Studzińska et al., 2014). While the high prevalence of sleep problems is well-documented, there remains a gap in understanding the specific factors that drive these disturbances, particularly in terms of how sleep is perceived versus how it is objectively measured.

Subjective sleep assessments, such as self-reported questionnaires and sleep diaries, often show considerable differences when compared to objective measurements like polysomnography (PSG) and actigraphy. Investigating these discrepancies is critical, as they may reflect not only physiological factors but also psychological variables that influence how women perceive and experience sleep disturbances during midlife.

Such discrepancies between subjective and objective sleep assessments are not unique to midlife women; they are observed across various populations, from healthy individuals to those with medical conditions (Lauderdale et al., 2008; Trajanovic et al., 2007; Unruh et al., 2008). However, among midlife women, relatively few studies have rigorously compared subjective and objective sleep discrepancies within the same cohort. Where these comparisons have been made, findings indicate that subjective reports often underestimate sleep parameters, such as total sleep time (TST) and sleep efficiency (SE), and overestimate factors like sleep onset latency (SOL) and wakefulness after sleep onset (WASO) (Girschik et al., 2012; Trajanovic et al., 2007). Despite these findings, the mechanisms behind these subjective-objective mismatches remain largely unexplored, particularly in the context of menopause.

One of the primary contributors to these sleep discrepancies is insomnia, which is highly prevalent during menopause. Insomnia is known to be associated with heightened arousal in both the central nervous system (CNS) and peripheral nervous systems, which can

interfere with normal sleep regulation and sensory perception (Bonnet & Arand, 2010; Manconi et al., 2010). This dysregulation may result in sleep that feels unrefreshing or insufficient, despite normal sleep architecture. For example, increased beta activity in electroencephalographic (EEG) recordings has been observed during sleep in individuals with insomnia, suggesting ongoing cortical activation even during rest (Bonnet & Arand, 2010). Additionally, disruptions in thalamic sensory gating, which typically filters sensory input during sleep, may further exacerbate the perception of wakefulness in individuals who are, in fact, asleep (Buysse et al., 2011). This impaired sensory gating is often marked by reduced sleep spindles and K-complexes in EEG readings, which are hallmarks of sleep consolidation and sensory blocking during sleep (Maes et al., 2014).

Emerging evidence suggests that these neurophysiological mechanisms are also at play in midlife women, particularly during the menopause transition. For example, studies have shown increased beta EEG activity in women who are in the late premenopausal and early postmenopausal stages, compared to those in earlier reproductive phases (Campbell et al., 2011). Research focusing on perimenopausal women with and without insomnia has also revealed elevated acute stress responses, as evidenced by heightened salivary cortisol levels, heart rate, and heart rate variability, particularly among those with insomnia (de Zambotti et al., 2016). These findings point to a sustained autonomic and cortical arousal, potentially explaining the persistent discrepancies between subjective and objective sleep measurements in midlife women.

In addition to physiological mechanisms, psychological factors such as mood disturbances play a significant role in influencing sleep perceptions. The "emotional overlay" hypothesis posits that mood disturbances, which are common during the menopause transition, often triggered by hormonal fluctuations, can distort subjective symptom reporting, including

perceptions of sleep (Shaver & Woods, 2015). Studies have consistently demonstrated that the menopause transition is associated with an increased risk of depressive symptoms, even in women without a prior history of depression (Freeman et al., 2006; Freeman, 2015). Since poor sleep and depression are known to have a bidirectional relationship (Alvaro et al., 2013), the presence of mood disturbances may not only exacerbate sleep problems but may also amplify subjective reports of sleep disturbance, even when objective measures reveal relatively minor disruptions. Mood disturbances also have been linked to an increased perception of vasomotor symptoms (VMS), such as hot flashes, which are commonly reported as disrupting sleep (Cohen et al., 2006; Gibson et al., 2011).

Stress, too, plays a multifaceted role in contributing to these discrepancies in women during menopause. Research has shown that acute stress is associated with heightened CNS arousal and increased discrepancies between subjective and objective sleep assessments (Campbell et al., 2011; de Zambotti et al., 2016). Elevated cortisol levels, especially in women experiencing high stress, have been linked to more severe vasomotor symptoms and worse sleep outcomes (Cagnacci et al., 2011; Woods et al., 2009). Moreover, alterations in the hypothalamic-pituitary-adrenal (HPA) axis, as reflected by flatter diurnal cortisol slopes, have been associated with more intense VMS, greater sleep disturbances, and depressive symptoms (Gibson et al., 2016). This suggests that stress-related mechanisms are central to the complex interplay between physiological arousal, mood, and sleep in menopausal women.

Considering this evidence, exploring the discrepancies between subjective and objective sleep assessments in this population is essential, as it may reveal significant insights into how women perceive and experience sleep disturbances during their menopause transition. Understanding these discrepancies can help healthcare providers interpret sleep assessments more accurately and develop more targeted interventions. By investigating both physiological

and psychosocial factors, this research has the potential to enhance symptom management strategies for midlife women, ultimately improving their quality of life during this critical stage.

This dissertation provides a comprehensive analysis of the existing literature on sleep discrepancies, with a specific focus on their prevalence in women during the menopause transition and postmenopause. It further explores whether the pronounced physiological symptoms experienced by these women contribute to the occurrence of sleep discrepancies. Additionally, the dissertation delves into the potential implications of these discrepancies as revealed through the study findings.

The analysis is divided into two primary chapters (Chapters 3 and 4), following a brief literature review (Chapter 2). It draws on data from the Finding Lasting Answers for Symptoms and Health (MsFLASH) research network. The MsFLASH dataset is robust and multifaceted, comprising clinical data collected for both research and treatment purposes from women undergoing menopause at five clinical sites across the United States, as outlined by Newton et al. (2014). Specifically, the study focuses on women aged 40 to 62 years who are either in the late stages of the menopause transition or within the first five years postmenopause.

The purposes of the dissertation chapters are to: 1) examine the occurrence of discrepancies between subjective and objective sleep assessments in women undergoing the menopause transition and postmenopause, and to explore potential contributing factors; 2) compare subjective and objective sleep measures between women with and without insomnia within this demographic; and 3) investigate the role of vasomotor symptoms and stress in influencing these sleep discrepancies and, if applicable, to elucidate how these factors contribute to the observed differences.

As outlined in the objectives of this dissertation, the study is organized into five distinct

chapters, each contributing to a comprehensive understanding of sleep discrepancies in women during the menopause transition and postmenopausal periods. Chapter 1 serves as an introductory chapter, setting the stage by providing a clear and concise background of the study. It outlines the study's primary objectives, highlights the significance of the dissertation study, and introduces the three major themes that will be rigorously explored in the subsequent chapters. This chapter also frames the relevance of sleep research within the context of menopause, emphasizing the critical importance of understanding sleep discrepancies in this specific population.

Chapter 2, addressing the first aim, conducts a review of sleep research over the past 13 years, particularly focusing on the evolution of sleep studies and the increasing interest in diverse sleep assessment methodologies. This chapter provides an in-depth exploration of sleep phenomena, specifically concentrating on the experiences of women during the menopause transition and postmenopausal stages. It critically examines the occurrence of discrepancies between subjective and objective sleep assessments, exploring their underlying causes and potential implications. Through a comprehensive synthesis of current literature, this chapter sets the foundation for understanding the multifaceted nature of sleep measurement discrepancies in this demographic, providing crucial context for the empirical analyses that follow in later chapters.

Chapter 3, aligned with the second aim of the dissertation, shifts the focus toward a comparative analysis of objective sleep measurements (using actigraphy) and subjective sleep assessments, including the Pittsburgh Sleep Quality Index (PSQI) and sleep diaries. This chapter investigates how symptoms of insomnia contribute to the observed discrepancies between these two assessment methods. By thoroughly analyzing the degree of alignment—or misalignment—between objective and subjective measures of sleep, this chapter seeks to

uncover the complexities of sleep perception in women during the menopause transition and postmenopause. Additionally, it delves into the clinical implications of these measurement discrepancies, offering insights into how they may influence the diagnosis and management of sleep disturbances in this population.

In Chapter 4, which addresses the third aim, the dissertation examines the relationship between sleep discrepancies and various stress-related indicators, as well as vasomotor symptoms, such as hot flashes and night sweats. This chapter investigates the extent to which both physiological and psychological stress, along with vasomotor symptoms, contribute to poor sleep quality and exacerbate the discrepancies between objective and subjective sleep assessments. By integrating data on stress and vasomotor symptoms with sleep measures, this chapter offers a nuanced understanding of the potential drivers behind sleep discrepancies, shedding light on how these factors uniquely affect sleep in menopausal and postmenopausal women.

Chapter 5 serves as the concluding chapter, offering a synthesis of the key findings from Chapters 2, 3, and 4. It provides a comprehensive discussion on the characteristics of sleep in women during the menopause transition and postmenopausal stages, with a specific focus on the discrepancies observed between objective and subjective sleep assessments. This chapter not only summarizes the findings related to insomnia symptoms, stress, and vasomotor disturbances but also addresses their broader implications for clinical practice. The discussion explores how these insights can inform more accurate diagnostic approaches and targeted interventions aimed at improving sleep health in this population, particularly in relation to menopausal symptoms.

REFERENCES FOR CHAPTER 1

Alvaro, P. K., Roberts, R. M., & Harris, J. K. (2013). A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. *Sleep, 36*(7), 1059-1068. https://doi.org/10.5665/sleep.2810

Bonnet, M. H., & Arand, D. L. (2010). Hyperarousal and insomnia: State of the science. *Sleep Medicine Reviews, 14*(1), 9-15. https://doi.org/10.1016/j.smrv.2009.05.002

Buysse, D. J., Germain, A., Hall, M., Monk, T. H., & Nofzinger, E. A. (2011). A neurobiological model of insomnia. *Drug Discovery Today: Disease Models, 8*(4), 129-137. https://doi.org/10.1016/j.ddmod.2011.07.002

Cagnacci, A., Cannoletta, M., Caretto, S., Zanin, R., Xholli, A., & Volpe, A. (2011). Increased cortisol level: A possible link between climacteric symptoms and cardiovascular risk factors. *Menopause, 18*(3), 273-278. https://doi.org/10.1097/gme.0b013e3181f7e613

Campbell, I. G., Bromberger, J. T., Buysse, D. J., Hall, M. H., Hardin, K. A., Kravitz, H. M., … & Gold, E. (2011). Evaluation of the association of menopausal status with delta and beta EEG activity during sleep. *Sleep, 34*(11), 1561-1568. https://doi.org/10.5665/sleep.1406

Cohen, L. S., Soares, C. N., Vitonis, A. F., Otto, M. W., & Harlow, B. L. (2006). Risk for new onset of depression during the menopausal transition: The Harvard study of moods and cycles. *Archives of General Psychiatry, 63*(4), 385-390. https://doi.org/10.1001/archpsyc.63.4.385

de Zambotti, M., Sugarbaker, D., Trinder, J., Colrain, I. M., & Baker, F. C. (2016). Acute stress alters autonomic modulation during sleep in women approaching menopause. *Psychoneuroendocrinology, 66*, 1-10. https://doi.org/10.1016/j.psyneuen.2015.12.020

Freeman, E. W. (2015). Depression in the menopause transition: Risks in the changing hormone milieu as observed in the general population. *Women's Midlife Health, 1*(1), 2.

https://doi.org/10.1186/s40695-015-0002-y

Freeman, E. W., Sammel, M. D., Lin, H., & Nelson, D. B. (2006). Associations of hormones and menopausal status with depressed mood in women with no history of depression. *Archives of General Psychiatry, 63*(4), 375-382. https://doi.org/10.1001/archpsyc.63.4.375

Gibson, C., Thurston, R., & Matthews, K. (2016). Cortisol dysregulation is associated with daily diary-reported hot flashes among midlife women. *Clinical Endocrinology, 85*(4), 645-651. https://doi.org/10.1111/cen.13111

Gibson, C. J., Thurston, R. C., Bromberger, J. T., Kamarck, T., & Matthews, K. A. (2011). Negative affect and vasomotor symptoms in the study of women's health across the nation (SWAN) daily hormone study. *Menopause, 18*(12), 1270. https://doi.org/10.1097/gme.0b013e318222a710

Girschik, J., Fritschi, L., Heyworth, J., & Waters, F. (2012). Validation of self-reported sleep against actigraphy. *Journal of Epidemiology, 22*(5), 462-468. https://doi.org/10.2188/jea.JE20120012

Gordon, J. L., Eisenlohr-Moul, T. A., Rubinow, D. R., Schrubbe, L., & Girdler, S. S. (2016). Naturally occurring changes in estradiol concentrations in the menopause transition predict morning cortisol and negative mood in perimenopausal depression. *Clinical Psychological Science, 4*(5), 919-935. https://doi.org/10.1177/2167702615618971

Jackowska, M., Dockray, S., Hendrickx, H., & Steptoe, A. (2011). Psychosocial factors and sleep efficiency: Discrepancies between subjective and objective evaluations of sleep. *Psychosomatic Medicine, 73*(9), 810-816. https://doi.org/10.1097/PSY.0b013e3182359808

Knight, J. M., Avery, E. F., Janssen, I., & Powell, L. H. (2010). Cortisol and depressive symptoms in a population-based cohort of midlife women. *Psychosomatic Medicine, 72*(9), 855-861. https://doi.org/10.1097/PSY.0b013e3181e9ea0e

Kravitz, H. M., & Joffe, H. (2011). Sleep during the perimenopause: A SWAN story. *Obstetrics and Gynecology Clinics, 38*(3), 567-586. https://doi.org/10.1016/j.ogc.2011.05.011

Lauderdale, D. S., Knutson, K. L., Yan, L. L., Liu, K., & Rathouz, P. J. (2008). Sleep duration: how well do self-reports reflect objective measures? The CARDIA Sleep Study. *Epidemiology, 19*(6), 838-845. https://doi.org/10.1097/EDE.0b013e318187a7b0

Maes, J., Verbraecken, J., Willemen, M., De Volder, I., Van Gastel, A., Michiels, N., … & Willemen, T. (2014). Sleep misperception, EEG characteristics and autonomic nervous system activity in primary insomnia: A retrospective study on polysomnographic data. *International Journal of Psychophysiology, 91*(3), 163-171. https://doi.org/10.1016/j.ijpsycho.2013.10.011

Makara-Studzińska, M. T., Kryś-Noszczyk, K. M., & Jakiel, G. (2014). Epidemiology of the symptoms of menopause–an intercontinental review. *Menopause Review/Przegląd Menopauzalny, 13*(3), 203-211. https://doi.org/10.5114/pm.2014.43824

Manconi, M., Ferri, R., Sagrada, C., Punjabi, N., Tettamanzi, E., Zucconi, M., … & Ferini-Strambi, L. (2010). Measuring the error in sleep estimation in normal subjects and in patients with insomnia. *Journal of Sleep Research, 19*(3), 478-486. https://doi.org/10.1111/j.1365-2869.2010.00831.x

Newton, K. M., Carpenter, J. S., Guthrie, K. A., Anderson, G. L., Caan, B., Cohen, L. S., … & Reed, S. D. (2014). Methods for the design of vasomotor symptom trials: The MsFLASH network. *Menopause, 21*(1), 45-58. https://doi.org/10.1097/GME.0b013e31829d6825

Nosek, M., Kennedy, H. P., Beyene, Y., Taylor, D., Gilliss, C., & Lee, K. (2010). The effects of perceived stress and attitudes toward menopause and aging on symptoms of menopause. *Journal of Midwifery & Women's Health, 55*(4), 328-334. https://doi.org/10.1016/j.jmwh.2009.07.004

Shaver, J. L., & Woods, N. F. (2015). Sleep and menopause: A narrative review. *Menopause, 22*(8), 899-915. https://doi.org/10.1097/GME.0000000000000419

Trajanovic, N. N., Radivojevic, V., Kaushansky, Y., & Shapiro, C. M. (2007). Positive sleep state misperception–a new concept of sleep misperception. *Sleep Medicine, 8*(2), 111-118. https://doi.org/10.1016/j.sleep.2006.07.009

Unruh, M. L., Redline, S., An, M. W., Buysse, D. J., Nieto, F. J., Yeh, J. L., & Newman, A. B. (2008). Subjective and objective sleep quality and aging in the sleep heart health study. *Journal of the American Geriatrics Society, 56*(7), 1218-1227. https://doi.org/10.1111/j.1532-5415.2008.01755.x

Woods, N. F., & Mitchell, E. S. (2010). Sleep symptoms during the menopausal transition and early postmenopause: Observations from the Seattle Midlife Women's Health Study. *Sleep, 33*(4), 539-549. https://doi.org/10.1093/sleep/33.4.539

Woods, N. F., Mitchell, E. S., & Smith-DiJulio, K. (2009). Cortisol levels during the menopausal transition and early postmenopause: Observations from the Seattle Midlife Women's Health Study. *Menopause, 16*(4), 708-718. https://doi.org/10.1097/gme.0b013e3181974fa3

CHAPTER 2. Sleep Measures and Discrepancies in Menopausal Transition and Postmenopausal Women: A Literature Review

Target journal: Sleep Medicine Research (https://www.sleepmedres.org/)

Abstract word count: Limited to 250 words. Abstracts are required for Reviews, but the authors can format the structure.

Manuscript word count (without references): Limited to 4000.

Figures: No limitation.

Tables: Limited to five for Original Papers.

References: No more than 40.

Abstract

Background: Previous research on women around menopause has primarily relied on single-method approaches to assess sleep, limiting the ability to accurately compare subjective and objective sleep measures within the same cohort. Given that sleep architecture and quality can vary with the assessment method, a comprehensive approach using both subjective and objective measures may enhance understanding and interpretation of sleep patterns in this population. **Methods:** This review analyzed literature from 2010 to 2022, drawing from the Web of Science and PubMed databases to evaluate discrepancies between subjective and objective sleep assessments in women going through the menopause. Sixteen studies meeting inclusion criteria were reviewed to identify the extent and causes of measurement discrepancies. **Results:** Notable discrepancies were observed between subjective and objective sleep measures across most studies, particularly in total sleep time (TST), sleep onset latency (SOL), and wake after sleep onset (WASO). Subjective reports often overestimated TST and SOL, while objective measures like polysomnography (PSG) and actigraphy revealed shorter durations. Key contributing factors included the simplicity of self-reported measures, which lack detailed insights into neurobiological sleep architecture, and the relatively low sensitivity of objective measures to the nuanced brain activity changes associated with menopause. **Conclusions:** The observed mismatches underscore the need for dual-method assessments to gain a more accurate and comprehensive understanding of sleep disturbances in menopausal women. These findings highlight critical implications for the development of enhanced sleep evaluation tools and tailored interventions targeting menopausal sleep disturbances.

Keywords: Menopause, Sleep discrepancies, Sleep measures

INTRODUCTION

One of the most prominent health issues experienced by women during the menopausal transition and postmenopause is sleep disturbance, with the prevalence ranging from 40% to 56% (Baker et al., 2018; Lee et al., 2019). These disturbances can be attributed to the aging process, which naturally alters the sleep-wake cycle, causing earlier wake times and reduced deep sleep, leading to more fragmented sleep (Lavoie et al., 2018). Additionally, hormonal fluctuations during menopause, particularly in estrogen and progesterone, cause hot flashes and night sweats that disrupt sleep, as well as mood and stress changes that increase insomnia and other sleep disorders (Baker, 2023).

Sleep disturbances during this period often occur alongside vasomotor symptoms and psychological issues such as depression and anxiety, creating a complex interplay that negatively impacts sleep and perpetuates a vicious cycle (Woods & Mitchell, 2010; Kim et al., 2018). Consequently, there has been a sharp increase in middle-aged women visiting sleep clinics (Santoro et al., 2021), highlighting the importance of accurate sleep assessments.

Evaluating sleep in women undergoing menopausal transition and postmenopause is essential for diagnosing sleep disorders such as insomnia and obstructive sleep apnea and for developing personalized treatment plans. Accurate evaluation helps in understanding the impact of hormonal changes on sleep quality and enables effective treatment strategies, including hormone replacement therapy. Moreover, sleep assessments are crucial for the early diagnosis of comorbid conditions like cardiovascular disease, diabetes, depression, and anxiety, which are often associated with sleep disturbances. Tailored treatment plans can prevent long-term health issues and significantly improve quality of life (Kravitz & Joffe, 2011; Baker & de Zambotti, 2017).

Sleep is predominantly measured using two approaches: objective and subjective

methods. Objective assessments, such as polysomnography (PSG) and actigraphy, offer precise insights into sleep patterns by tracking physiological parameters like brain waves, heart rate, and movement. These methods excel in identifying specific sleep stages and measuring sleep latency but require specialized equipment and clinical settings (Ibáñez et al., 2018; Mendonça et al., 2019). In contrast, subjective methods, including questionnaires, sleep diaries, and logs, offer a more accessible means of evaluating sleep, capturing individuals' habitual sleep patterns and personal perceptions of sleep quality. While less precise, subjective assessments are crucial for providing a holistic view of sleep behavior, especially in large-scale studies (Ibáñez et al., 2018; Mendonça et al., 2019).

Despite the advantages of each method, there is ongoing debate concerning the concordance between the two. Some researchers argue that specific brain wave patterns during sleep align with subjective sleep experiences, suggesting a strong relationship between objective brain wave activities and perceived sleep quality (Gorfine et al., 2006; Muller et al., 2016). However, discrepancies between objectively measured sleep and self-reported sleep have been observed in both healthy (Jackowska et al., 2011; Girschik et al., 2012) and unhealthy populations (Unruh et al., 2008; Hughes et al., 2018). These studies emphasize the tendency for self-reported sleep duration to be overestimated compared to objective measurements. Psychosocial factors such as stress, emotional well-being, and pain, along with health conditions, significantly influence sleep perception, potentially reducing the accuracy of sleep measurements. Discrepancies in sleep measurements across different age and ethnic groups further highlight the need for objective assessments that consider cultural differences, chronic illnesses, and gender-related changes in sleep quality. Collectively, these findings suggest that incorporating both self-reported and objective measures in sleep research and clinical assessments is crucial for collecting accurate sleep data and designing tailored

interventions.

However, a notable limitation in previous research is the reliance on a single method of sleep evaluation, restricting the ability to fully understand the interrelation between different sleep measures within the same study population. This study underscores the complexity and multifaceted nature of sleep assessments, emphasizing the necessity of integrating various sleep measures for a comprehensive understanding of sleep patterns and disturbances.

It is crucial to conduct a comparative analysis of both objective and subjective sleep measures within the same cohort. This approach is key to developing a thorough and accurate assessment of sleep. Recognizing the distinctions between these methods and understanding the reasons behind observed differences is vital. In particular, a review of sleep discrepancies targeting middle-aged women in the menopausal transition, who frequently experience sleep problems, is especially necessary.

The expected implications of this study's results are as follows. Firstly, the study aims to enhance the understanding of sleep-wake activity by identifying how different methods capture sleep disturbances in mid-life women. Secondly, it seeks to highlight the factors contributing to sleep disturbances by examining the reasons for discrepancies between subjective and objective measures, leading to a better understanding of the contributing factors. Thirdly, the study aims to inform the development of improved sleep measurements by acknowledging the simplicity of self-reported questions and the low sensitivity of current objective measures to complex brain activity. Furthermore, it provides a foundation for future research to explore neurobiological models explaining these discrepancies, aiding in the creation of more nuanced and effective assessment strategies. Additionally, the study offers insights for healthcare providers, emphasizing the need for a multifaceted approach that integrates both subjective experiences and objective data to better diagnose and treat sleep

disturbances. By addressing these aspects, this study seeks to contribute to a more comprehensive approach to evaluating and addressing sleep disturbances in mid-life women, ultimately leading to better health outcomes in this population.

For this review study, the literature from 2010 to 2022 will be reviewed to determine whether sleep discrepancies between sleep measures have been identified among women going through menopause and explore why any differences occurred. The selection of literature to review will be finalized based on the criteria of the study, through searches of relevant keywords in PubMed and Web of Science databases.

The aim of the study is to 1) review the purposes for which two different sleep measurements have been applied in studies over the past 13 years, specifically targeting women in the menopausal transition and postmenopause, 2) examine whether there are differences in sleep parameters between the measures within this population experiencing significant physiological changes, and 3) summarize and synthesize the evidence on the potential causes and implications based on the identified discrepancies between different sleep measures.

METHODS

Research spanning the past 13 years, from January 2010 to December 2022, was reviewed using the Web of Science and PubMed databases for relevant studies. PubMed is a complimentary platform designed to facilitate the search and retrieval of literature in the fields of biomedicine and life sciences, with a dual focus on enhancing global health (see https://pubmed.ncbi.nlm.nih.gov/about/). The Web of Science is a subscription-based service offering access to a range of databases, which include reference and citation information from scholarly journals, conference proceedings, and other academic publications across diverse disciplines (see https://webofscience.com/wos/woscc/basic-search).

The search terms, used both separately and in combination, included: 'sleep discrepancy', 'sleep difference', 'subjective and objective sleep', 'physiological and self-reported sleep', 'menopause', 'menopausal transition', and 'peri-menopause'. Additional articles were identified through a hand search in Google Scholar, a free search engine that accesses a broad spectrum of scholarly material.

Publications were eligible for this review if they were written in English and relevant to women during the menopausal transition and menopause. The included studies needed to measure sleep variables using two or more methods, including both objective and subjective. The study outcomes should include sleep variables obtained from the different sleep measures. Excluded from this review were non-peer-reviewed articles, letters to the editor, and conference abstracts.

After excluding duplicates, the initial literature search yielded 172 papers. Following a review of abstracts and the removal of papers that did not meet the inclusion criteria, sixteen articles were selected for the final review. The search protocol is documented according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines to ensure high-quality study findings (Parums, 2021; PRISMA2020, n.d.). The journal search process is depicted in Figure 2.1.

[Place Figure 2.1 here]

RESULTS

The characteristics of the selected studies include publication year, source of studies, study design, type of samples, study objectives, sleep measures used, significant findings associated with sleep, and causes of sleep discrepancies (if applicable). These details are

summarized in Table 2.1.

Publication year

A total of 16 studies met the inclusion criteria for the study. One article was published in 2010 (Grandner et al., 2010), two in 2011 (Joffe et al., 2011; Xu et al., 2011), three in 2012 (Liu et al., 2012; Oliveira et al., 2012; Thurston et al., 2012), one in 2013 (Lucchesi et al., 2013), one in 2014 (de Zambotti et al., 2014), four in 2015 (Baker et al., 2015; Hsu et al., 2015; Jiang et al., 2015; Regestein et al., 2015), two in 2017 (Fu et al., 2017; Thurston et al., 2017), and one in 2020 (Thurston et al., 2020).

Source of studies

A total of nine studies were carried out in the USA (Grandner et al., 2010; Joffe et al., 2011; Liu et al., 2012; de Zambotti et al., 2014; Baker et al., 2015; Hsu et al., 2015; Regestein et al., 2015; Fu et al., 2017; Thurston et al., 2020), indicating a substantial focus on this region. Three studies were conducted in Brazil (Oliveira et al., 2012; Lucchesi et al., 2013; Frange et al., 2017), reflecting significant research activity in South America. China was the site for two studies (Jiang et al., 2015; Fu et al., 2017), demonstrating research contributions from Asia. Additionally, one study was undertaken in Canada (Xu et al., 2011), and another in Taiwan (Hsu et al., 2015), further adding to the geographical diversity of the studies.

Study design

The articles reviewed (n = 16) encompass a variety of study designs. A significant number of studies employed a cross-sectional descriptive approach (Lucchesi et al., 2013; Thurston et al., 2012; Hsu et al., 2015; Regestein et al., 2015; Thurston et al., 2017; Thurston et al., 2020), while several others utilized a cross-sectional comparative design (Xu et al., 2011; Thurston et al., 2012; de Zambotti et al., 2014; Frange et al., 2017). Randomized controlled trials (RCTs) were also prominently featured in the review (Joffe et al., 2011; Liu et al., 2012;

Oliveira et al., 2012; Jiang et al., 2015; Fu et al., 2017). These diverse methodologies highlight the comprehensive nature of the research, ranging from observational studies to intervention-based trials.

Type of samples

The studies reviewed included various populations categorized by menopausal status and age ranges. Eleven studies involved postmenopausal women, with ages ranging from 45 to 81 years (Grandner et al., 2010; Oliveira et al., 2012; Hsu et al., 2015; Frange et al., 2017; Thurston et al., 2020; Liu et al., 2012; Regestein et al., 2015; Thurston et al., 2017). Six studies included both perimenopausal and postmenopausal women, covering an age range of 40 to 60 years (Joffe et al., 2011; Xu et al., 2011; Lucchesi et al., 2013; Fu et al., 2017; Jiang et al., 2015; Thurston et al., 2012). Two studies specifically targeted women in the menopausal transition, with participants aged 30 to 65 years (de Zambotti et al., 2014; Baker et al., 2015). Large cohort studies were also included: one focused on 576 women from the Sao Paulo Epidemiologic Sleep Study (EPISONO) (Lucchesi et al., 2013), and another involved 52 participants from the Pittsburgh site of the SWAN study (Baker et al., 2015). Additionally, one study recruited 222 perimenopausal women from the San Francisco Bay area community (Thurston et al., 2012). A study of 59 menopausal women with sleep disturbances included participants randomly assigned to experimental and control groups (Fu et al., 2017). Finally, another study used retrospective data from 88 women seeking relief from hot flashes (Regestein et al., 2015).

Study objectives

The studies reviewed on sleep disturbances and menopause can be grouped into three main categories: dietary and hormonal interventions, therapeutic and behavioral interventions, and physiological and psychological impacts. Several studies focused on dietary and hormonal interventions, exploring how dietary nutrient variables and hormone replacement therapy affect

sleep in menopausal women. These included investigations into the relationship between dietary nutrient variables and sleep (Grandner et al., 2010), the effects of estradiol, sleep, and hot flashes on depression (Joffe et al., 2011), the relationship between menopause and sleep quality in women with and without hormone replacement therapy (HRT) (Xu et al., 2011), and the efficacy of oral synthetic conjugated estrogens-B tablets on nocturnal vasomotor symptoms in postmenopausal women (Liu et al., 2012).

Therapeutic and behavioral interventions were also examined, with studies assessing the impact of therapeutic massage on insomnia (Oliveira et al., 2012), the relationship between vasomotor symptoms and sleep quality (Thurston et al., 2012), the influence of menopausal status on nocturnal awakenings with headache (Lucchesi et al., 2013), the quantification of objectively recorded hot flashes on sleep (de Zambotti et al., 2014), and sleep disturbances in women with and without clinical insomnia during the menopausal transition (Baker et al., 2015). Additionally, the effectiveness of interventions aimed at improving sleep quality in menopausal women with sleep disturbances (Hsu et al., 2015) and the effect of black cohosh on sleep in early postmenopausal women were evaluated (Jiang et al., 2015).

Lastly, the physiological and psychological impacts of menopause on sleep were investigated. Studies addressed the controversy over hot flashes and affective symptoms (Regestein et al., 2015), the association between sleep quality and cardiovascular risk (Thurston et al., 2017), the influence of insomnia on pain and daily function in postmenopausal women (Frange et al., 2017), the short-term efficacy of acupuncture for peri-menopausal insomnia (Fu et al., 2017), and the relationship between disrupted sleep and white matter hyperintensities (Thurston et al., 2020).

Sleep measures used

Various parameters of sleep were studied using a combination of subjective and

objective tools to provide a comprehensive assessment. Subjective measures included sleep diaries, the Pittsburgh Sleep Quality Index (PSQI), the Insomnia Severity Index (ISI), the Stanford Sleepiness Scale, and a range of sleep questionnaires such as the UNIFESP Sleep Questionnaire, the Berlin Questionnaire, and the Epworth Sleepiness Scale (ESS). Objective measures were typically obtained through actigraphy and polysomnography (PSG).

In detail, several studies used sleep diaries and actigraphy to capture both subjective and objective sleep data (Grandner et al., 2010; Thurston et al., 2017; Thurston et al., 2020). The combination of PSQI and actigraphy was also common (Joffe et al., 2011; Jiang et al., 2015; Frange et al., 2017), while other studies paired the PSQI with PSG for a thorough evaluation (Hsu et al., 2015; Fu et al., 2017). The ISI was frequently used alongside PSG (Thurston et al., 2012; Thurston et al., 2020), and in some instances, both the ISI and PSQI were used together with PSG (Thurston et al., 2020).

Further diversity in methods was seen in studies using sleep diaries, morning sleep questionnaires, and PSG (Baker et al., 2015), as well as those combining the PSQI with actigraphy (Jiang et al., 2015). A comprehensive assessment was achieved in studies using the UNIFESP Sleep Questionnaire, PSQI, ISI, Berlin Questionnaire, and ESS alongside PSG (Oliveira et al., 2012). Additionally, some research included the St. Mary's Hospital Sleep Questionnaire and actigraphy (Regestein et al., 2015).

Significant findings associated with sleep discrepancies

In 16 studies, discrepancies between subjective and objective sleep assessments commonly emerged in various sleep parameters, particularly for total sleep time (TST), sleep onset latency (SOL), wake after sleep onset (WASO), and sleep efficiency (SE).

1. Total Sleep Time (TST)

Many studies found that subjective reports often overestimated TST compared to

objective measurements like actigraphy or polysomnography (PSG). For example, in studies using both PSQI and PSG, women reported longer TST on PSQI than was measured by PSG (Hsu et al., 2015; Frange et al., 2017). Similarly, in studies using sleep diaries alongside actigraphy, participants reported significantly longer TST in sleep diaries, as seen in Grandner et al. (2010) and Baker et al. (2015). This discrepancy suggests that subjective measures may capture perceived restfulness or time spent in bed, rather than actual sleep duration recorded by objective ones.

2. Sleep Onset Latency (SOL)

Discrepancies in SOL were also prominent, with subjective measures frequently overestimating SOL compared to PSG or actigraphy data. For instance, in studies by Joffe et al. (2011) and Thurston et al. (2012), participants reported longer SOL in subjective measures such as the ISI and sleep diaries than was indicated by actigraphy. Similarly, in Fu et al. (2017), which used both PSQI and PSG, women perceived a longer time to fall asleep than what was objectively recorded. This overestimation may result from increased sensitivity to time spent awake due to symptoms like anxiety or hot flashes, which subjective tools capture more readily than objective devices.

3. Wake After Sleep Onset (WASO)

WASO discrepancies were frequently noted, with subjective reports often indicating more nighttime awakenings than actigraphy or PSG recorded. Studies by Thurston et al. (2017, 2020) found that PSQI and sleep diaries reported higher WASO, while actigraphy showed fewer instances of wakefulness after sleep onset. Jiang et al. (2015) observed similar results, where subjective measures like PSQI reported prolonged WASO compared to PSG data. These findings suggest that while objective tools capture physiological awakenings, subjective measures may reflect an exaggerated perception of nighttime disruptions, likely influenced by

heightened arousal or discomfort.

4. Sleep Efficiency (SE)

Discrepancies in SE were observed across studies, with subjective assessments typically showing lower SE than objective measures. For example, in studies combining the PSQI with actigraphy (Thurston et al., 2017) and PSG (Fu et al., 2017), participants reported reduced sleep efficiency, though objective measures indicated a higher SE. Frange et al. (2017) also found this trend using ISI and PSG, where subjective measures showed lower efficiency, reflecting participants' sense of restless or non-restorative sleep.

5. Fragmented Sleep and Nocturnal Awakenings

Subjective measures frequently reported greater sleep fragmentation and more nocturnal awakenings than objective tools. Regestein et al. (2015), using the St. Mary's Hospital Sleep Questionnaire alongside actigraphy, found that participants reported more frequent nighttime awakenings than were recorded by actigraphy. Similarly, Oliveira et al. (2012) observed that multiple subjective tools (e.g., PSQI, ISI) reported higher levels of fragmented sleep, while PSG data showed relatively stable sleep architecture. This discrepancy may be related to menopausal symptoms such as hot flashes or chronic pain, which increase nighttime arousal, leading to an exaggerated subjective perception of sleep disruption.

6. Perceived Restorative Quality of Sleep

In studies evaluating interventions such as acupuncture or herbal supplements, subjective measures often reflected greater perceived improvements in sleep quality than objective data suggested. For example, in Fu et al. (2017) and Jiang et al. (2015), subjective measures like PSQI and ISI indicated a significant perceived improvement in sleep quality after treatment, while PSG data showed only modest changes in TST and SE. This discrepancy implies that while interventions may improve subjective sleep quality by reducing symptoms

like anxiety or hot flashes, they may not result in substantial objective changes in sleep parameters.

[Place Table 2.1 here]

DISUSSION

The present review synthesizes findings from studies conducted between 2010 and 2022, focusing on sleep disturbances in women during the menopausal transition and postmenopause. The studies used both subjective (e.g., PSQI, ISI) and objective (e.g., actigraphy, PSG) sleep measures, revealing key discrepancies between methods.

In reviewing the 16 studies, notable discrepancies were identified across all primary sleep parameters: TST, SOL, WASO, and SE. For instance, subjective measures often reported longer TST than objective methods like actigraphy or PSG, indicating that participants perceived a longer sleep duration than was recorded (Grandner et al., 2010; Frange et al., 2017). This suggests that TST from subjective tools may be influenced by perception rather than physiological reality. Similarly, studies using tools like the ISI and morning sleep questionnaires found that menopausal women commonly reported longer SOL, suggesting delayed sleep onset, whereas objective measures often recorded shorter sleep onset times (Joffe et al., 2011; Fu et al., 2017). Such findings indicate that subjective reports may capture a heightened awareness of wakefulness that objective tools do not measure. Further, WASO was frequently overestimated in subjective reports compared to actigraphy or PSG (Thurston et al., 2020; Regestein et al., 2015), particularly in cases where hot flashes or nighttime awakenings were reported. This trend suggests that subjective assessments capture the perceived intensity of awakenings rather than their frequency. Lastly, subjective measures showed lower SE than

objective assessments in several studies, likely reflecting symptom-driven biases (Thurston et al., 2017; Oliveira et al., 2012).

These discrepancies arise from a range of factors that highlight the complexities of accurately assessing sleep in menopausal women. Instrument-specific factors are one major contributor. Subjective measures such as the PSQI and ISI capture an individual's perceptions of sleep but are prone to recall bias and psychological influences (Baker et al., 2018; Silva et al., 2007). This can lead to divergences between subjective perceptions and physiological data. In contrast, objective measures like PSG and actigraphy record sleep parameters directly and thus may not fully align with personal perceptions, particularly for women experiencing fluctuating symptoms typical in menopause (Xu et al., 2011).

Another contributing factor is the use of aggregate scoring in subjective tools, such as the PSQI's single-score format, which offers a broad assessment of sleep quality but may overlook specific parameters like TST or SE that objective measures capture more precisely (Baker et al., 2018; Kline et al., 2013).

Symptom-driven perceptual bias, particularly from vasomotor symptoms like hot flashes, also plays a significant role. Studies have shown that hot flashes can intensify perceptions of sleep disruptions, particularly in WASO and SOL (Regestein et al., 2015). This bias suggests that subjective assessments may overestimate sleep disturbances due to increased awareness of symptoms rather than actual physiological fragmentation (Xu et al., 2011).

Lastly, psychological factors such as stress, anxiety, and mood disturbances contribute to these discrepancies. Emotional states can heighten perceptions of sleep disruption, especially during menopause, when psychological arousal is often elevated (Okun et al., 2009). This can lead to higher subjective reports of poor sleep quality, even when objective measures show relatively stable patterns (Thurston et al., 2012).

Implication

The findings from this review underscore the critical need for an integrated approach to sleep assessment in menopausal women, incorporating both subjective and objective measures. Subjective tools, such as the PSQI and ISI, provide insight into individuals' perceptions, capturing the psychological and symptomatic experiences associated with menopausal sleep disruptions, such as hot flashes and anxiety (Baker et al., 2018; Silva et al., 2007). However, objective measures like actigraphy and PSG offer an unbiased physiological perspective, crucial for assessing long-term health impacts such as cardiovascular disease and cognitive decline, which have been linked to sleep disturbances in this population (Thurston et al., 2020; Kline et al., 2013). Clinically, this suggests that healthcare providers should avoid relying solely on one method of assessment. Instead, combining subjective and objective data offers a more comprehensive view, informing more accurate diagnoses, personalized interventions, and preventive strategies for managing menopausal sleep issues.

Strengths and Weaknesses of the Study

A significant strength of this review is its comprehensive synthesis of both subjective and objective data from 16 studies, providing a nuanced perspective on sleep discrepancies in menopausal women. By focusing on specific sleep parameters—such as TST, SOL, WASO, and SE—this study delineates the precise points of divergence between perceived and physiological sleep, which has important implications for developing targeted clinical interventions. Furthermore, the review encompasses a range of menopausal symptoms and emotional factors, allowing for a multidimensional understanding of sleep health in this population (Silva et al., 2007).

Despite its strengths, this study has limitations. Variations in methodologies and scoring systems among the included studies present a challenge for direct comparisons, as each

tool assesses sleep differently. For instance, aggregated scoring systems, as seen with the PSQI, might obscure granular details of sleep quality (Baker et al., 2018; Xu et al., 2011). Additionally, the review lacks longitudinal data, which would allow for an assessment of how these discrepancies evolve over time and impact long-term health outcomes. Lastly, a potential selection bias is present, as many studies have limited representation of diverse ethnic, socioeconomic, and health backgrounds, underscoring the need for more inclusive research in the future (Kline et al., 2013; Silva et al., 2007).

Future Directions

Future research should prioritize understanding the mechanisms behind these sleep discrepancies in menopausal women. This includes examining the specific roles that instrument features, symptom-driven perceptual biases, and emotional factors play in creating these differences. Additionally, studies should investigate how sleep disturbances affect long-term health outcomes, with a focus on cardiovascular and neurological health. Longitudinal research, in particular, would help clarify how these discrepancies influence health risks over time, providing guidance for more effective interventions. Expanding studies to include more diverse populations is also crucial, as variability in sleep experiences across age groups, ethnicities, and socioeconomic backgrounds would increase the generalizability of findings (Kline et al., 2013).

CONCLUSIONS

The observed discrepancies between subjective and objective sleep measures in menopausal women reveal the challenges of accurately assessing sleep disturbances in this population. This review highlights that while physiological symptoms like hot flashes significantly contribute to objective sleep disturbances, subjective measures often reflect an

overestimation of sleep disruptions, influenced by psychological and symptomatic factors. The combined use of subjective tools, such as the PSQI, and objective ones, such as PSG, offers a holistic approach, where each method brings unique insights—subjective measures capture perceived sleep quality, while objective measures offer detailed physiological data. These findings suggest that an integrated assessment approach is essential to accurately evaluate sleep in menopausal women, supporting effective, individualized interventions that address both perceived and physiological sleep health. Further research into these discrepancies across diverse populations is necessary to refine sleep assessment strategies, contributing to better sleep health management for this population.

REFERENCES FOR CHAPTER 2

Baker, F. C. (2023). It's not just about the hot flashes: Menopausal hormone changes and disrupted sleep. *The Journal of Clinical Endocrinology & Metabolism, 108*(2), e25-e26. https://doi.org/10.1210/clinem/dgac108

Baker, F. C., & de Zambotti, M. (2017). Sleep and menopause: A narrative review. *Journal of Clinical Sleep Medicine, 13*(2), 215-226. https://doi.org/10.5664/jcsm.6456

Baker, F. C., De Zambotti, M., Colrain, I. M., & Bei, B. (2018). Sleep problems during the menopausal transition: Prevalence, impact, and management challenges. *Nature and Science of Sleep, 10*, 73-95. https://doi.org/10.2147/NSS.S125807

Baker, F. C., Willoughby, A. R., Sassoon, S. A., Colrain, I. M., & de Zambotti, M. (2015). Insomnia in women approaching menopause: Beyond perception. *Psychoneuroendocrinology, 60*, 96-104. https://doi.org/10.1016/j.psyneuen.2015.06.005

de Zambotti, M., Colrain, I. M., Javitz, H. S., & Baker, F. C. (2014). Magnitude of the impact of hot flashes on sleep in perimenopausal women. *Fertility and Sterility, 102*(6), 1708-1715. https://doi.org/10.1016/j.fertnstert.2014.08.014

Fu, C., Zhao, N., Liu, Z., Yuan, L. H., Xie, C., Yang, W. J., ... & Chen, Y. F. (2017). Acupuncture improves peri-menopausal insomnia: A randomized controlled trial. *Sleep, 40*(11), zsx153. https://doi.org/10.1093/sleep/zsx153

Girschik, J., Fritschi, L., Heyworth, J., & Waters, F. (2012). Validation of self-reported sleep against actigraphy. *Journal of Epidemiology, 22*(5), 462-468. https://doi.org/10.2188/jea.JE20110119

Gorfine, T., Assaf, Y., Goshen-Gottstein, Y., Yeshurun, Y., & Zisapel, N. (2006). Sleep-anticipating effects of melatonin in the human brain. *Neuroimage, 31*(1), 410-418. https://doi.org/10.1016/j.neuroimage.2005.11.024

Grandner, M. A., Kripke, D. F., Naidoo, N., & Langer, R. D. (2010). Relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women. *Sleep Medicine, 11*(2), 180-184. https://doi.org/10.1016/j.sleep.2009.06.002

Hsu, H. C., Tsao, L. I., & Lin, M. H. (2015). Improving sleep quality interventions among menopausal women with sleep disturbances in Taiwan: A preliminary study. *Applied Nursing Research, 28*(4), 374-380. https://doi.org/10.1016/j.apnr.2015.04.009

Hughes, J. M., Song, Y., Fung, C. H., Dzierzewski, J. M., Mitchell, M. N., Jouldjian, S., ... & Martin, J. L. (2018). Measuring sleep in vulnerable older adults: a comparison of subjective and objective sleep measures. *Clinical gerontologist*, *41*(2), 145-157. https://doi.org/10.1080/07317115.2017.1408734

Ibáñez, V., Silva, J., & Cauli, O. (2018). A survey on sleep assessment methods. *PeerJ, 6*, e4849. https://doi.org/10.7717/peerj.4849

Jackowska, M., Dockray, S., Hendrickx, H., & Steptoe, A. (2011). Psychosocial factors and sleep efficiency: Discrepancies between subjective and objective evaluations of sleep. *Psychosomatic Medicine, 73*(9), 810-816. https://doi.org/10.1097/PSY.0b013e318236b3ed

Jiang, K., Jin, Y., Huang, L., Feng, S., Hou, X., Du, B., ... & Li, L. (2015). Black cohosh improves objective sleep in postmenopausal women with sleep disturbance. *Climacteric, 18*(4), 559-567. https://doi.org/10.3109/13697137.2015.1030565

Joffe, H., Petrillo, L. F., Koukopoulos, A., Viguera, A. C., Hirschberg, A., Nonacs, R., ... & Cohen, L. S. (2011). Increased estradiol and improved sleep, but not hot flashes, predict enhanced mood during the menopausal transition. *The Journal of Clinical Endocrinology & Metabolism, 96*(7), E1044-E1054. https://doi.org/10.1210/jc.2010-2784

Kim, M. J., Yim, G., & Park, H. Y. (2018). Vasomotor and physical menopausal symptoms are associated with sleep quality. *PLOS ONE, 13*(2), e0192934.

https://doi.org/10.1371/journal.pone.0192934

Kline, C. E., Shih, Y. T., Krafty, R. T., Kravitz, H. M., Hall, M. H., & Matthews, K. A. (2013). Consistently high sports/exercise activity is associated with better sleep quality, continuity, and depth in midlife women: The SWAN Sleep Study. *Sleep, 36*(9), 1279-1288. https://doi.org/10.5665/sleep.2894

Kravitz, H. M., & Joffe, H. (2011). Sleep during the perimenopause: A SWAN story. *Obstetrics and Gynecology Clinics of North America, 38*(3), 567-586. https://doi.org/10.1016/j.ogc.2011.05.009

Lauderdale, D. S., Knutson, K. L., Yan, L. L., Liu, K., & Rathouz, P. J. (2008). Self-reported and measured sleep duration: How similar are they? *Epidemiology, 19*(6), 838-845. https://doi.org/10.1097/EDE.0b013e318187a7b0

Lavoie, C. J., Zeidler, M. R., & Martin, J. L. (2018). Sleep and aging. *Sleep Science and Practice, 2*, 1-8. https://doi.org/10.1186/s41606-018-0037-0

Lee, J., Han, Y., Cho, H. H., & Kim, M. R. (2019). Sleep disorders and menopause. *Journal of Menopausal Medicine, 25*(2), 83-90. https://doi.org/10.6118/jmm.2019.25.2.83

Liu, J. H., Reape, K. Z., & Hait, H. I. (2012). Synthetic conjugated estrogens-B and postmenopausal nocturnal vasomotor symptoms: A randomized controlled trial. *Obstetrics & Gynecology, 119*(1), 78-84. https://doi.org/10.1097/AOG.0b013e31823d415f

Lucchesi, L. M., Hachul, H., Yagihara, F., Santos-Silva, R., Tufik, S., & Bittencourt, L. R. (2013). Does menopause influence nocturnal awakening with headache? *Climacteric, 16*(3), 362-368. https://doi.org/10.3109/13697137.2013.765684

Mendonça, F., Mostafa, S. S., Morgado-Dias, F., Ravelo-Garcia, A. G., & Penzel, T. (2019). A review of approaches for sleep quality analysis. *IEEE Access, 7*, 24527-24546. https://doi.org/10.1109/ACCESS.2019.2899300

Muller, L., Piantoni, G., Koller, D., Cash, S. S., Halgren, E., & Sejnowski, T. J. (2016). Rotating waves during human sleep spindles organize global patterns of activity that repeat precisely through the night. *eLife, 5*, e17267. https://doi.org/10.7554/eLife.17267

Okun, M. L., Kravitz, H. M., Sowers, M. F., Moul, D. E., Buysse, D. J., & Hall, M. (2009). Psychosocial stress and sleep in midlife women: The Study of Women's Health Across the Nation (SWAN). *Sleep, 32*(11), 1391-1402. https://doi.org/10.1093/sleep/32.11.1391

Oliveira, D. S., Hachul, H., Goto, V., Tufik, S., & Bittencourt, L. R. (2012). Effect of therapeutic massage on insomnia and climacteric symptoms in postmenopausal women. *Climacteric, 15*(1), 21-29. https://doi.org/10.3109/13697137.2011.592873

Parums, D. V. (2021). Review articles, systematic reviews, meta-analysis, and the updated preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines. *Medical Science Monitor, 27*, e934475-1. https://doi.org/10.12659/MSM.934475

Regestein, Q., Friebely, J., & Schiff, I. (2015). How self-reported hot flashes may relate to affect, cognitive performance, and sleep. *Maturitas, 81*(4), 449-455. https://doi.org/10.1016/j.maturitas.2015.05.001

Santoro, N., Roeca, C., Peters, B. A., & Neal-Perry, G. (2021). The menopause transition: Signs, symptoms, and management options. *The Journal of Clinical Endocrinology & Metabolism, 106*(1), 1-15. https://doi.org/10.1210/clinem/dgaa764

Silva, G. E., Goodwin, J. L., Sherrill, D. L., Quan, S. F., & Carden, K. A. (2007). Relationship between reported and measured sleep times: The Sleep Heart Health Study (SHHS). *Journal of Clinical Sleep Medicine, 3*(6), 622-630. https://doi.org/10.5664/jcsm.26999

Thurston, R. C., Wu, M., Aizenstein, H. J., Chang, Y., Barinas Mitchell, E., Derby, C. A., & Maki, P. M. (2020). Sleep characteristics and white matter hyperintensities among midlife women. *Sleep, 43*(6), zsz298. https://doi.org/10.1093/sleep/zsz298

Unruh, M. L., Redline, S., An, M. W., Buysse, D. J., Nieto, F. J., Yeh, J. L., & Newman, A. B. (2008). Subjective and objective sleep quality and aging in the sleep heart health study. *Journal of the American Geriatrics Society, 56*(7), 1218-1227. https://doi.org/10.1111/j.1532-5415.2008.01753.x

Woods, N. F., & Mitchell, E. S. (2010). Sleep symptoms during the menopausal transition and early postmenopause: Observations from the Seattle Midlife Women's Health Study. *Sleep, 33*(4), 539-549. https://doi.org/10.1093/sleep/33.4.539

Xu, M., Bélanger, L., Ivers, H., Guay, B., Zhang, J., & Morin, C. M. (2011). Comparison of subjective and objective sleep quality in menopausal and non-menopausal women with insomnia. *Sleep Medicine, 12*(1), 65–69. https://doi.org/10.1016/j.sleep.2010.09.003

FIGURES AND TABLES FOR CHAPER 2

Figure 2.1 PRISMA flow diagram of search procedure

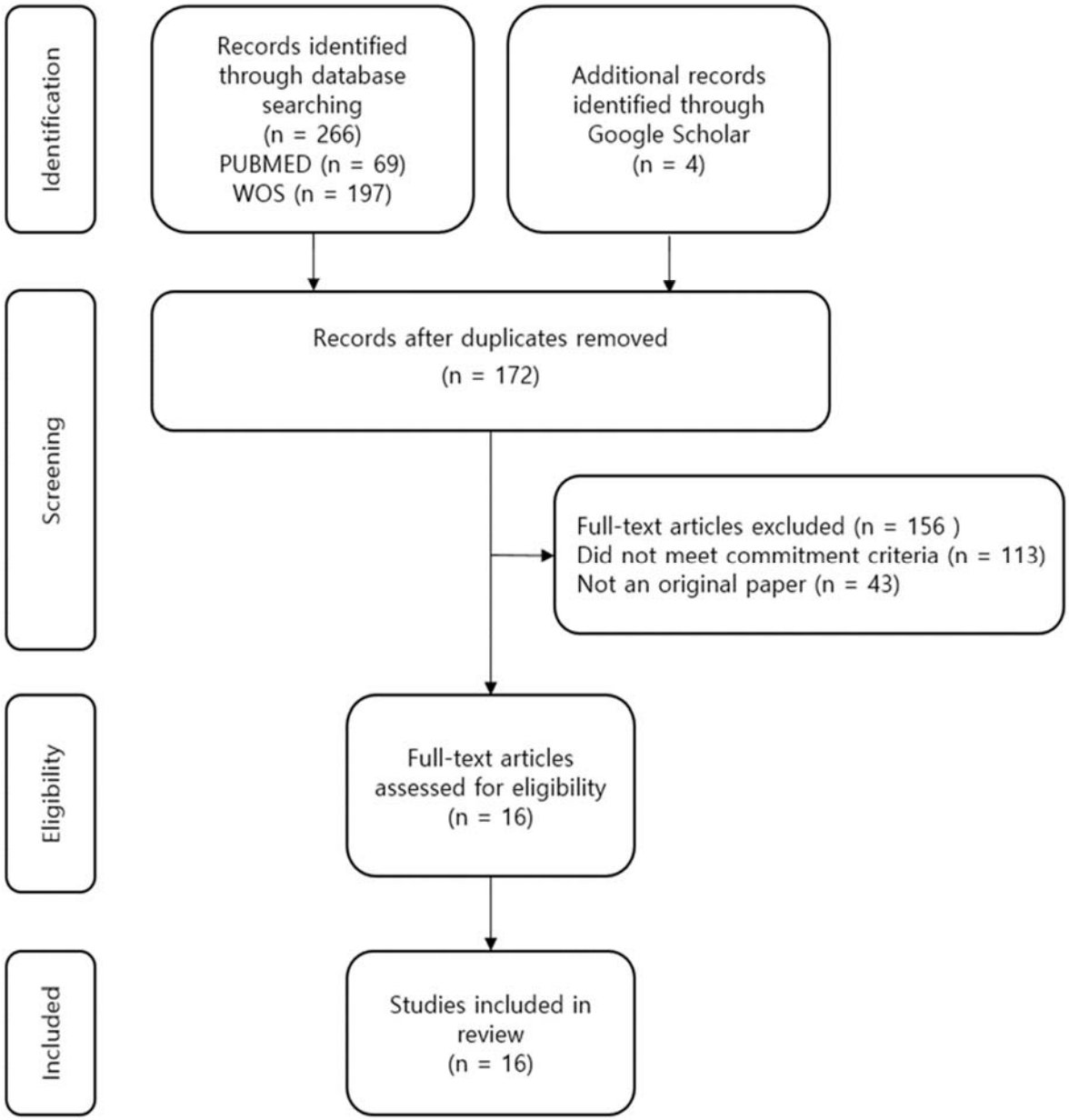


Table 2.1 The characteristics of the studies (n=16)

Authors/ Year/ Country (study recruited)	Study design	Population (age/status/n)	Study objectives	Sleep measures used S: Subjective, O: Objective	Findings associated with sleep discrepancies
Grandner et al. (2010)/ USA	Cross-sectional descriptive	Postmenopausal women (Mean age 68, SD 7.76, range 50–81; n=423)	Examine relationships between dietary nutrients and subjective/objective sleep, and napping	S: Sleep diaries, O: Actigraphy	Discrepancy: Participants reported longer sleep durations in sleep diaries, while actigraphy recorded shorter durations, indicating overestimation. Dietary factors influenced this discrepancy, with higher fat intake linked to shorter actigraphy-measured sleep. Napping also showed discrepancies between diaries and actigraphy.
Joffe et al. (2011)/ USA	Randomized Controlled Trial	Women aged 40–60, perimenopausal or postmenopausal with depression (n=72, mean age 51.1, SD=5.0)	Investigate the effects of estradiol, sleep, and hot flashes on depression during menopausal transition	S: PSQI, O: Actigraphy	Discrepancy: Improvement in PSQI sleep quality associated with better mood, while actigraphy did not show significant improvement. Increased estradiol improved PSQI-reported sleep quality and mood.
Xu et al. (2011)/ Canada	Cross-sectional comparative	Women with insomnia, premenopausal or peri/postmenopausal (Mean age 50.3, range 40–59; peri/postmenopausal n=41, premenopausal n=33)	Examine relationship between menopause and sleep in women with insomnia, comparing menopausal groups with and without HRT	S: Sleep diaries, O: PSG	Discrepancy: PSG showed longer total wake time and lower SE in menopausal women vs. non-menopausal women. No significant difference in sleep diary reports.

Table 2.1 The characteristics of the studies (n=16) cont.

Authors/ Year/ Country (study recruited)	Study design	Population (age/status/n)	Study objectives	Sleep measures used S: Subjective, O: Objective	Findings associated with sleep discrepancies
Liu et al. (2012)/ USA	Randomized Controlled Trial	Naturally or surgically menopausal women aged 30–65 with nocturnal vasomotor symptoms (Mean age 54.1, SD=5.87; n=157)	Evaluate two doses of estrogens-B on awakenings due to nocturnal vasomotor symptoms	S: Sleep diaries (3-point scale), Stanford Sleepiness Scale, O: Actigraphy	Discrepancy: Actigraphy showed reduced awakenings in estrogen groups, while sleep diaries showed no significant subjective improvement.
Oliveira et al. (2012)/ Brazil	Randomized Controlled Trial	Postmenopausal women aged 50–65 with BMI ≤ 30 kg/m² and insomnia (n=44)	Evaluate effect of therapeutic massage on insomnia and climacteric symptoms	S: ISI, O: PSG	Discrepancy: ISI scores showed significant improvement, while PSG parameters showed minimal change.
Thurston et al. (2012)/ USA	Cross-sectional comparative	Subcohort from SWAN study at Pittsburgh site, midlife women (n=52)	Investigate associations between VMS and sleep quality in midlife women	S: Sleep diaries, 4-point scale questionnaire, O: Actigraphy	Discrepancy: VMS recalled upon waking associated with lower SE and longer WASO in actigraphy, but physiological VMS measures showed no significant link to sleep.
Lucchesi et al. (2013)/ Brazil	Cross-sectional descriptive	Women from the Sao Paulo Epidemiologic Sleep Study (EPISONO): premenopausal (n=341), perimenopausal (n=15), early menopause (n=61), late menopause (n=135)	Assess influence of menopausal status on nocturnal awakening with headache (NAH) and associated symptoms	S: The UNIFESP Sleep Questionnaire, PSQI, ISI, Berlin Questionnaire, ESS, O: PSG	Discrepancy: Perimenopausal women reported more NAH, hot flashes, and worse sleep quality, but PSG showed no objective deterioration in sleep.
de Zambotti et al. (2014)/ USA	Cross-sectional descriptive	Perimenopausal women (n=222)	Quantify impact of objectively-recorded hot flashes on sleep	S: Sleep questionnaires, O: PSG	Discrepancy: Subjective reports underestimated WASO, awakenings, and hot flashes compared to PSG. Objective hot flash

					frequency and wake time negatively impacted SE.

Table 2.1 The characteristics of the studies (n=16) cont.

Authors/ Year/ Country (study recruited)	Study design	Population (age/status/n)	Study objectives	Sleep measures used S: Subjective, O: Objective	Findings associated with sleep discrepancies
Baker et al. (2015)/ USA	Cross-sectional comparative	Menopausal transition women aged 43–57 with or without insomnia (n=72; insomnia n=38, no insomnia n=34)	Quantify sleep disturbances and the role of hot flashes in women with and without insomnia	S: Sleep diaries, Morning sleep questionnaires, O: PSG	Discrepancy: Both groups reported longer TST and SOL in questionnaires than PSG showed. Insomniacs had shorter PSG-measured TST and more hot flashes.
Hsu et al. (2015)/ Taiwan	Randomized Controlled Trial	Menopausal women with sleep disturbances (experimental n=29, control n=30; total n=59)	Evaluate effectiveness of sleep quality improvement interventions	S: PSQI, O: Actigraphy	Discrepancy: Experimental group showed improved PSQI scores and reduced actigraphy-measured latency, while control group saw increased awake time percentage.
Jiang et al. (2015)/ China	Randomized Controlled Trial	Postmenopausal women aged 45–60 with sleep complaints (n=48)	Evaluate effect of black cohosh on sleep in early postmenopausal women	S: PSQI O: PSG	Discrepancy: Black cohosh led to improved PSG-measured SE and reduced WASO, while PSQI showed general improvement without specific detail.
Regestein et al. (2015)/ USA	Cross-sectional descriptive	Women seeking relief from bothersome hot flashes (n=88)	Examine association of self-reported hot flashes with affective symptoms, cognitive performance, and sleep	S: St. Mary's Hospital Sleep Questionnaire, O: Actigraphy	Discrepancy: All hot flash measures linked to worse subjective sleep, but only diary-documented hot flashes affected objective sleep.

Table 2.1 The characteristics of the studies (n=16) cont.

Authors/ Year/ Country (study recruited)	Study design	Population (age/status/n)	Study objectives	Sleep measures used S: Subjective, O: Objective	Findings associated with sleep discrepancies
Thurston et al. (2017)/ USA	Cross-sectional descriptive	Peri- and postmenopausal women aged 40–60 (n=256)	Examine relationship between sleep characteristics and carotid atherosclerosis	S: PSQI, O: Actigraphy	Discrepancy: Shorter actigraphy-measured sleep was linked to carotid plaque, while poorer PSQI sleep quality correlated with intima media thickness.Additional Findings: These associations remained significant even after adjusting for cardiovascular disease risk factors, hot flashes, and estradiol levels.
Frange et al. (2017)/ Brazil	Cross-sectional comparative	Postmenopausal women aged 50–70 with sleep complaints (n=54)	Investigate effect of insomnia on pain in postmenopausal women	S: ISI, O: PSG	Discrepancy: Insomniac women reported greater pain interference and climacteric symptoms, but PSG showed no significant differences in objective sleep or pain.
Fu et al. (2017)/ China	Randomized Controlled Trial	Peri-menopausal women with insomnia disorder (Acupuncture n=38, Placebo n=38; total n=76)	Evaluate short-term efficacy of acupuncture for peri-menopausal insomnia	S: PSQI, ISI, O: PSG	Discrepancy: Acupuncture group showed improvements in PSQI, ISI, and PSG-measured sleep, while placebo group showed no significant changes.
Thurston et al. (2020)/	Cross-sectional descriptive	Midlife women without stroke or dementia (Mean age 58.86, SD=4.14; n=122)	Examine association between disrupted sleep and WMH	S: PSQI, Sleep diaries, O: Actigraphy	Discrepancy: Greater WASO in actigraphy linked to more WMH, while subjective sleep quality showed no association.

Note. PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; ESS, Epworth Sleepiness Scale; HRT, Hormone Replacement Therapy; PSG, Polysomnography; SE, Sleep Efficiency; WASO, Wake After Sleep Onset; SWAN, Study of Women's Health Across the Nation; TST, Total Sleep Time; VMS, Vasomotor Symptoms; WMH, White Matter Hyperintensities; CVD, Cardiovascular Disease

CHAPTER 3. Sleep Discrepancies between Actigraphy, PSQI, and Sleep Diaries among Women with and without Insomnia Symptoms in the Menopause Transition and Postmenopause

Target journal: SLEEP (https://academic.oup.com/sleep)

Abstract: Limited to 250 words

Figures and tables: No minimum or maximum length for original articles

Abstract

Objectives: Although insomnia has been reported as one determinant of discrepancies between objective and subjective sleep measures, few studies of this phenomenon examined women near menopause. This study aims to examine insomnia as an influence on objective-subjective sleep discrepancies among women in the menopause transitional and postmenopause. **Methods:** A secondary analysis examined actigraphy, PSQI, and sleep diary data from 398 women. Repeated Measures ANOVA was used to explore the discrepancies of sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO), and sleep efficiency (SE) between measurements according to the insomnia severity determined by insomnia severity index (ISI). Linear regression was used to examine the insomnia on sleep discrepancies. **Results:** Discrepancies in all four parameters between actigraphy and PSQI were significant in women with insomnia whereas discrepancies in all four parameters between actigraphy and diaries were significant in women without insomnia. In both groups, SOL and SE discrepancies were significant. Meanwhile, the magnitude of discrepancies were greater in women with insomnia than those without insomnia for all measurement comparisons. In the regression, insomnia effect on all sleep parameters between actigraphy and two subjective measures were significant. Higher level of insomnia was associated with underestimation of reported SOL and WASO and overestimation of reported TST and SE. **Conclusions:** Although significant discrepancies in both groups between all measurements were reported, greater sleep discrepancies in insomnia group and greater distortion of self-reports suggest the insomnia impact on the individual's sleep perception, finally contributing to the objective and subjective sleep discrepancies.

***Keywords*:** Actigraphy, diaries, insomnia, menopause, PSQI, sleep discrepancies

INTRODUCTION

Insomnia is the most common and troublesome health issue among midlife women (Baker et al., 2018; Shaver & Woods, 2015). Studies have estimated the prevalence of insomnia symptoms to be around 35–60% among women in the menopausal transition and postmenopausal period, compared to 16–42% among premenopausal women (Kravitz et al., 2008; Xu & Lang, 2014). Poor sleep patterns, such as delayed sleep onset latency, shorter sleep duration, more wakefulness, and decreased sleep efficiency, have been reported to affect women in the menopausal transitional or postmenopausal period, either jointly or individually (Baker et al., 2018; Campbell et al., 2011). Decreased sleep quality or lack of sleep increases the risk of physical disorders (Blümel et al., 2012; Haseli-Mashhadi et al., 2009; Hoevenaar-Blom et al., 2011), psychological problems (Bromberger et al., 2016; Taylor et al., 2003), and decreased cognitive function (Spira et al., 2014). Additionally, insomnia and related disorders are associated with greater healthcare costs (Kaufmann et al., 2013) and reduced quality of life (Kyle et al., 2010).

Discrepancies between sleep parameters measured by objective (i.e., actigraphy or polysomnography [PSG]) versus subjective (e.g., sleep diary) methods have been examined in varied populations, including midlife women. Sleep discrepancies between the two measurement methods can provide insights into the etiology of insomnia patterns; however, the full implications and clinical utility of objective-subjective sleep discrepancies remain unknown. Objective-subjective sleep discrepancy in persons with insomnia is a well-recognized phenomenon (Bonnet & Arand, 2010; Manconi et al., 2010). For insomnia, current theories based on research evidence propose that increased central nervous system (CNS) and peripheral arousal mechanisms affect the functioning of sleep regulation and sensory perception, leading to non-refreshing sleep, possibly due to persistent cortical activation

(Bonnet & Arand, 2010; Buysse et al., 2011). Cortical activation in persons with insomnia can be seen in electroencephalographic (EEG) sleep microstructure, specifically in increased beta activity (Bonnet & Arand, 2010). Another theory proposes that thalamic sensory gating, which normally does not permit the relay of sensory information to the cortex, is dysfunctional. With the persistence of sensory input, a person may perceive that she is awake when she is, in fact, asleep (Buysse et al., 2011). This pattern is supported by findings of reduced sleep spindles and K-complexes, EEG waveforms associated with sensory gating, in those with insomnia (Maes et al., 2014).

Prior studies focusing on adults and older adults have addressed objective-subjective sleep discrepancies, showing that insomnia or insomnia symptoms can affect one's sleep perception and play a role in sleep discrepancies. These studies have been discussed in two main respects. First, when comparing two groups (persons with insomnia vs. healthy sleepers), subjectively measured sleep duration is underestimated compared to objectively measured sleep duration (Means et al., 2003; Fernandez-Mendoza et al., 2011). Second, sleep discrepancy, or variability, is greater in groups experiencing insomnia compared to healthy controls (Berg et al., 2008; Buysse et al., 2009). A major study conducted with middle-aged and older adults reported that persons with insomnia reported less sleep time in their sleep logs than in PSG (both home and laboratory) compared to normal sleepers (Means et al., 2003). A study of a large-scale general population over 20 years old also revealed similar findings, showing that individuals with insomnia reported slightly shorter total sleep time than those without insomnia, given similar sleep duration (Fernandez-Mendoza et al., 2011).

Additionally, Berg et al. (2008) found that as the quality of individuals' sleep improved, the discrepancy between actigraphic and diary-recorded total sleep time declined, implying that insomnia affects one's perception of sleep. Moreover, Buysse et al. (2009) compared sleep

variability in older adults with and without chronic insomnia, showing greater night-to-night variability in sleep diaries than in actigraphy among older adults with chronic insomnia. Given these findings, the literature presently suggests that insomnia status may affect responses to subjective sleep measurements.

Recent studies on insomnia treatments have also examined the characteristics of sleep perception among persons with insomnia by assessing treatment effects on objectively and subjectively measured sleep. Tang and Harvey (2004) investigated whether behavioral sleep perception therapy reduced objective-subjective sleep discrepancies among patients with primary insomnia. Participants were divided into a "Shown-Discrepancy Group," which was shown the discrepancy between actigraphy and diary on the day following the experiment's start, and a "No-Demonstration Group," which was not. Results showed a greater effect of therapy on subjective but not objective sleep onset latency (SOL) and a reduction in anxiety and unwanted pre-sleep thoughts in the Shown-Discrepancy Group. In a meta-analysis, Okajima et al. (2011) found that self-reported, rather than objective, measurements showed improvements in selected sleep parameters, including sleep efficiency (SE) and wake after sleep onset (WASO), following cognitive behavioral treatment for insomnia (CBT-I). Additionally, this meta-analysis did not find a significant change in objectively measured total sleep time (TST) between pre- and post-treatment, whereas self-reported TST significantly improved at 3 and 12 months after treatment. Findings from a CBT-I study by Kay et al. (2015) showed greater discrepancies in SOL and WASO between actigraphy and diary in older adults with insomnia compared to good sleepers; these discrepancies reduced following CBT-I treatment, with greater improvements in self-reported than actigraphic SOL and WASO in the insomnia group. Thus, cognitive and behavioral therapies suggest that reports by subjective sleep measures may be more distorted than objective ones in persons with insomnia, potentially

affecting sleep discrepancies.

Given this evidence, exploring discrepancies between objectively and subjectively measured sleep in women in the menopausal transition and postmenopause, with and without insomnia, could provide insights into insomnia symptoms as one factor affecting perceptions of poor sleep. Moreover, understanding the causes of mismatches between different sleep measurement methods will provide a foundation for comprehensive sleep evaluation and treatment planning. In particular, the lack of recent studies on objective and subjective sleep discrepancies among middle-aged women around menopause calls for further research to assess their sleep issues, often affected by physiological changes. This study builds upon prior studies by examining not only total sleep time but also three additional sleep parameters (SOL, SE, and WASO), and by representing self-reported sleep through both retrospective (Pittsburgh Sleep Quality Index [PSQI]) and prospective (sleep diary) measures. The study aimed to examine whether insomnia status was associated with discrepancies between objective and subjective sleep measures among women in the menopausal transition and postmenopausal periods. The specific aims were: (1) to compare objectively and subjectively measured sleep parameters—SOL, TST, WASO, and SE—by insomnia level, based on the Insomnia Severity Index (ISI), and (2) to examine whether the magnitude of discrepancies in sleep outcomes differed between individuals with and without insomnia symptoms.

METHODS

Design

The study is a secondary analysis of baseline data from Menopause Strategies: Finding Lasting Answers for Symptoms and Health (MsFLASH) network trials. The MsFLASH network implemented a series of trials on menopause management (Newton et al., 2014). We

used data from MsFLASH trials 2 (Sternfeld et al., 2014) and 3 (LaCroix et al., 2012), which were both randomized controlled trials of interventions for menopause symptom relief.

Subjects

MsFLASH studies 2 and 3 required participants to be women aged 40–62 years in the late menopause transition or the first 5 years postmenopause. The participants also had to have at least 3 nights of actigraphy and sleep diary data as well as complete Pittsburgh Sleep Quality Index (PSQI) data on items 1 to 4 that assessed sleep parameters.

Measures

Demographic Characteristics

Demographics included participants' age, employment status, marital status, ethnicity/race, and education level. They were considered as possible covariates affecting objective-subjective sleep discrepancies.

Sleep Measures

Actigraphy. Actigraphy is a measurement method that uses a physiologic device (actigraph) with motion biosensors (Philips Respironics, 2023) to measure sleep-wake behavioral patterns. Actigraphy data for this study were collected for about 7 days using Actiwatch-2 (MiniMitter, Bend, OR). To balance the unequal number of nights observed between subjects, each sleep parameter was represented as the within-subject mean. Trained personnel scored actigraphy data for the primary MsFLASH study analyses (Buchanan et al., 2017). Sleep parameters for analyses included: 1) Total sleep time (TST): total minutes asleep while in bed (TIB); 2) Sleep onset latency (SOL): time between bedtime and falling asleep; 3) Wake after sleep onset (WASO): time spent awake between initial sleep onset and final sleep offset; 4) Sleep efficiency (SE): percentage of time in bed spent asleep, (TST/TIB)*100%.

Pittsburg Sleep Quality Index (PSQI). PSQI is a retrospective self-report

questionnaire developed by Buysse, Reynolds, Monk, Berman, and Kupfer (1989) to assess sleep quality, latency, duration, efficiency, and sleep disturbances, use of sleep medication, and daytime dysfunction over the past month (Buysse et al., 1989). The present study used only items 1-4 from the subjective sleep quality subscale. Variables used in the analyses included TST, SOL, WASO, and SE. The questionnaire assessed TST and SOL directly, while WASO was calculated as TIB (between reported bedtime and rise time) minus TST and SOL, and SE was calculated as TST/TIB*100.

Sleep Diaries. Sleep diaries were completed prospectively every morning after the night when actigraphy data were collected. To balance unequal nights observed between subjects, each variable was represented as the within-subject mean. Like PSQI, sleep parameters used in the analyses included self-reported SOL and TST, WASO (calculated as TIB minus SOL and TST), and SE (calculated as TST/TIB*100).

Insomnia Symptoms

Insomnia Severity Index (ISI). The ISI is a 7-item instrument assessing participants' self-rated insomnia symptoms over the past two weeks (Morin, 1993). The items assess difficulty falling asleep, difficulty staying asleep, problems with early awakening, satisfaction with current sleep pattern, interference of sleep problem with daily functioning, noticeability of impairment attributed to the sleep problem, and degree of distress caused by the sleep problem. Items are rated on a scale from 0 to 4, with the overall scale score computed as the sum of item scores. Higher scores indicate more severe insomnia symptoms (0 to 28). Based on the ISI interpretation (Morin, 1993), ISI scores of 0 to 7 are considered clinically insignificant insomnia, scores 8 to 14 as sub-threshold insomnia, scores 15 to 21 as clinical insomnia (moderate), and scores 22 to 28 as clinical insomnia (severe). For this study, good sleepers (ISI scores ≤ 14) and those with clinical insomnia (ISI scores > 14) were compared.

Covariates

In addition to demographic variables, body mass index (BMI) and blood pressure were examined as covariates because of their potential effects on sleep, as shown in studies (Appelhans et al., 2013; Matthews et al., 2014). The degree of hot flash-related interference was measured by the Hot Flash-Related Daily Interference Scale (HFRDIS) in this study, which also was selected as a covariate due to its high relation to sleep and sleep discrepancy in middle-aged women (Lampio et al., 2014; Thurston, Santoro, & Matthews, 2012).

Statistical Analyses

SPSS 23.0 (IBM, Armonk, New York) was used to manage and analyze the data. Descriptive statistics were computed for all demographic variables and sleep. First, the study aimed to describe discrepancies between objective (actigraphy) and subjective (PSQI and diaries) sleep measures on sleep parameters (TST, SOL, WASO, and SE) by comparing the mean values between women with and without insomnia (ISI scores 0-14 as no insomnia vs. 15-28 as insomnia). Repeated measures analysis of variance (RM ANOVA) analyses were performed for each of the four sleep parameters to examine the interaction effects between sleep measurements and insomnia (insomnia versus no insomnia groups based on the ISI scores) on the sleep measurements. In detail, RM ANOVA was conducted for 2 groups of women divided by ISI scores x 3 sleep measurements x 4 sleep parameters. The two insomnia groups were defined as a between-subjects factor, three sleep measurements as a within-subject factor, and four sleep parameters as dependent variables. Independent t-tests were used for pairwise comparisons of variables for which the RM ANOVA showed significant interactions between the insomnia group and sleep measurements. Second, linear regression analyses were performed to confirm the association of ISI groups and four sleep parameters' discrepancies by considering the effects of multiple covariates on the sleep discrepancies. Notably, sleep

discrepancies were calculated by subtracting subjective (PSQI and diaries) from objective (actigraphy) measures of four sleep parameters (SOL, TST, WASO, and SE). In the regression analyses, insomnia scores were treated as predictors (independent variable) and the sleep discrepancies (actigraphy-PSQI, actigraphy-diaries, PSQI-diaries) of specific sleep parameters as outcomes (dependent variable). All regression models were analyzed separately and controlled by selected covariates. Before all the analyses, the assumptions of RM ANOVA and the multiple linear regression were checked to verify that these tests are appropriate for the data in this study. In addition, in some cases, calculating subjective WASO and SE from diary and PSQI responses (bedtime, rise time, and wake time) resulted in SE>100% or WASO <0 minutes. In these cases, values were adjusted from WASO = 0 minutes and SE =100%.

RESULTS

Characteristics of the Participants

As shown in Table 3.1, 398 participants were included in the analyses. The mean age was 54.88 (±3.68). More than half of the participants were presently married (59.3%) or living in a marriage-like relationship (8.8%). About 75% were employed full-time (58.5%) or part-time (15.8%). White participants accounted for 73.1%, followed by African Americans at 22.6%. Educational attainment was baccalaureate or higher for 60.3% of the participants and associate degree for 24.1%.

[Place Table 3.1 here]

Sleep Measurement Discrepancies

As presented in Table 3.2 for RM ANOVA, the main effect of sleep measurements

(actigraphy, diaries, and PSQI) on all four sleep parameters (SOL, TST, WASO, and SE) was significant ($p < .001$). Partial η^2 values showed a large effect size for SOL ($\eta p^2 = .24$), indicating that about 24% of the variance in SOL was attributed to the factor of sleep measurements (Cohen, 1992). Effect sizes for the main effect of sleep measurement were medium for TST ($\eta p^2 = .09$) and small for WASO ($\eta p^2 = .04$) and SE ($\eta p^2 = .05$).

Sleep Measurement Discrepancies by Insomnia Status

The interaction effects between sleep measurements and insomnia were significant for all sleep parameters ($p < .001$ and $p < .005$, see Table 3.2). This indicated that the differences in four sleep parameters between the measurements significantly differ depending on the insomnia severity. Effect sizes for the measurement-by-insomnia interactions were small for each sleep parameter (SOL, $\eta p^2 = .05$; TST, $\eta p^2 = .05$; WASO, $\eta p^2 = .02$; SE, $\eta p^2 = .04$).

[Place Table 3.2 here]

Comparison of Sleep Parameters by Insomnia Status across the Three Measurements

Pairwise comparisons (independent *t*-tests) of women with and without insomnia showed that women with insomnia scored significantly worse on each sleep parameter compared to those without insomnia (Figures 3.1-3.4), regardless of the sleep measurement. However, the *magnitude* of difference in each parameter between women with and without insomnia varied across the three measurements, with actigraphy indicating the smallest mean difference in the sleep parameters between insomnia groups and PSQI showing the greatest mean difference.

Women with insomnia had significantly longer SOL and shorter TST on PSQI and diaries compared to women without insomnia but did not significantly differ in actigraphy. The

insomnia groups differed significantly in WASO and SE across all three sleep measures, with comparisons showing greater WASO and lower SE in the women with insomnia versus those without insomnia.

[Place Figure 3.1-3.4 (2x2 grid) here]

Comparison of Sleep Measurements by Insomnia Status

Pairwise comparisons of each sleep measurement within each insomnia group showed significant differences between actigraphy and the two subjective measurements and between PSQI and the diaries (see Table 3.3 and Figures 3.1-3.4). The measurement differences for all three measurement comparisons were greater for women with insomnia than those without insomnia.

Among women with insomnia, actigraphy consistently showed less sleep disturbance than PSQI, as indicated by lower SOL ($p < .001$) and WASO ($p = .047$), and higher TST ($p < .001$) and SE ($p = .047$) on actigraphy. In this group, actigraphy showed significantly lower SOL than diaries ($p < .001$), but no other differences were significant. The PSQI indicated significantly poorer sleep than the diaries on all sleep parameters except for SOL, with lower TST ($p < .001$) and SE ($p = .001$) and higher WASO ($p = .008$).

In the group of women without insomnia, the measurement differences across the sleep parameters were less consistent. Compared to PSQI, actigraphy showed lower SOL ($p < .001$), indicating better sleep but lower SE ($p < .001$), indicating poorer sleep, and no significant differences in TST or WASO. Compared to diaries, actigraphy also showed significantly lower SOL ($p < .001$) but worse sleep according to other outcomes: lower TST ($p = .002$) and SE ($p < .001$) and higher WASO ($p < .001$). However, the subjective measures differed in the same

manner as the insomnia group, with PSQI indicating poorer sleep, as shown by lower TST ($p < .001$), lower SE ($p < .001$), and higher WASO ($p < .001$). The two groups did not differ in SOL.

[Place Table 3.3 here]

Interaction Effect of Insomnia and Sleep Discrepancies

Table 3.4 presents the results of a regression analysis of the association of continuous ISI scores with discrepancies between the objective (actigraphy) and subjective measurements (PSQI and diaries) in four sleep parameters (SOL, TST, WASO, SE). All regression models were analyzed separately and controlled for the selected covariates (age, ethnicity, marital status, employment, education level, BMI, BP, and vasomotor symptoms). The results revealed that the insomnia score was associated significantly with the magnitude of discrepancies between objective and subjective measurements (actigraphy-PSQI and actigraphy-diaries) in all four sleep parameters.

The ISI score was associated *negatively* with discrepancies in SOL and WASO, indicating that women with higher ISI scores (i.e., more insomnia symptoms) tended to *overestimate* SOL and WASO on the two subjective measures versus actigraphy. On SOL, a β coefficient of greater absolute value for actigraphy-PSQI versus actigraphy-diaries (actigraphy-PSQI: $\beta = -.212$, $p = <.001$; actigraphy-diaries: $\beta = -.143$, $p = .012$, respectively) indicated the tendency to overestimate PSQI than reports in diaries as ISI scores increased. Overestimation of subjective WASO with increasing ISI scores was similar for PSQI and diaries ($\beta = -.141$, $p = .014$; $\beta = -.160$, $p = .006$, respectively).

The regression analyses showed *positive* associations of ISI scores with TST and SE,

indicating that women with higher ISI scores tended to *underestimate* TST and SE on the two subjective measures versus actigraphy. The β coefficients indicated that those with higher ISI scores were more likely to underestimate PSQI versus diary reports for TST (PSQI: $\beta = .225$, $p = <.001$; diaries: $\beta = .198$, $p = .001$) but underestimation was similar for SE (PSQI: $\beta = .192$, $p = .001$; diaries: $\beta = .201$, $p = .001$).

On the other hand, the associations between ISI score and the discrepancies between two self-reported measurements (PSQI-diaries) in all sleep parameters were non-significant (SOL: $\beta = .096$, $p = .092$; WASO: $\beta = .012$, $p = .838$; TST: $\beta = -.084$, $p = .141$; SE: $\beta = -.029$, $p = .612$, respectively).

[Place Table 3.4 here]

DISCUSSION

This study collected objective and subjective data from middle-aged women experiencing menopause to compare and analyze four sleep parameters. These parameters included actigraphy, which collects objective data on sleep behavior; PSQI, a retrospective self-reported survey summarizing sleep quality in the prior month; and sleep diaries, which prospectively track sleep over several days or weeks. In addition, we examined the measurement discrepancies in SOL, TST, WASO, and SE between women with and without insomnia, as categorized by ISI score (>14 or ≤14, respectively). Based on the study aims and results, two main points are discussed: 1) significant differences in sleep parameters between actigraphy and subjective measures (PSQI and sleep diaries) depending on the insomnia level and 2) the trends in the magnitude of the sleep discrepancies are.

Differences between measures in women with and without insomnia in sleep parameters

Women with insomnia

Among women with insomnia, the findings showed that all four sleep parameters were significantly associated with poorer sleep on PSQI compared to actigraphy, showing longer SOL by 18 mins, shorter TST by 48 mins, longer WASO by 16 mins and lower SE by 3.5%. The large underestimation of TST on PSQI versus actigraphy (48 mins) contributed to positive SE differences (actigraphy-PSQI, lower SE on PSQI than actigraphy). These findings are comparable with previous studies that have shown significant differences, or only weak relationships, between self-report and objective measures in those with insomnia. In particular, earlier studies have shown that participants with insomnia tended to overestimate their SOL and WASO (Williams et al., 2013) and underestimate their TST compared to objective measures (Means et al., 2003), indicating that insomnia had a greater effect on self-reports than objective measures, thus accounting for measurement discrepancies.

Meanwhile, the present study showed a significant difference in SOL but not in other sleep parameters (TST, WASO, and SE) between actigraphy and diaries among women with insomnia. SOL reported in diaries was longer by 16 mins compared to actigraphy, which is a larger gap than women without insomnia (9 mins longer on diary versus actigraphy). This result is in line with some CBT studies (Kay et al., 2015; Tang & Harvey, 2004) showing that insomnia subjects overestimated their SOL in diaries compared to actigraphy. Among women with insomnia, it is noteworthy that SOL discrepancies were found on both subjective measures compared to actigraphy. Previous studies provided several explanations for SOL discrepancy. Responses to subjective sleep measures can be more affected by one's health and emotional status in female older adults than in males, especially longer SOL in self-reports was associated with poor sleep quality (Kay et al., 2015) and negative mood or preoccupation with sleep (McCrae et al., 2008; Tang & Harvey, 2004), which may have led to the objective and

subjective SOL discrepancy.

However, unlike findings from prior literature, actigraphy and diaries did not differ significantly in TST and WASO in this study. Several studies have shown that those with insomnia overestimated TST and WASO on subjective measures compared to objective measures (Fernandez-Mendoza et al., 2011; Means et al, 2003; Williams et al., 2013). Compared to the significant TST, SOL, and WASO differences between actigraphy and PSQI in the insomnia group, this study showed that insomnia did not significantly affect the reporting of TST and WASO on the diaries that contained self-reported sleep quality on the previous day. Tang & Harvey (2004), who argued that the farther the memory is, the less continuity of the self-reporting and the more differences in the accuracy, could explain this mechanism. After all, insignificant differences in TST and WASO between actigraphy and diaries seem to not make a difference in the SE of the insomnia group.

Women without insomnia

Significant differences emerged between actigraphy and PSQI in SOL and SE among women without insomnia. Whereas differences in TST and WASO between actigraphy and PSQI were non-significant, SOL was 6 mins longer, and SE was 3.5% higher on PSQI compared to actigraphy. SOL discrepancy between actigraphy and PSQI was comparable to the findings by Williams et al. (2013), suggesting SOL may be over-reported due to some psychological factors among older adults without insomnia symptoms. However, this finding differed from the result reported in O'Donnell et al. (2009), which indicated similar subjective and objective SOL estimates in a healthy population. The SOL overestimation of self-reports was also found in healthy adults in Baker et al.'s (1999) study, showing no significant objective/subjective SOL difference in the first three days of reporting, during which participants tended to be more concerned and aware of their sleep records. However, given the

discontinuity of sleep records after 6 and 12 weeks, it was argued that long-term reporting might have induced significant SOL discrepancies. Meanwhile, shorter TIB of PSQI (462 mins in PSQI vs. 473 mins in actigraphy) and insignificant differences in TST between actigraphy and PSQI measures in the present study might have caused the significantly higher SE of PSQI than that of actigraphy in women without insomnia. Lastly, the insignificant TST and WASO differences between actigraphy and PSQI among those without insomnia are similar to the findings of O'Donnell et al. (2009), showing similarities in TST and WASO between subjective and objective estimates in healthy older adults without sleep-disordered breathing.

Actigraphy and diary reports differed significantly in all four sleep parameters among women without insomnia. Compared to actigraphy, diary reports showed longer SOL by 9 mins, shorter WASO by 18 mins, longer TST by 11 mins, and higher SE by 6%. Among them, it should be noted that women without insomnia significantly overestimated SOL of actigraphy and underestimated WASO of diaries compared to actigraphy, which contributed to the negative SE differences (actigraphy-diaries, higher SE of diaries than that of actigraphy). Subjective SOL overestimation compared to actigraphy was a consistent finding that appears to characterize women in the menopause transition and postmenopause, regardless of measure (PSQI or diaries) or insomnia status, and thus might not be a very specific indicator of insomnia.

However, since the SOL overestimation in women without insomnia was smaller than in women with insomnia, insomnia might still affect SOL discrepancies. Underestimation of reported WASO and overestimation of TST may imply that women without insomnia reported their sleep symptoms less than those with insomnia, which was also shown in some previous studies. Physically and physiologically healthy older adults may adapt to their disturbed sleep as an aging process or aging-related changes, so they underestimate their sleep problems on subjective measures (Buysse et al., 1991). Another study by Vitiello et al. (2004) reported a

similar pattern in healthy older women who did not report sleep problems, but their sleep on PSG recordings showed disruption. In the case of our study, since WASO was calculated, such perception may be related to the over-reporting of TST in women without insomnia, which may eventually result in the underestimation of WASO and better SE of diaries.

The trends in the magnitude of sleep discrepancies between women with insomnia and women without insomnia

The RM ANOVA and regression findings clearly showed insomnia effects on objective-subjective sleep discrepancies in all collected parameters (SOL, TST, WASO, and SE). In particular, actigraphy-measured discrepancies in all sleep parameters between women with and without insomnia symptoms were small, whereas subjectively reported sleep differences between the two groups were large. This phenomenon implies that insomnia influenced the responses to subjective measures. In detail, the interaction of ISI score with the differences between actigraphy and PSQI was found in all four sleep parameters (SOL by 12 mins, TST by 44 mins, WASO by 21 mins, and SE by 6%). However, the differences in sleep parameters were greater for PSQI than actigraphy among women with insomnia than those without insomnia, suggesting that insomnia significantly affects the responses to PSQI. Similarly, the interaction of ISI score with the differences between actigraphy and sleep diaries was found in all four sleep parameters (SOL by 7 mins, TST by 23 mins, WASO by 16 mins, and SE by 2%) and the differences in all the parameters of diaries were greater than those of actigraphy among women with insomnia than those without insomnia. However, it showed a smaller insomnia effect on the differences between actigraphy and diaries compared to the differences between actigraphy and PSQI. In sum, the interaction effect between the two variables (ISI score and measurements) was significant, but the magnitude of discrepancies between actigraphy and diaries was smaller than the differences between actigraphy and PSQI.

This implies that insomnia might affect the responses to self-reports more than actigraphy, although its effect on the diaries was smaller compared to PSQI.

The findings are in line with some previous CBT-I studies and other insomnia treatment trials, which showed that insomnia affected the responses on the subjective measures more than on the objective measure when confirming the therapeutic effect on insomnia, demonstrating the effect of insomnia on the subjective sleep perception (Kay et al., 2015; McCrae et al., 2008; Perlis et al., 1997; Okajima et al., 2011; Tang & Harvey, 2004). Their study findings revealed that sleep medicine or psychological treatment programs enhanced subjective sleep more than objective one. Moreover, the discrepancies' negative association with SOL and WASO and positive link with TST implied that insomnia negatively distorted the responses to those three subjectively measured sleep parameters, contributing to better actigraphic SE than SE of two subjective measurements. Studies by Bonnet and Arand (2010) and Buysse et al. (2011) might clarify insomnia's effect on sleep perception. They reviewed various insomnia models and concluded that insomnia obscures the difference between sleep and wake activity patterns due to persistent cortical activation and sensory input throughout the day and night, increasing the individuals' perception of being awake despite sleeping.

Furthermore, Tang and Harvey (2004) discussed that distorted responses to subjective measures might be due to the influence of various environments (e.g., distortion of memory from information acquisition in one's daily life, reinforcement of awareness of sleep patterns, etc.). Okajima et al. (2011) argued that these external factors might contribute to pre-sleep anxiety or thoughts of insomnia, consistent with some studies (Lane et al., 1996; Nofzinger et al., 2004; Schmukle & Egloff, 2005), arguing emotional state or mood is strongly involved in the responses to psychological tests. Their research may suggest that negative emotional states, such as insomnia, may greatly influence reported sleep, enlarging the differences between

subjective and objective sleep measurements. Lastly, the effect of insomnia had the greatest influence on PSQI, followed by sleep diaries and actigraphy, which eventually led to greater sleep discrepancies between actigraphy and PSQI than between actigraphy and sleep diaries. This phenomenon may have distorted the recall of a month distant sleep pattern reported in the PSQI compared to diaries that required the participants to recall the previous night. Some study findings suggesting that insomnia or insufficient sleep can impair one's memory or performance supported that phenomenon (Haimov et al., 2008; Nofzinger et al., 2004).

Implication

This study presents several noteworthy clinical implications for improving sleep assessment in middle-aged women undergoing the menopausal transition. First, the findings indicate that insomnia in this group may largely be a subjective experience. Therefore, incorporating objective measures, such as actigraphy, alongside subjective assessments could provide a more accurate interpretation of their sleep patterns. Actigraphy, in particular, stands out as a practical option due to its cost-effectiveness and ease of use in non-clinical, natural settings (Martin & Hakim, 2011). Since actigraphy continuously monitors sleep and wake patterns, it offers additional insight into sleep habits that self-reported measures might miss, enhancing the understanding of patients' overall sleep behavior (Martin & Hakim, 2011). However, as Kay et al. (2013) suggest, this approach is especially beneficial if used over multiple nights, given the variability in sleep patterns among older adults. This recommendation may be particularly relevant for middle-aged women whose sleep quality is affected by both menopausal and age-related changes, underscoring the importance of multi-day monitoring.

If objective measures such as actigraphy are unavailable, e-diaries on smartphones may serve as a practical alternative. According to Min et al. (2014), smartphone-based e-diaries

can collect sleep data over extended periods, offering a viable option for long-term sleep tracking. Not only do e-diaries address limitations of objective measures, such as high maintenance costs and limited large-scale availability, but they also allow data to be transmitted directly from patients to clinicians, thereby facilitating integrated sleep management and reducing the need for frequent clinic visits (Yousaf et al., 2014). Importantly, combining actigraphy with sleep diaries may also help mitigate potential inaccuracies. As actigraphy tends to overestimate total sleep time (TST) in less active individuals and misestimates sleep onset latency (SOL), using a sleep diary in conjunction could provide a more comprehensive assessment (Martin & Hakim, 2011). Notably, changes in the degree of discrepancy between actigraphy and diary data may offer clearer insights into treatment effectiveness, a point echoed in the American Academy of Sleep Medicine's guidelines, which recommend using self-reports alongside actigraphy for adults with insomnia (Schutte-Rodin et al., 2008).

Strength and Weakness of the Study

While the study provides valuable clinical insights, certain limitations must also be acknowledged. Notably, it did not consider participants' existing medical conditions, medication use, or lifestyle habits, all of which could influence sleep patterns and assessment results. Additionally, with approximately 70% of the participants being White women, the findings may not fully generalize to other ethnic groups, thus warranting further research with more diverse populations. Nevertheless, despite these limitations, this study significantly advances the understanding of differences between subjective and objective sleep assessments in nearly 400 middle-aged women around menopause, offering an in-depth exploration of how insomnia symptoms may influence these discrepancies.

Future Directions

Further studies need to further compare sleep parameters measured by objective and

subjective measurements targeting middle-aged women near menopause in a more diverse group to confirm the role of insomnia in influencing sleep perception. Such studies will also add more objective results on the compatibility between sleep measurements. In addition, since subjective measures are still more convenient and economically more feasible than objective ones, it can be considered to conduct the studies on predicting the results of objective measures with sleep data obtained from subjective ones. Finally, further study can identify factors (i.e., underlying or current health issues or lifestyles etc.) that influence insomnia perception and complaints in this particular population.

CONCLUSIONS

This study found discrepancies in sleep patterns between objective and subjective measures in women with (actigraphy vs. PSQI) and without insomnia (actigraphy vs. diaries) undergoing the menopause transition and postmenopause. The findings suggest that insomnia symptoms and other factors may have contributed to the discrepancies in sleep parameters between measurements. However, a greater magnitude of measurement discrepancies in all selected sleep parameters was found in women with insomnia than in women without insomnia, verifying the effect of insomnia on subjective and objective sleep discrepancies. In particular, after controlling for various variables, insomnia negatively affected the responses to the sleep parameters in self-reports, increasing the differences between actigraphy and two subjective sleep measurements and thus confirming the influence of insomnia on one's distorted perception of sleep. Although this study did not identify the factors affecting insomnia, the results extended prior evidence showing differences between objective and subjective measurements after controlling multiple covariates in participants with and without insomnia. Moreover, the findings of the inaccuracy of the subjective sleep perception will inform the

selection of measurements for evaluating sleep patterns and planning clinical interventions. Nevertheless, further large-scale research with more diverse ethnic groups is still needed to add evidence of a relationship between insomnia's effects on sleep perception in this population.

REFERENCES FOR CHAPTER 3

American Psychiatric Association. *Diagnostic criteria from DSM-IV-TR*. (2000). The Association.

Ancoli-Israel, S., Cole, R., Alessi, C., Chambers, M., Moorcroft, W., & Pollak, C. P. (2003). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*, *26*(3), 342-392. https://doi.org/10.1093/sleep/26.3.342

Appelhans, B. M., Janssen, I., Cursio, J. F., Matthews, K. A., Hall, M., Gold, E. B., Burns, J. W., & Kravitz, H. M. (2013). Sleep duration and weight change in midlife women: The SWAN sleep study: Sleep Duration and Weight Change. *Obesity (Silver Spring, Md.)*, *21*(1), 77–84. https://doi.org/10.1002/oby.20251

Baker, F. C., de Zambotti, M., Colrain, I. M., & Bei, B. (2018). Sleep problems during the menopausal transition: prevalence, impact, and management challenges. *Nature and Science of Sleep, 10*, 73–95. https://doi.org/10.2147/NSS.S125807

Baker, F. C., Maloney, S., & Driver, H. S. (1999). A comparison of subjective estimates of sleep with objective polysomnographic data in healthy men and women. *Journal of Psychosomatic research*, *47*(4), 335-341.

Blümel, J. E., Cano, A., Mezones-Holguín, E., Barón, G., Bencosme, A., Benítez, Z., ... & Chedraui, P. (2012). A multinational study of sleep disorders during female mid-life. *Maturitas*, *72*(4), 359-366. doi:10.1016/j.maturitas.2012.05.011

Bonnet, M. H., & Arand, D. L. (2010). Hyperarousal and insomnia: state of the science. *Sleep Medicine Reviews*, *14*(1), 9-15. doi:10.1016/j.smrv.2009.05.002

Bromberger, J. T., Kravitz, H. M., Youk, A., Schott, L. L., & Joffe, H. (2016). Patterns of depressive disorders across 13 years and their determinants among midlife women: SWAN mental health study. *Journal of Affective Disorders*, *206*, 31-40.

doi:10.1016/j.jad.2016.07.005

Buchanan, D. T., Landis, C. A., Hohensee, C., Guthrie, K. A., Otte, J. L., Paudel, M., ... & Ensrud, K. E. (2017). Effects of yoga and aerobic exercise on actigraphic sleep parameters in menopausal women with hot flashes. *Journal of Clinical Sleep Medicine*, *13*(1), 11-18. doi:10.5664/jcsm.6376

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Hoch, C. C., Yeager, A. L., & Kupfer, D. J. (1991). Quantification of subjective sleep quality in healthy elderly men and women using the Pittsburgh Sleep Quality Index (PSQI). *Sleep*, *14*(4), 331-338. doi:10.1093/sleep/14.4.331

Buysse, D. J., Germain, A., Hall, M., Monk, T. H., & Nofzinger, E. A. (2011). A neurobiological model of insomnia. *Drug Discovery Today: Disease Models*, *8*(4), 129-137. doi:10.1016/j.ddmod.2011.07.002

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. doi:10.1016/0165-1781(89)90047-4

Buysse, D. J., Cheng, Y., Germain, A., Moul, D. E., Franzen, P. L., Fletcher, M., & Monk, T. H. (2010). Night-to-night sleep variability in older adults with and without chronic insomnia. *Sleep Medicine*, *11*(1), 56-64. doi:10.1016/j.sleep.2009.02.010

Campbell, I. G., Bromberger, J. T., Buysse, D. J., Hall, M. H., Hardin, K. A., Kravitz, H. M., ... & Gold, E. (2011). Evaluation of the association of menopausal status with delta and beta EEG activity during sleep. *Sleep*, *34*(11), 1561-1568. doi:10.5665/sleep.1398

Carpenter, J. S. (2001). The Hot Flash Related Daily Interference Scale: a tool for assessing the impact of hot flashes on quality of life following breast cancer. *Journal of Pain and Symptom Management*, *22*(6), 979-989. doi:10.1016/S0885-3924(01)00353-0

Cohen, J. (1992). A Power Primer. *Psychological Bulletin*, *112*(1), 155–159. doi:10.1037/0033-2909.112.1.155

Fernandez-Mendoza, J., Calhoun, S. L., Bixler, E. O., Karataraki, M., Liao, D., Vela-Bueno, A., ... & Vgontzas, A. N. (2011). Sleep misperception and chronic insomnia in the general population: the role of objective sleep duration and psychological profiles. *Psychosomatic Medicine*, *73*(1), 88. doi:10.1097/PSY.0b013e3181fe365a

Haimov, I., Hanuka, E., & Horowitz, Y. (2008). Chronic insomnia and cognitive functioning among older adults. *Behavioral Sleep Medicine*, *6*(1), 32-54. doi:10.1080/15402000701796080

Hardy, M. A. (1993). *Regression with dummy variables* (Vol. 93). Sage Publications. https://doi.org/10.4135/9781412985628

Haseli-Mashhadi, N., Dadd, T., Pan, A., Yu, Z., Lin, X., & Franco, O. H. (2009). Sleep quality in middle-aged and elderly Chinese: distribution, associated factors and associations with cardio-metabolic risk factors. *BMC Public Health*, *9*(1), 1-11. doi:10.1186/1471-2458-9-130

Hoevenaar-Blom, M. P., Spijkerman, A. M., Kromhout, D., van den Berg, J. F., & Verschuren, W. M. (2011). Sleep duration and sleep quality in relation to 12-year cardiovascular disease incidence: the MORGEN study. *Sleep*, *34*(11), 1487-1492. doi:10.5665/sleep.1382

Jafari, B., & Mohsenin, V. (2010). Polysomnography. *Clinics in Chest Medicine*, *31*(2), 287-297. doi:10.1016/j.ccm.2010.02.005

Kaufmann, C. N., Canham, S. L., Mojtabai, R., Gum, A. M., Dautovich, N. D., Kohn, R., & Spira, A. P. (2013). Insomnia and health services utilization in middle-aged and older adults: results from the Health and Retirement Study. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *68*(12), 1512-1517. doi:10.1093/gerona/glt050

Kay, D. B., Buysse, D. J., Germain, A., Hall, M., & Monk, T. H. (2015). Subjective–objective

sleep discrepancy among older adults: associations with insomnia diagnosis and insomnia treatment. *Journal of Sleep Research*, *24*(1), 32-39. doi:10.1111/jsr.12220

Kay, D. B., Dzierzewski, J. M., Rowe, M., & McCrae, C. S. (2013). Greater night-to-night variability in sleep discrepancy among older adults with a sleep complaint compared to noncomplaining older adults. *Behavioral Sleep Medicine*, *11*(2), 76-90. doi:10.1080/15402002.2011.602775

Kravitz, H. M., Zhao, X., Bromberger, J. T., Gold, E. B., Hall, M. H., Matthews, K. A., & Sowers, M. R. (2008). Sleep disturbance during the menopausal transition in a multi-ethnic community sample of women. *Sleep, 31*(7), 979-990. https://doi.org/10.5665/sleep/31.7.979

Kyle, S. D., Morgan, K., & Espie, C. A. (2010). Insomnia and health-related quality of life. *Sleep Medicine Reviews*, *14*(1), 69-82. doi:10.1016/j.smrv.2009.07.004

Carpenter, J. S., Guthrie, K. A., Larson, J. C., Freeman, E. W., Joffe, H., Reed, S. D., ... & LaCroix, A. Z. (2012). Effect of escitalopram on hot flash interference: a randomized, controlled trial. *Fertility and Sterility*, *97*(6), 1399-1404. doi:10.1016/j.fertnstert.2012.03.001

Lampio, L., Polo-Kantola, P., Polo, O., Kauko, T., Aittokallio, J., & Saaresranta, T. (2014). Sleep in midlife women: effects of menopause, vasomotor symptoms, and depressive symptoms. *Menopause*, *21*(11), 1217-1224. doi:10.1097/GME.0000000000000239

Lane, R. D., Lee, S., Reidel, R., Weldon, V., Kaszniak, A., & Schwartz, G. E. (1996). Impaired verbal and nonverbal emotion recognition in alexithymia. *Psychosomatic Medicine*, *58*(3), 203-210. doi:10.1097/00006842-199605000-00002

Larsen, W. A., & McCleary, S. J. (1972). The use of partial residual plots in regression analysis. *Technometrics*, *14*(3), 781-790. doi:10.1080/00401706.1972.10488966

Maes, J., Verbraecken, J., Willemen, M., De Volder, I., Van Gastel, A., Michiels, N., ... &

Cluydts, R. (2014). Sleep misperception, EEG characteristics and autonomic nervous system activity in primary insomnia: a retrospective study on polysomnographic data. *International Journal of Psychophysiology*, *91*(3), 163-171. doi:10.1016/j.ijpsycho.2013.10.012

Mallinson, D. C., Kamenetsky, M. E., Hagen, E. W., & Peppard, P. E. (2019). Subjective sleep measurement: comparing sleep diary to questionnaire. *Nature and Science of Sleep*, 197-206. doi:10.2147/NSS.S217867

Manconi, M., Ferri, R., Sagrada, C., Punjabi, N. M., Tettamanzi, E., Zucconi, M., ... & FERINI-STRAMBI, L. U. I. G. I. (2010). Measuring the error in sleep estimation in normal subjects and in patients with insomnia. *Journal of Sleep Research*, *19*(3), 478-486. doi:10.1111/j.1365-2869.2009.00801.x

Martin, J. L., & Hakim, A. D. (2011). Wrist actigraphy. *Chest*, *139*(6), 1514-1527. doi:10.1378/chest.10-1872

Matthews, K. A., Chang, Y., Kravitz, H. M., Bromberger, J. T., Owens, J. F., Buysse, D. J., & Hall, M. H. (2014). Sleep and risk for high blood pressure and hypertension in midlife women: the SWAN (Study of Women's Health Across the Nation) Sleep Study. *Sleep Medicine*, *15*(2), 203-208. doi:10.1016/j.sleep.2013.11.002

McCrae, C. S., McNAMARA, J. P., Rowe, M. A., Dzierzewski, J. M., Dirk, J., Marsiske, M., & Craggs, J. G. (2008). Sleep and affect in older adults: Using multilevel modeling to examine daily associations. *Journal of Sleep Research*, *17*(1), 42-53. doi:10.1111/j.1365-2869.2008.00621.x

Means, M. K., Edinger, J. D., Glenn, D. M., & Fins, A. I. (2003). Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. *Sleep Medicine*, *4*(4), 285-296. doi:10.1016/S1389-9457(03)00057-1

Min, Y. H., Lee, J. W., Shin, Y. W., Jo, M. W., Sohn, G., Lee, J. H., ... & Ahn, S. H. (2014).

Daily collection of self-reporting sleep disturbance data via a smartphone app in breast cancer patients receiving chemotherapy: a feasibility study. *Journal of Medical Internet Research*, *16*(5), e135. doi:10.2196/jmir.3421

Morin, C. M. (1993). *Insomnia: Psychological assessment and management*. Guilford press.

Newton, K. M., Carpenter, J. S., Guthrie, K. A., Anderson, G. L., Caan, B., Cohen, L. S., ... & LaCroix, A. Z. (2014). Methods for the design of vasomotor symptom trials: the MsFLASH network. *Menopause (New York, NY)*, *21*(1). doi:10.1097/GME.0b013e31829337a4

Nofzinger, E. A., Buysse, D. J., Germain, A., Price, J. C., Miewald, J. M., & Kupfer, D. J. (2004). Functional neuroimaging evidence for hyperarousal in insomnia. *American Journal of Psychiatry*, *161*(11), 2126-2128. doi:10.1176/appi.ajp.161.11.2126

O'donnell, D., Silva, E. J., Münch, M., Ronda, J. M., Wang, W., & Duffy, J. F. (2009). Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. *Journal of sleep research, 18*(2), 254-263. doi:10.1111/j.1365-2869.2008.00719.x

Okajima, I., Komada, Y., & Inoue, Y. (2011). A meta-analysis on the treatment effectiveness of cognitive behavioral therapy for primary insomnia. *Sleep and Biological Rhythms*, *9*, 24-34. doi:10.1111/j.1479-8425.2010.00481.x

Penzel, T., & Conradt, R. (2000). Computer based sleep recording and analysis. *Sleep Medicine Reviews*, *4*(2), 131-148. doi:10.1053/smrv.1999.0087

Perlis, M. L., Giles, D. E., Mendelson, W. B., Bootzin, R. R., & Wyatt, J. K. (1997). Psychophysiological insomnia: the behavioural model and a neurocognitive perspective. *Journal of Sleep Research*, *6*(3), 179-188. doi:10.1046/j.1365-2869.1997.00045.x

Philips Respironics (2023, July 22). Motion Biosensors.

https://www.usa.philips.com/healthcare/sites/actigraphy/solutions/motion-biosensors#motion_biosensors

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: an update. *Sleep Medicine Reviews*, *15*(4), 259-267. doi:10.1016/j.smrv.2010.10.001

Schmukle, S. C., & Egloff, B. (2005). A latent state-trait analysis of implicit and explicit personality measures. *European Journal of Psychological Assessment*, *21*(2), 100-107. doi:10.1027/1015-5759.21.2.100

Schutte-Rodin, S., Broch, L., Buysse, D., Dorsey, C., & Sateia, M. (2008). Clinical guideline for the evaluation and management of chronic insomnia in adults. *Journal of Clinical Sleep Medicine*, *4*(5), 487-504. doi:10.5664/jcsm.27286

Shaver, J. L., & Woods, N. F. (2015). Sleep and menopause: a narrative review. *Menopause*, *22*(8), 899-915. doi:10.1097/GME.0000000000000499

Smith, M. T., & Wegener, S. T. (2003). Measures of sleep: the insomnia severity index, medical outcomes study (MOS) sleep scale, Pittsburgh sleep diary (PSD), and Pittsburgh sleep quality index (PSQI). *Arthritis Care & Research: Official Journal of the American College of Rheumatology*, *49*(S5), S184-S196.

Spira, A. P., Chen-Edinboro, L. P., Wu, M. N., & Yaffe, K. (2014). Impact of sleep on the risk of cognitive decline and dementia. *Current Opinion in Psychiatry*, *27*(6), 478-483. doi:10.1097/YCO.0000000000000106

Sternfeld, B., Guthrie, K. A., Ensrud, K. E., LaCroix, A. Z., Larson, J. C., Dunn, A. L., Anderson, G. L., Seguin, R. A., Carpenter, J. S., Newton, K. M., Reed, S. D., Freeman, E. W., Cohen, L. S., Joffe, H., Roberts, M., & Caan, B. J. (2014). Efficacy of exercise for menopausal symptoms: a randomized controlled trial. *Menopause (New York, N.Y.)*, *21*(4), 330–338. doi:10.1097/GME.0b013e31829e4089

Tang, N. K., & Harvey, A. G. (2004). Correcting distorted perception of sleep in insomnia: a novel behavioural experiment?. *Behaviour Research and Therapy*, *42*(1), 27-39. doi:10.1016/S0005-7967(03)00068-8

Taylor, D. J., Lichstein, K. L., & Durrence, H. H. (2003). Insomnia as a health risk factor. *Behavioral Sleep Medicine*, *1*(4), 227-247. doi:10.1207/S15402010BSM0104_5

Thurston, R. C., Santoro, N., & Matthews, K. A. (2012). Are vasomotor symptoms associated with sleep characteristics among symptomatic midlife women? Comparisons of self-report and objective measures. *Menopause (New York, NY)*, *19*(7), 742-748 doi:10.1097/gme.0b013e3182422973

Vitiello, M. V., Larsen, L. H., & Moe, K. E. (2004). Age-related sleep change: gender and estrogen effects on the subjective–objective sleep quality relationships of healthy, noncomplaining older men and women. *Journal of Psychosomatic Research*, *56*(5), 503-510. doi:10.1016/S0022-3999(04)00023-6

Williams, J. M., Kay, D. B., Rowe, M., & McCrae, C. S. (2013). Sleep discrepancy, sleep complaint, and poor sleep among older adults. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *68*(5), 712-720. doi:10.1093/geronb/gbt030

Yousaf, F., Hamida, S. T. B., & Ahmed, B. (2014, February). Sleep eDiary: A mobile health application for insomnia assessment. In *2014 2nd Middle East Conference on Biomedical Engineering (MECBME)* (pp. 285–288). IEEE. https://doi.org/10.1109/MECBME.2014.6783260

Xu, Q., & Lang, C. P. (2014). Examining the relationship between subjective sleep disturbance and menopause: a systematic review and meta-analysis. *Menopause*, *21*(12), 1301-1318. DOI: 10.1097/GME.0000000000000240

FIGURES AND TABLES FOR CHAPER 3

Table 3.1 Characteristics of the participants

Age (n=398), Mean (SD)		54.89 (±3.68)
Marital Status (n=396), n (%)	Never married	38 (9.5%)
	Divorced	78 (19.6%)
	Widowed	9 (2.3%)
	Presently married	236 (59.3%)
	Living in a marriage like relationship	35 (8.8%)
Employment (n=397), n (%)	Full-time	233 (58.5%)
	Part-time	63 (15.8%)
	Housewife	9 (2.3%)
	Retired	21 (5.3%)
	Unable to work	11 (2.8%)
	Not working	29 (7.3%)
	Other	31 (7.8%)
Ethnicity (n=372), n (%)	White	272 (73.1%)
	Black, African American	84 (22.6%)
	Asian	10 (2.7%)
	Other	3 (0.8%)
	American Indian/Native	2 (0.5%)
	Hispanic	1 (0.3%)
Education (n=397), n (%)	Some high school	7 (1.8%)
	High school diploma	25 (6.3%)
	Vocational/training school	29 (7.3%)
	Associate Degree	96 (24.1%)
	Baccalaureate Degree	90 (22.6%)
	Professional school	56 (14.1%)
	Master’s Degree	77 (19.3%)
	Doctoral Degree	17 (4.3%)

Table 3.2 Description of SOL, TST, WASO, and SE measured by actigraphy, PSQI, and diaries between women with and without insomnia

	Group	Actigraphy M (SD)	PSQI M (SD)	Diaries M (SD)	Measurement effect			Measurement x Group interaction		
					F	*p*	ηp^2	F	*p*	ηp^2
SOL, min.	Women without insomnia (n=287)	12.26 (11.54)	19.16 (14.58)	21.34 (14.41)	122.45	**<.001**	0.24	19.37	**<.001**	0.05
	Women with insomnia (n=106)	13.91 (11.60)	32.35 (23.72)	30.35 (20.82)						
TST, min.	Women without insomnia (n=288)	405.34 (47.72)	400.48 (67.50)	416.48 (54.91)	37.47	**<.001**	0.09	19.34	**<.001**	0.05
	Women with insomnia (n=105)	411.80 (60.10)	363.60 (75.12)	399.15 (76.03)						
WASO, min.	Women without insomnia (n=287)	54.89 (20.21)	48.98 (51.77)	36.46 (42.24)	15.12	**<.001**	0.04	7.49	**.001**	0.02
	Women with insomnia (n=104)	63.57 (31.54)	80.08 (69.29)	60.60 (43.47)						
SE, %	Women without insomnia (n=287)	83.08 (6.38)	86.64 (11.55)	89.14 (9.15)	19.95	**<.001**	0.05	15.12	**<.001**	0.04
	Women with insomnia (n=104)	81.27 (8.03)	77.72 (14.01)	82.45 (9.83)						

Note. SOL, sleep onset latency; WASO, wake after sleep onset; TST, total sleep time; SE, sleep efficiency; PSQI, Pittsburg Sleep Quality Index. Values for SOL, WASO and TST were reported in minutes. The effect of sleep measurements and the interaction effects of sleep measurements and insomnia status are significant at the .05 level.

Table 3.3 The pairwise comparison of three sleep measurements between women with and without insomnia

	Comparison		Mean difference ($M_I - M_{II}$)		*p*-value comparison	
	Measurement I	Measurement II	Women without insomnia	Women with insomnia	Women without insomnia	Women with insomnia
SOL, min.	Actigraphy	PSQI	-6.905	-18.440	**<.001**	**<.001**
	Actigraphy	Diaries	-9.077	-16.443	**<.001**	**<.001**
	PSQI	Diaries	-2.171	1.997	**.005**	.676
TST, min.	Actigraphy	PSQI	4.865	48.196	.599	**<.001**
	Actigraphy	Diaries	-11.136	12.650	**.002**	.169
	PSQI	Diaries	-16.001	-35.546	**<.001**	**<.001**
WASO, min.	Actigraphy	PSQI	5.909	-16.504	.147	**.047**
	Actigraphy	Diaries	18.433	2.969	**<.001**	1.000
	PSQI	Diaries	12.523	19.473	**<.001**	**.008**
SE, %	Actigraphy	PSQI	-3.559	3.552	**<.001**	**.047**
	Actigraphy	Diaries	-6.065	-1.177	**<.001**	.848
	PSQI	Diaries	-2.506	-4.729	**<.001**	**.001**

Note. Table 3 was the result of a pairwise comparison obtained from the RM-ANOVA analysis. SOL, sleep onset latency; WASO, wake after sleep onset; TST, total sleep time; SE, sleep efficiency; PSQI, Pittsburg Sleep Quality Index. The mean difference is significant at the .05 level.

Table 3.4 The association between insomnia level and discrepancies of objective and subjective measured sleep parameters (SOL, TST, WASO, SE)

Predictor	Outcome	Actigraphy – PSQI		Actigraphy – Diaries		PSQI – Diaries	
		Coefficient β*	*P*	Coefficient β*	*p*	Coefficient β*	*p*
Insomnia scores	SOL, min.	-.212	**<.001**	-.143	**.012**	.096	.092
	TST, min	.225	**<.001**	.198	**.001**	-.084	.141
	WASO, min.	-.141	**.014**	-.160	**.006**	.012	.838
	SE, %	.192	**.001**	.201	**.001**	-.029	.612

Note. All results are presented as standardized regression coefficients β. Analyses were adjusted for age, ethnicity, marital status, employment, education level, BMI, BP (systolic/diastolic), and vasomotor symptoms. SOL, sleep onset latency; WASO, wake after sleep onset; TST, total sleep time; SE, sleep efficiency; PSQI, Pittsburg Sleep Quality Index; BMI, body mass index; BP, blood pressure. The mean difference is significant at the .05 level. Positive sleep discrepancy score: underestimation of the self-reported sleep parameters. Negative sleep discrepancy score: overestimation of the self-reported sleep parameters.

Figure 3.1 SOL measured by actigraphy, PSQI, and diaries between women with and without insomnia

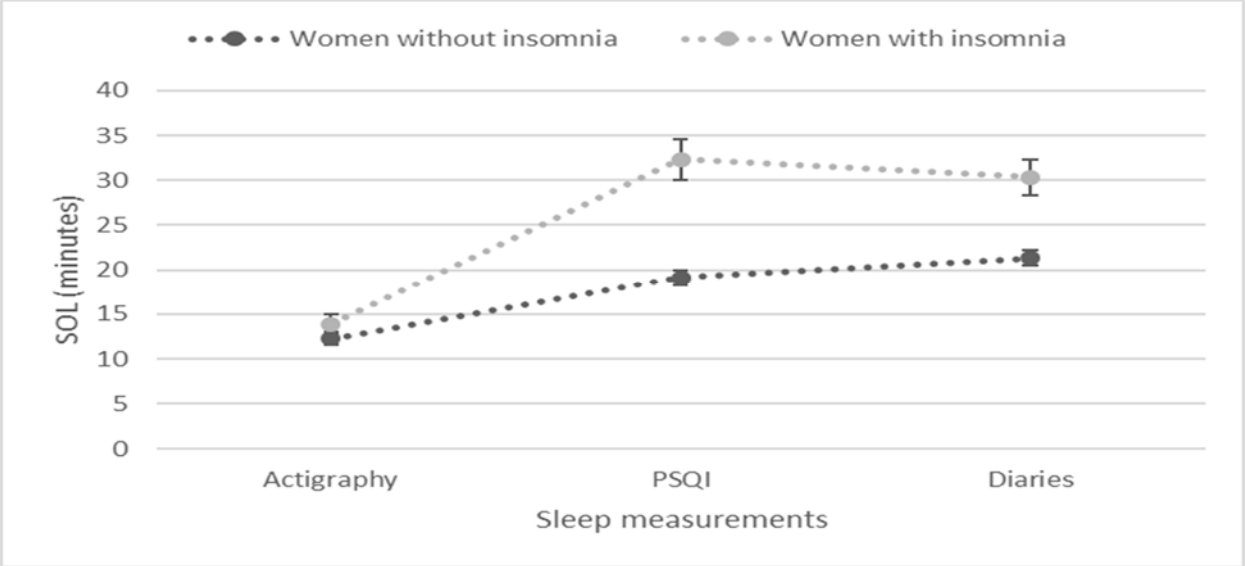


Figure 3.2 TST measured by actigraphy, PSQI, and diaries between women with and without insomnia

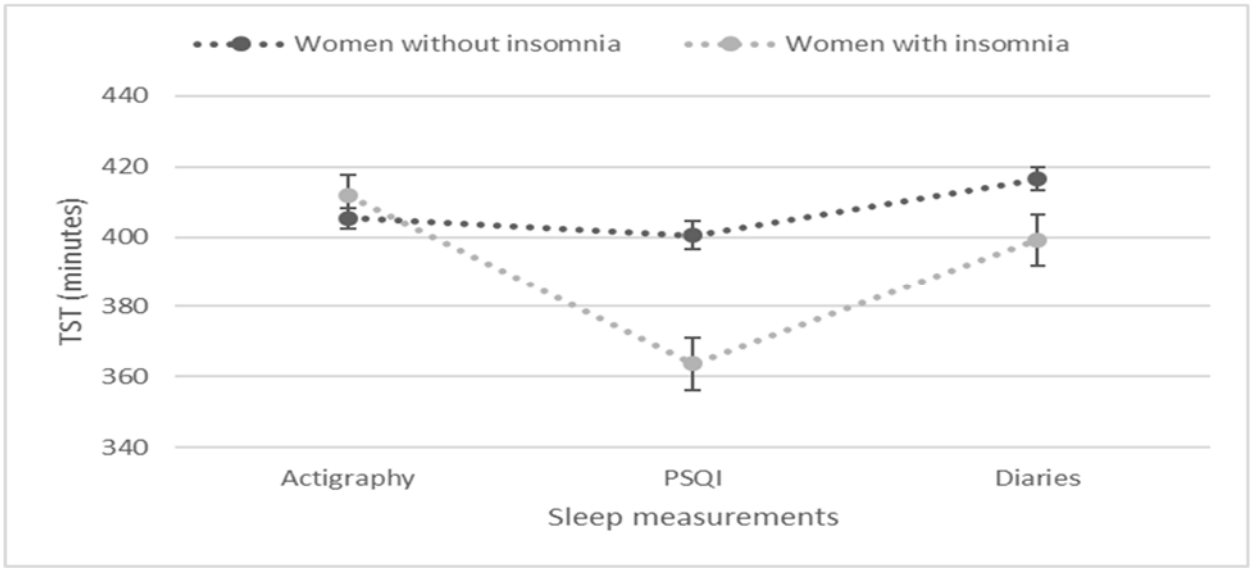


Figure 3.3 WASO measured by actigraphy, PSQI, and diaries between women with and without insomnia

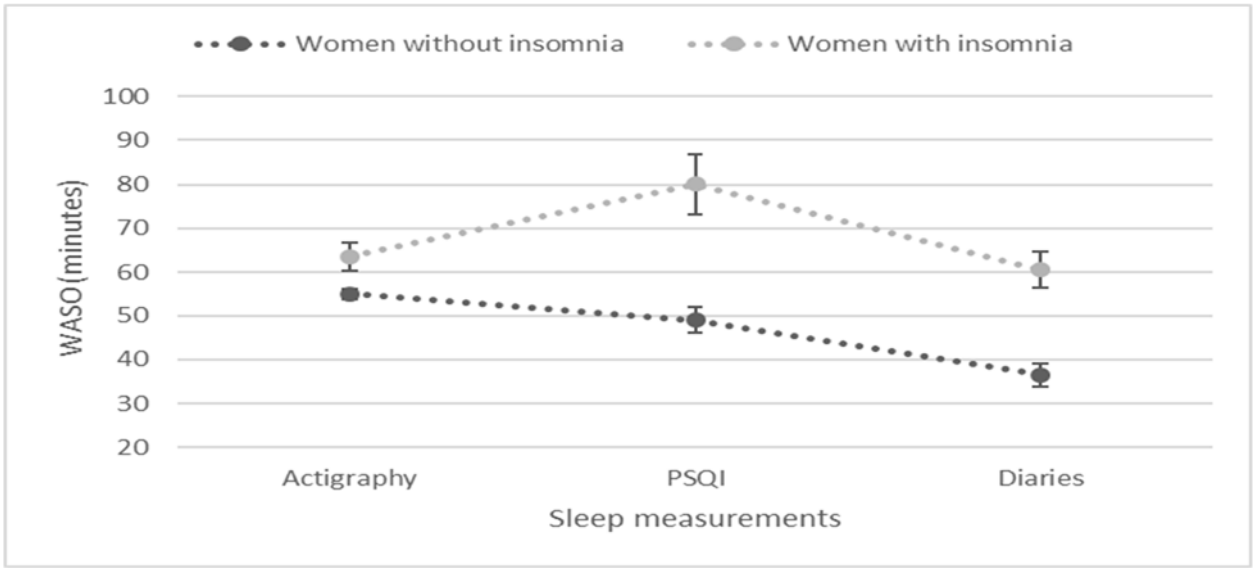
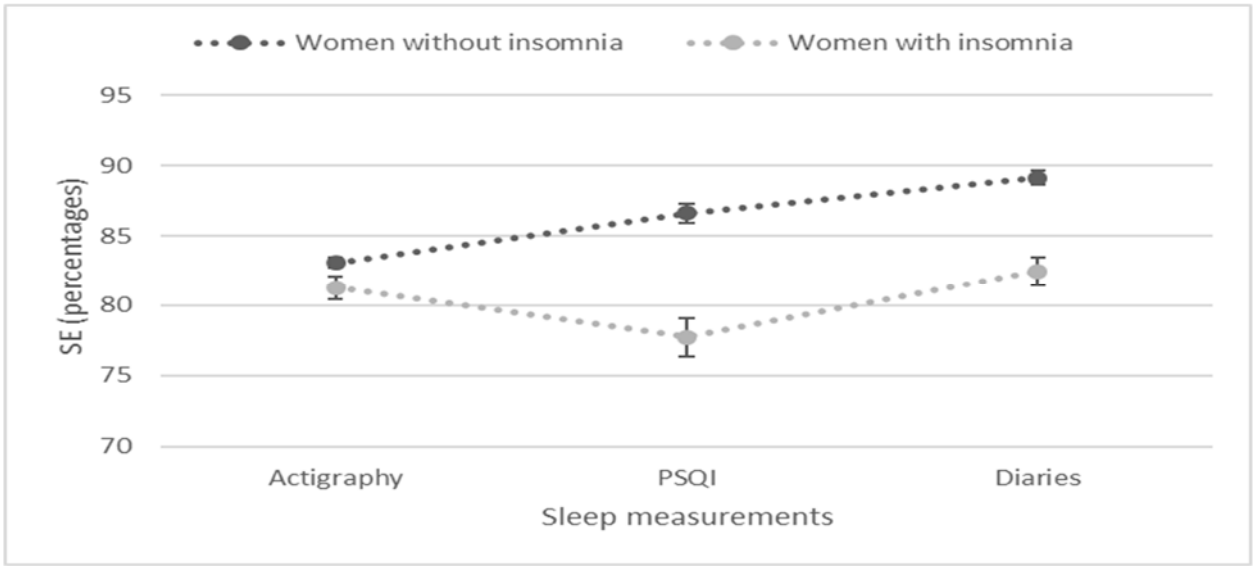


Figure 3.4 SE measured by actigraphy, PSQI, and diaries between women with and without insomnia



CHAPTER 4. Do Vasomotor Symptoms and Perceived and Physiological Stress Impact on Objective and Subjective Sleep Differences among Women in the Menopausal Transition and Postmenopause?

Target journal: Menopause (https://journals.lww.com/menopausejournal/pages/default.aspx)

Abstract: Limited to 250 words

Manuscript word count: No word limit

Figures and tables: No limit to the number of figures and tables

References: No limit to the number of references (but ≤75 possible)

Abstract

Objective: Vasomotor symptoms (VMS) and stress are featured near and after menopause. While the effect of physiological and mental changes on sleep in menopausal transitional women has been often explored, their effects on sleep discrepancy in this group has not been clearly identified. This study aims to examine the association of the discrepancies of objectively and subjectively measured sleep variables with vasomotor symptom interferences and with the stress indicators. **Methods:** To evaluate the association of vasomotor symptoms and perceived and physiological stress level and the sleep discrepancies between objective (actigraphy) and subjective (Pittsburg Sleep Quality Index [PSQI]/sleep diaries) measures, multiple linear regression was performed. VMS was measured by Hot Flash Related Daily Interference Scale and perceived stress was measured by Perceive Stress Scale, and night salivary cortisol was used as physiological stress index for the analysis. **Results:** Both greater VMS and perceived stress had a significant effect on larger discrepancy of sleep onset latency between actigraphy and PSQI/sleep diaries. VMS also showed the significant association of discrepancies in total sleep time, wake after sleep onset, and sleep efficiency between actigraphy and PSQI. Meanwhile, physiological stress did not show any association of sleep discrepancy. **Conclusion:** Association of VMS and perceived stress with objective and subjective sleep discrepancy suggests that those symptoms plays on important role on the perception of sleep among women in the menopausal transition and postmenopause. Careful interpretation about those discrepancies would be needed for sleep assessment in this population.

Keywords: Menopause, stress, sleep discrepancy, vasomotor symptoms

INTRODUCTION

Vasomotor symptoms (VMS) is well-known as the most representative physical symptom such as redness and sweating caused by decreased female hormones experienced in middle-aged women before and after menopause starting aged the late 40s (Kaunitz & Manson, 2015; Pachman, et al., 2010). Along with their physiological changes, middle-aged women are also in the midst of a change in their social roles in the family and society, playing a double care between children and elderly parents and these complex factors are more exposed to the risk of mental stress than other age groups (Darling et al., 2012). These physiological changes and psychological stress have been reported their close association with sleep problems in this population (Darling et al., 2012; Shaver & Woods, 2015). According to the number of previous studies, VMS has a strong association with one of the strongest predictors in decreased sleep quality of women around menopause (Freeman et al., 2015). With the increase in sleep clinic visits, it has been reported that decreased sleep quality is closely related to a decrease in one's quality of life (Soh, 2019).

Considering these situations, the importance of sleep assessment cannot be overemphasized. One's sleep is mainly measured using self-reported instruments such as surveys and sleep diaries and physiological measures. In recent years, thanks to its ease of use and the advantage of being able to measure sleep in a natural environment, actigraphy, an activity-based physiological measure, has been increasing in its clinical use than traditionally used self-reports (Park & Aini, 2021). Along with the increase in its use, studies on the agreement between actigraphy and other self-reported sleep measures have been also conducted. Sleep discrepancy can add sleep details and ultimately help interpret diagnose and determine sleep treatment option by showing how different the physiologically expressed sleep from sleep reported by the subject. In fact, some recent studies have revealed that differences

between two methods of sleep assessment in various population (Girschik et al., 2012; Jackowska et al., 2011; Kaplan et al., 2017; Minarik, 2009; Tsuchiyama et al., 2003; Vitiello et al., 2004)

In most studies, it can be seen that the gaps and magnitude between objectively and subjectively measured sleep are inconsistent in each parameters. Research has indicated that the differences in perceived and actual sleep are more pronounced in individuals with sleep disorders such as insomnia, or those experiencing higher levels of physical or mental stress, particularly in terms of total sleep time and sleep efficiency (Jackowska et al., 2011; Tsuchiyama et al., 2003). Additionally, Vitiello et al. (2004) found that these sleep discrepancies tend to increase with age, especially among women. Moreover, various studies on Cognitive Behavioral Therapy (CBT) for insomnia have shown its effectiveness in diminishing the gap between subjective and objective sleep measurements (Crönlein et al., 2019; Nishikawa et al., 2021). On the other hand, the impact of vasomotor symptoms (VMS) on both objectively measured and self-reported sleep varies, leaving questions about their influence on the discrepancy between perceived and actual sleep (Joffe et al., 2010). In addition, limited studies on the sleep discrepancies between sleep measures and factors on the differences have explored in spite of increasing trend of physiological sleep measures use although studies on sleep quality and its influencing factors in relation to sleep problems in middle-aged women, especially those before and after menopause have been actively conducted. Considering that vasomotor symptoms and stress, which are representative symptoms, affect women's sleep problems near menopause, these changes might affect objectively and subjectively measured sleep differences.

Therefore, this study aims to investigate the discrepancies between objectively and subjectively measured sleep in menopausal transitional women and to understand how VMS

and stress, representative physical and psychological symptoms of this group, affect the discrepancies. The results of the study could be used by healthcare providers as basic resources to help interpret sleep diagnosis and to make a decision for this group's sleep treatment. The purpose of this study is how vasomotor symptoms (VMS) and stress impact on the degree of objectively and subjectively measured sleep discrepancies among women during menopausal transitional and menopause. The hypothesis is that higher level of stress and vasomotor symptoms would be linked to the larger sleep discrepancies between objective and subjective measures. The specific aims of this study was to examine the association of the objective/subjective discrepancies (actigraphy versus PSQI/sleep diaries) in the sleep variables (TIB, TST, SOL, WASO, and SE) with vasomotor symptom interferences (Hot Flash-Related Daily Interference Scale, [HFRDIS]) and with the stress indicators (salivary cortisol and Perceived Stress Scale, [PSS]). Additionally, the relationship between the discrepancy of two subjectively measured sleep variables and VMS and stress indicators will be reported to possibly explain the above association.

METHODS

Participants

This cross-sectional design study used the secondary data obtained from Menopause Strategies Finding Lasting Answers for Symptoms and Health (MsFLASH) 02 and 03. The data included women aged 40 to 62 years who were in the late menopause transition or in the first 5 years post menopause regardless of menopause type. Additional inclusion criteria for the analysis are that participants must have at least 3 nights of actigraphy and sleep dairy data and must have complete PSQI data on items 1 to 4. The characteristics of study participants including demographics and health information were shown in Table 4.1.

Measures

1. Sleep Measures

Actigraphy. To obtain objective sleep-wake data, Actiwatch-2 (MiniMitter, Bend, OR) was used. The data from actigraphy was basically recorded for about a week. Each sleep variable was shown as the within-subject mean to balance unequal nights observed between subjects. Actigraphy data in this study have already been scored for prior analyses (Buchanan et al., 2017).

Pittsburg Sleep Quality Index (PSQI). PSQI is a questionnaire consisting of 19 questions that fills in information about individual's sleep for the past month to evaluate sleep quality (Buysse et al., 1989).

Sleep diaries. Sleep diaries were completed every morning on the same nights when actigraphy data were collected (Newton et al., 2014). Like actigraphy, to balance unequal nights observed between subjects, each sleep variable was represented as the within-subject mean.

Calculation of sleep parameters and sleep discrepancy variable between sleep measures

Selected sleep parameters from actigraphy, time in bed (TIB), sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO), and sleep efficiency (SE) were directly obtained. The data from PSQI and sleep diaries were calculated as follow. SOL and TST were directly obtained from the measures. TIB was calculated by the time between wake time and rise time. WASO was calculated by TIB minus SOL and TST. SE refers to the percentage of time in bed spent asleep, which was calculated by (TST/TIB)*100%. Sleep discrepancies was refers to the differences and magnitude of discordant responses to each selected sleep variables between 1) actigraphy and PSQI, 2) actigraphy and sleep diaries, and 3) PSQI and sleep diaries, which were calculated by subtraction one from another.

2. Vasomotor Symptoms

Hot Flash-Related Daily Interference Scale (HFRDIS). The level of perceived interferences by VMS was assessed by HFRDIS. This is a 10-item questionnaire to measure individual's hot flash related daily inferences for daily activities with nine items and for an overall quality of life for the past week with one itme (Carpenter, 2001). Higher scores indicate higher level of hot flash related daily interferences (score range 0-100).

3. Stress

Perceived Stress Scale (PSS). The level of perceived stress were measured by the PSS. This scale is a widely-used and validated 10-item self-report of individual's severity for perceived feelings and thoughts in life for the past month (Cohen et al., 1983). The PSS produces a summed score of the person's overall stress level. Higher scores indicate higher level of perceived stress (score range 0-40).

Salivary cortisol. Salivary cortisol samples were collected using Salivette swabs (Starstedt AG & Co, Lumbrecht, Germany) on two consecutive days as four times a day: on awakening (wake), 30 minutes after awakening (wake + 30), early afternoon, and bedtime. In this study, bedtime cortisol levels were selected as a physiologic stress indicator because it reflects disturbed HPA functions that induce persistent activation of arousal and has been found to predict insomnia symptom and sleep quality more strongly than other cortisol time points (Byun et al., 2017; Kumari et al, 2009; Reed et al., 2016). Salivary cortisol level was shown as the within-subject mean to balance unequal nights observed between subjects.

4. Covariates

Participants' general characteristics were explored as covariates due to possible impacts on sleep and/or stress and VMS that have been shown in studies (Baker et al., 2018; Grandner et al., 2010; Shaver & Woods, 2015). As demographics, their age, ethnicity, marital status, employment, and education level were selected. As their health information in addition

to HFRDIS, PSS, and bedtime salivary cortisol, body mass index (BMI), blood pressure (BP, systolic/diastolic), the level of depression measured by the Patient Health Questionnaire-8 (PHQ-8), and the level of anxiety measured by the Generalized Anxiety Disorder-7 (GAD-7) were provided.

	IVs (predictor)	DVs (outcome)	covariates
	PSS, salivary cortisol (bedtime), HFRDIS	Subjective/objective discrepancy in TIB, TST, SOL, WASO, SE 1) Actigraphy-PSQI (a-p) 2) Actigraphy-Diaries (a-d) 3) PSQI-Diaries (p-d)	age, ethnicity, marital status, employment, education, BMI, BP, depression (PHQ-8), anxiety (GAD-7)

IVs, independent variables; DVs, dependent variables

Statistical Analyses:

First, to explore the correlation between perceived and physiological stress, and VMS and the discrepancies of objective and subjective measures in selected sleep variables (TIB, SOL, TST, WASO, and SE), bivariate correlation was performed. The use of the bivariate correlation is prevalent before designing the regression model. It quickly and concisely summarizes the strength and direction of the relationship between variables (Crawford, 2006). Specifically, it checks the linear relationship between variables and ensures that independent variables were absence from highly relationship (collinearity; Cohen et al., 2013). Prior to explore the main question, the collinearity between independent variables was checked. The positive value of *r* indicates that the two variables move together in the same direction whereas the negative value means that the variables have opposing directions in relationship (Cohen et al., 2013).

Second, the association of vasomotor symptoms and perceived and physiological stress level and the sleep discrepancies between measures was evaluated with multiple linear regression. It was considered as most fit analysis because it can predict the expected value of the outcome by calculating its relationship to a specific combination value of the predictors' set (Cohen et al., 2013; Crawford, 2006; Dodd et al., 2006; Uyanık & Güler, 2013). Additionally, the statistical model with multiple predictors is possibly to assess the variables' association while adjusting the potential confounding variables (Cohen et al., 2013; Hidalgo & Goodman, 2013; Marill, 2004).

In this study, vasomotor symptoms measured by HFRDIS and perceived stress level measured by PSS were treated as independent variables (predictors) whereas the discrepancies of sleep variables (TIB, SOL, TST, WASO, and SE) from different measures was treated as dependent variable (outcomes). It examines to which extent the self-reported sleep measures (PSQI and diaries) fits with the objective measure (actigraphy). In addition, the regression was controlled by multiple covariates (demographics and health information) due to the previous theoretical frameworks suggested of these factors were related (Baker et al., 2018; Grandner et al., 2010; Shaver & Woods, 2015). Meanwhile, due to the sample size differences between two stress indicators, the separate model was performed by adding the physiological stress level which was collected by salivary bedtime cortisol as the predictor. (Maas & Hox, 2005). A value of $p < .05$ was considered statistically significant. The positive β coefficient indicates that the independent variable is associated with underestimation of reported sleep measures. In contrast, a negative β coefficient indicates that the predictor is associated with overestimation of reported sleep measures.

RESULTS

Characteristics of the Participants

[Place Table 4.1 here]

Table 4.1 provided the information of participants' characteristics. A total of 398 women during menopausal transitional and post menopause participated in this study. Particularly, the age ranged from 42 to 62 with an average of 54.89. The ethnicity was vary, but Caucasian was the biggest with 72.6% and African-American was the second largest one with 22.4%. More than half of the total respondents were presently married (59.3%) and work full-time (58.5%). The educational level was dominated by them who obtained associate degree (24.1%), bachelor degree (22.6%), master degree (19.3%), and professional school (14.1%). Furthermore, the health information was collected. It included the systolic (M = 120.10, SD = 14) and diastolic BP (M = 73.92, SD = 9.46), BMI (M = 26.96, SD = 4.90), and the bedtime cortisol level (M = 2.88, SD = 4.29). The health information of self-reported measures gathered the data of vasomotor symptoms (M = 31.28, SD = 21), stress level (M = 12.95, SD = 7.09), depression (M = 3.60, SD = 3.66), and anxiety (M = 2.67, SD = 3.48).

Correlations between sleep discrepancies and stress and vasomotor symptoms

[Place Table 4.2 here]

Table 4.2 elicited the bivariate correlation between independent variables (level of vasomotor symptom, perceived and physiological stress) and dependent variables (sleep discrepancies between objective and subjective measures in TIB, SOL, TST, WASO, and SE).

The level of vasomotor symptoms was significantly correlated with SOL discrepancy between all three measures (actigraphy and PSQI, r = -.211, p = <.001; actigraphy and diaries, r = -.115, p = .022; PSQI and diaries, r = .123, p = 014). Meanwhile, the level of vasomotor symptoms significantly related to the discrepancies of TST (r = .210, p = <.001), WASO (r = -.158, p = .002), and SE (r = .195, p = <.001) between actigraphy and PSQI. It also significantly related to the discrepancies of TST (r = -.220, p = <.001), WASO (r = .149, p = .003), and SE (r = -.183, p = <.001) between two subjective measures, PSQI and diaries. Furthermore, the stress level only revealed the significant correlation of the TST and SE discrepancies between PSQI and diary (r = -.133, p = .008; r = -.121, p = .017 respectively). In the meanwhile, the level of bedtime cortisol significantly did not correlate with the discrepancies of any sleep variables between all three measures.

The association of sleep discrepancies with stress and vasomotor symptoms

[Place Table 4.3 here]

Table 4.3 depicts the association between vasomotor symptoms and stress level and sleep discrepancies of the five sleep parameters (TIB, SOL, TST, WAS, SE) between measures. In the analysis, vasomotor symptom and stress level as predictors (independent variables) and the sleep discrepancy was treated as the outcome (dependent variable). The regression models were analyzed separately and controlled by covariates. The result revealed that the vasomotor symptom and stress were associated significantly with SOL discrepancy between objective and subjective measures (actigraphy-PSQI and actigraphy-diaries). In contrast, both predictors were not significantly associated with all models of TIB discrepancy between measures. On

the other hand, an only vasomotor symptom which was associated significantly with the sleep discrepancy (actigraphy-PSQI and PSQI-diaries) in TST, WASO, and SE. The elaboration of each regression result was presented as follows.

Time in bed (TIB). The vasomotor symptoms and stress level were not associated significantly with TIB discrepancies between objective and subjective measures as well as between subjective measures (*p*-value ranged .377 - .898). Specifically, the effect of vasomotor symptoms showed positive TIB discrepancy scores between actigraphy and PSQI while it showed negative between the actigraphy and diaries as well as between PSQI and diaries. In contrast, the sign of the coefficient β was opposite for the effect of perceived stress level on TIB sleep discrepancies.

Sleep onset latency (SOL). The vasomotor symptoms were significantly associated with the SOL discrepancies between the objective and subjective measures (actigraphy-PSQI, β = -.228, p = <.001; actigraphy-diaries, β = -.157, p = .008, respectively). The negative value of coefficient β suggested that respondents with higher vasomotor symptoms overestimated their SOL measured by PSQI and diaries. Particularly, the overestimation score was estimated to be higher when SOL reported by PSQI instead of diaries based on the lower value of coefficient β. Furthermore, the perceived stress level also showed the significant association with the SOL discrepancy between objective and subjective measures (actigraphy-PSQI, β = .145, p = .020; actigraphy-diaries, β = .160, p = .012, respectively). In contrast with vasomotor symptoms, the positive value of coefficient β was revealed in the effect of stress level. It explained that underestimation of the subjective measures was notified by respondents who have higher levels of stress. In particular, the score was reported higher in the diaries than PSQI due to the higher coefficient β.

Total sleep time (TST). The perceived stress level did not depict a significant association

with the TST discrepancies between all three sleep measures. On the other hand, vasomotor symptoms showed a significant association with TST discrepancy value between actigraphy and PSQI (β = .204, p = <.001) as well as PSQI and diaries (β = -220, p = <.001). Specifically, TST underestimation of PSQI was reported by respondents with higher vasomotor symptoms. In addition, the score underestimated reported by them with vasomotor symptoms in PSQI than diaries.

Wake after sleep onset (WASO). The result elicited statistically significant difference between vasomotor symptoms with WASO discrepancies between actigraphy and PSQI as well as between two subjective measures (PSQI-diaries). The presented values indicated that the overestimation WASO on PSQI showed by respondent with higher vasomotor symptom (β = -.186, p = .002). Additionally, the overestimation of WASO in PSQI compared to diaries was reported by those who had higher vasomotor symptoms (β = .183. p = .002). Nonetheless, the perceived stress level had no significant relationship with the WASO discrepancy between all three sleep measures.

Sleep efficiency (SE). The statistically significant value demonstrated by the association between vasomotor symptoms and the SE discrepancies between actigraphy and PSQI (β = .231, p = <.001) and PSQI and diaries (β = -.206, p = .001). The positive value of coefficient β indicated that underestimation score of SE in PSQI reported by respondents with higher vasomotor symptoms. In addition, the underestimation on score of PSQI compared to diaries was reported by them who had higher vasomotor symptoms. Meanwhile, the perceived stress level had no significant relationship with the SE discrepancy between all three sleep measures.

[Place Table 4.4 here]

Table 4.4 elucidates the association between vasomotor symptoms, perceived stress level and the sleep discrepancies of the five sleep parameters (TIB, SOL, TST, WASO, and SE) between measures in the subjects who provided their cortisol data. Particularly, the sleep discrepancy was treated as the outcome (dependent variable) and vasomotor symptoms and perceived stress level as predictors (independent variables). The regression models were analyzed separately and controlled by multiple covariates. The result revealed that only vasomotor symptoms were statistically significant association with the sleep discrepancies in four parameters. Specifically, the vasomotor symptoms showed the significant relationship with the SOL discrepancy of actigraphy and two subjective measures (actigraphy-PSQI, actigraphy-diaries). Furthermore, vasomotor symptoms were associated significantly with the sleep discrepancies of TST, WASO, and SE between actigraphy and PSQI as well as PSQI and diaries. Nonetheless, the vasomotor symptoms were not significantly associated with all model of TIB discrepancies between all three sleep measures. The elaboration of each regression result was presented as follows.

Time in bed (TIB). The vasomotor symptoms and stress level were not associated significantly with TIB discrepancies between all three sleep measures. The positive coefficient β revealed as the effect of vasomotor symptoms for the discrepancy between actigraphy and PSQI while it showed negative for the actigraphy and diaries as well as PSQI and diaries. Nonetheless, the sign of the coefficient β was opposite for the effect of perceived stress level.

Sleep onset latency (SOL). The vasomotor symptoms were significantly associated with the SOL sleep discrepancies between actigraphy and two subjective measures (actigraphy-PSQI, β = -.238, p = .003; actigraphy-diaries, β = -.193, p = .015, respectively). The negative value of coefficient β indicated that the overestimation of two self-reports (PSQI and diaries) will be reported by respondents who have higher vasomotor symptoms. Particularly, the

overestimation score was estimated to be higher when SOL reported by PSQI instead of diaries based on the lower value of coefficient β. Meanwhile, the perceived stress level had no significant relationship with the any SOL discrepancies.

Total sleep time (TST). The vasomotor symptoms showed the significant association with TST discrepancies between actigraphy and PSQI (β = .185, p = .021) as well as PSQI and diaries (β = -211, p = .008). Particularly, the underestimation of TST reporting in PSQI was showed by respondent with higher vasomotor symptoms. In addition, the underestimation of TST report in PSQI than diaries would be reported by them with higher vasomotor symptoms. On the other hand, the perceived stress level did not elicit the significant association with the any TST discrepancies between measures.

Wake after sleep onset (WASO). The result depicted statistically significant association of vasomotor symptoms with WASO discrepancies between actigraphy and PSQI as well as two subjective measures (PSQI-diaries). The presented values suggested that the overestimation of WASO score in PSQI would be showed by respondents with higher vasomotor symptoms (β = -.191, p = .017). Additionally, the overestimation of WASO score in PSQI instead of diaries was also reported by those who had higher vasomotor symptoms (β = .178. p = .023). Nonetheless, the perceived stress level had no significant relationship with the any WASO discrepancies of all three sleep measures.

Sleep efficiency (SE). The statistically significant value demonstrated by the association of vasomotor symptoms with the SE discrepancies between actigraphy and PSQI (β = .242, p = .003) as well as PSQI and diaries (β = -.208, p = .009). The positive value of coefficient β indicated that overestimation of PSQI score would be reported by respondents with higher vasomotor symptoms. In addition, the underestimation of PSQI instead of diaries was reported by them who had higher level of vasomotor symptoms. Meanwhile, the perceived stress level

had no significant relationship with the any SE discrepancies of all three sleep measures.

[Place Table 4.5 here]

Table 4.5 elucidates the association between vasomotor symptoms, perceived and physiological stress level and sleep discrepancies of the five sleep parameters (TIB, SOL, TST, WASO, and SE) between measures in subject data who provided their cortisol. Particularly, the sleep discrepancy was treated as the outcome (dependent variable) and vasomotor symptoms, perceived and physiological stress level as predictors (independent variables). The regression models were analyzed separately and controlled by multiple covariates. First, the result revealed that only vasomotor symptoms were statistically significant association with the discrepancies of sleep measures. Specifically, the vasomotor symptoms showed the significant relationship with the SOL discrepancy of objective and subjective measures (actigraphy-PSQI, actigraphy-diaries). Furthermore, vasomotor symptoms were associated significantly with the sleep discrepancies of TST, WASO, and SE between actigraphy and PSQI as well as PSQI and diaries. Nonetheless, the vasomotor symptoms were not significantly associated with all model of TIB discrepancies between all three sleep measures. The elaboration of each regression result was presented as follows.

Time in bed (TIB). The vasomotor symptoms, stress level, and bedtime cortisol level were not associated significantly with TIB discrepancies between all three sleep measures. The positive coefficient β revealed as the effect of vasomotor symptoms for the discrepancy between actigraphy and PSQI while it showed negative for the actigraphy and diaries as well as PSQI and diaries. Nonetheless, the sign of the coefficient β was opposite for the effect of perceived stress level and bedtime cortisol.

Sleep onset latency (SOL). The vasomotor symptoms were significantly associated with the SOL sleep discrepancies between the objective and subjective measures (actigraphy-PSQI, β = -.242, p = .003; actigraphy-diaries, β = -.195, p = .015, respectively). The negative value of coefficient β indicated that the overestimation of the self-reported measures (PSQI and diaries) will be reported by respondents who have higher vasomotor symptoms. Particularly, the overestimation score was estimated to be higher when SOL reported by PSQI instead of diaries based on the lower value of coefficient β. Meanwhile, the perceived stress level and bedtime cortisol level had no significant relationship with the any SOL discrepancies.

Total sleep time (TST). The vasomotor symptoms showed the significant association with TST discrepancies between actigraphy and PSQI (β = .190, p = .017) as well as PSQI and diaries (β = -226, p = .007). Particularly, the underestimation of TST reporting in PSQI was showed by respondent with higher vasomotor symptoms. In addition, the underestimation of TST report score in PSQI than diaries would be reported by them with higher vasomotor symptoms. On the other hand, the perceived stress level and level of bedtime cortisol did not elicit the significant association with the any TST discrepancies between measures.

Wake after sleep onset (WASO). The result depicted statistically significant association of vasomotor symptoms with WASO discrepancies between objective and subjective measures (actigraphy-PSQI) and two subjective measures (PSQI-diaries). The presented values suggested that the overestimation of WASO score in PSQI would be showed by respondents with higher vasomotor symptoms (β = -.195, p = .014). Additionally, the overestimation of WASO score in PSQI instead of diaries was also reported by those who had higher vasomotor symptoms (β = .185. p = .017). Nonetheless, the perceived stress level and bedtime cortisol level had no significant relationship with the any WASO discrepancies of sleep measures.

Sleep efficiency (SE). The statistically significant value demonstrated by the association

of vasomotor symptoms with the SE discrepancies between actigraphy and PSQI (β = .247, p = .002) as well as PSQI and diaries (β = -.215, p = .006). The positive value of coefficient β indicated that overestimation of PSQI score would be reported by respondents with higher vasomotor symptoms. In addition, the underestimation of PSQI instead of diaries was reported by them who had higher vasomotor symptoms. Meanwhile, the perceived stress level and bedtime cortisol level had no significant relationship with the any SE discrepancies of sleep measures.

DISCUSSION

The current study evaluated how vasomotor symptom interferences and stress impact on the degree of objectively and subjectively measured sleep discrepancies in women during menopausal transitional and menopause. The hypotheses are that greater level of vasomotor symptoms and perceived and physiological stress would be linked to the larger sleep discrepancies between actigraphy and subjective measures of sleep (PSQI and diaries).

Vasomotor symptoms and sleep discrepancy

The first hypothesis of the current study that the more severe VMS symptoms, the greater the difference in sleep parameters between actigraphy and subjective measures was supported. First, bivariate correlation (table 2) showed that the level of VMS are correlated with SOL discrepancy between all three measures. In addition, all regression models (table 3, 4, and 5) also revealed that women with greater VMS interferences are negatively associated with the SOL and WASO discrepancies between actigraphy and PSQI, meaning over-estimation of PSQI than actigraphy and showed the positive association of VMS interferences with TST and SE discrepancy, meaning under-estimation on PSQI over actigraphy. Between actigraphy and diaries, the negative SOL discrepancy was found, which means the severe

women have VMS interferences, SOL is over-estimated in diaries compared to actigraphy. This result demonstrates that VMS had a negative impact on self-reported sleep parameters, creating significant discrepancies between objective and subjective sleep measurements. Specifically, the severity of VMS contributed to negative responses in SOL, which were consistently observed in both the PSQI and sleep diaries, leading to the emergence of these discrepancies. Moreover, there were significant differences in WASO, TST, and SE in addition to SOL discrepancy between actigraphy and PSQI compared to only SOL discrepancy between actigraphy and diaries. This finding indicates that VMS impacted on more collected sleep parameters in PSQI than in diaries.

To begin with, the principal discovery pertaining to the impact of VMS on the observed divergence between objective and subjective sleep measures can be explained from the Joffe et al. (2010)'s review study. Their study stated that sleep difficulties manifest more prominently in self-reported sleep patterns among middle-aged women experiencing vasomotor symptoms, such as hot flashes, as opposed to sleep challenges observed in middle-aged women afflicted with conditions like obstructive sleep apnea, where disruptions in sleep become conspicuous during objective sleep measurements. This underscores the substantial role played by VMS in contributing significantly to the reported sleep disturbances within this population. Furthermore, it is needed to explore the study's findings regarding the overestimation of SOL in two subjective sleep measurements and the overestimation of WASO, the underestimation of TST, and SE in PSQI compared to actigraphy. To shed light on these findings, Regestein et al. (2004), which concentrated on postmenopausal women may provide insights into this phenomenon. Their research revealed a significant association between low sleep quality and a heightened prevalence of menopause-related symptoms, alongside a decline in cognitive function. Remarkably, these associations were primarily evident through self-reported sleep

data rather than actigraphy. In addition, a notable trend emerged wherein the disparities between self-reported and actigraphy-measured data were more pronounced when individuals reported longer SOL and shorter TST durations. This trend was closely tied to insomnia and, consequently, contributed to the incongruities between subjective and objective sleep assessments. In this context, it is noteworthy that factors such as cognitive decline and VMS are intricately intertwined with sleep disturbances. This adverse impact extends to individuals' perception of sleep quality, which heavily relies on memory recall and is deemed a pivotal factor contributing to the wider gap observed between these two assessment methods.

Meanwhile, besides the SOL discrepancy between actigraphy and two subjective measurements, it is essential to examine whether there are significant differences between the sleep parameters (WASO, TST, and SE) reported in the PSQI and the data derived from actigraphy. First and foremost, the notable difference between PSQI and diaries lies in their data collection. PSQI relies on retrospective reporting over a 1-month period, whereas diaries calculate records averaging on the same day as the collection of actigraphy data. Considering such difference in reporting, the association between VMS and memory will have an important point. Some previous studies support this phenomenon during menopausal transition, reporting an association between the having VMS or VMS related stresss and lower memory functioning (Drogos et al., 2013; Mitchell & Woods, 2001; Schaafsma, Homewood, & Taylor, 2010). An escalation in the intensity or frequency of VMS, such as hot flashes, has been associated with various cognitive effects in women. Drogos et al. (2013) reported that women in this situation may notice impairments in their long-term memory. Additionally, Schaafsma et al. (2010) found that these women may also perceive difficulties in attention and memory. Furthermore, changes in a woman's menstrual cycle and associated hormonal shifts have been linked to an increase in reported memory-related issues, such as recalling retrospective information or

maintaining concentration (Mitchell & Woods, 2001; Woods, Mitchell, & Adams, 2000). While there is still no consensus on the mechanisms linking VMS and memory impairment, potential associations with cognitive functioning, both direct and indirect, have been suggested. These associations may arise due to the combined effects of VMS frequency and intensity (Schaafsma et al., 2010), memory problems resulting from the psychological stress, such as depressed mood, associated with VMS (Mitchell & Woods, 2001; Woods et al., 2000; Woods et al., 2008), and the negative impact on memory abilities due to the mutual influence of VMS and insomnia or sleep disturbances (Woods et al., 2008; Freeman, Sammel, Gross, & Pien, 2015). In sum, these evidences in previous research imply the potential for VMS to exert a greater influence on reported things, especially PSQI reporting of sleep quality when compared to diaries that rely on recalling past sleep quality based on the previous day's records.

Perceived stress and sleep discrepancy

The second hypothesis of the current study was the more perceived or physiological stress, the greater the sleep discrepancies between actigraphy and two self-reported measures. Although no statistically significant findings were observed between actigraphy and the two subjective measures in the bivariate correlation analysis, the findings on perceived stress and sleep discrepancy revealed the SOL discrepancy between actigraphy and two subjective sleep measures (PSQI and diaries). This association was indicated by a positive coefficient β, with significant p-values observed in the regression model analyzing all subjects (actigraphy-PSQI $p = 0.02$; actigraphy-diaries $p = 0.012$, respectively) as shown in Table 3. The result regarding SOL supported the hypothesis among women in the menopausal transition and postmenopause. However, contrary to expectations, the direction of the discrepancy was the opposite of the impact that VMS had on the objective/subjective SOL discrepancy in this study, indicating an overestimation of SOL in the actigraphy compared to PSQI and diaries. The interpretation for

this finding does not provide definite explanations, but some points can be inferred. First, based on the very low statistical significance of *p* value, this could be an accidental statistical result, or that it may be caused by a complex effect on the discrepancy due to various factors that cannot be interpreted. Another finding that should be discussed was that the significant association between perceived stress and SOL discrepancy shown in Table 3 that analyzed all subject disappeared in the regression models that analyzed only those who provided salivary cortisol (Table 4 and 5). As mentioned above, the significance of the relationship between perceived stress and SOL discrepancy is statistically very weak (low probability), which may be due to the difference in the number of analyzed subjects. The number of all samples in the regression was 398, whereas the number of samples provided with cortisol was 228. Therefore, this appears to be a change in statistical power due to reduced number of women who provided their salivary cortisol (Brooks & Barcikowski, 2012), and further interpretation about this is not possible at this point. Second, there is a need to discuss the characteristics of stressed individuals and the limitations of two methods of sleep measurement. The majority of studies indicate that individuals under stress experience poor sleep quality, particularly exhibiting prolonged sleep onset latency (Schäfer, & Bader, 2013; Yap, Slavish, Taylor, Bei, & Wiley, 2020; Zoccola, Dickerson, & Lam, 2009). However, in these studies, prolonged SOL is often observed either only through self-reported measures or physiological measures, and the direction of SOL overestimation shows mixed results across studies. Typically, individuals experiencing stress can spend a prolonged time engaged in various thoughts before falling asleep without any significant physical movement. In such cases, the limitations of actigraphy, a movement-based device, become more evident. Ongoing debates in several prior studies have addressed this issue, pointing out this limitations of actigraphy as a sleep-wake indicator. These include unclear sleep-wake cycles, low detection ability during periods of immobility in

inactive individuals, and interruptions in recording (Chae et al., 2009; Martin & Hakim, 2011; Paquet, Kawinska, & Carrier, 2007; Tworoger, Davis, Vitiello, Lentz, & McTiernan, 2005). Specifically, Chae et al. (2009) emphasized the importance of sensitivity to immobility time in detecting sleep onset latency, which is relatively more critical than other sleep parameters. Therefore, they highlighted the need for careful consideration of the placement of the actigraphy device and the criteria for its on and offset. Meanwhile, stress and the decline in sleep quality mutually influence each other, creating a vicious cycle where sustained stress can lead to problems with sleep or memory, which in turn can contribute to increased stress the following day (Yap et al., 2020). This is particularly evident in middle-aged women around menopause, where physiological changes such as VMS increase the frequency of stress. The association between this increased stress and the subsequent decline in insomnia and memory has been well-documented in previous studies (Drogos et al., 2013; Mitchell & Woods, 2001; Schaafsma, Homewood, & Taylor, 2010). Furthermore, the potential for distortion in self-reports due to these factors has been well-described in various studies (Mitchell & Woods, 2001; Woods, Mitchell, & Adams, 2000; Bonnet & Arand, 2010). In this context, it cannot be ruled out that there might be overestimation or underestimation in the self-reported sleep data from the previous day or month in groups experiencing stress.

Physiological stress and sleep discrepancy

Finally, this study attempted to examine the impact of physiological stress (assessed by salivary cortisol level at night) on sleep discrepancy. However, despite conducting separate analyses to address the limitations of physiological sample provision (228 salivary cortisol samples provided out of 398 participants), no statistically significant results were observed in any of the regression models as well as in the bivariate correlation, failing to support the study hypothesis.

Cortisol is more commonly collected and measured through saliva, as this method avoids the additional stress induced by blood collection (Kim, Chung & Park, 2004). Moreover, climacteric symptoms including VMS and sleep disturbances, as well as other negative physical and psychological disorders, are implicated in cortisol dysregulation (Gibson et al. 2016; Reed et al., 2016) and contribute to an increase in cortisol levels among mid-life women (Cagnacci et al., 2011; Gordon, Eisenlohr-Moul, Rubinow, Schrubbe, & Girdler, 2016; Knight, Avery, Janssen, & Powell, 2010). However, these studies vary in their methods of cortisol collection (saliva, serum, and urine), data collection timing, and participant ethnicity, depending on the researchers' choice and study objectives. Moreover, the use of cortisol levels to capture chronic stress induced by social factors is still controversial (Rudmin, 2009). In the current study, nighttime salivary cortisol was used for analysis, but it is challenging to conclude whether this method falls into these limitations at this point.

Implication

This study offers valuable clinical implications for improving sleep assessment in menopausal and postmenopausal women. The findings indicate that higher levels of vasomotor symptoms (VMS) and stress may contribute to greater discrepancies between subjective and objective sleep assessments. Such discrepancies could serve as a diagnostic marker for menopause-related symptoms, highlighting the need for comprehensive sleep assessments that address both physiological and perceptual aspects of sleep. Clinically, identifying notable differences between objective and subjective sleep measures can help in recognizing the presence or intensity of VMS and stress, suggesting that a multifaceted interpretation of sleep—whether by physiological or self-reported measures—may be beneficial for tailored interventions in this population.

Strengths and Limitations of the Study

This study has several strengths, notably its robust sample size of nearly 400 women, enhancing statistical power and the reliability of its findings. Additionally, it employs a combination of objective actigraphy data and widely used subjective measures (PSQI and sleep diaries), which allows for a comprehensive examination of sleep discrepancies and associations with menopausal symptoms like VMS and stress. By focusing on multiple sleep variables across diverse measures, this study provides valuable reference data and insights that extend beyond traditional research focusing on single sleep variables or limited measurement comparisons.

However, certain limitations should be acknowledged. The study's racial composition, with approximately 73% White participants, while reflective of the US average (U.S. Census Bureau, 2021), may limit the generalizability of findings across diverse racial and ethnic groups. Moreover, the sample includes higher-than-average levels of education and employment (60.3% with at least a bachelor's degree and 74.3% employed), which may restrict the generalizability of findings to all groups of middle-aged women approaching menopause. A further limitation involves the assessment of stress: only 228 of the 398 participants provided salivary cortisol samples due to collection constraints, necessitating separate analyses within this subset. Nonetheless, these factors provide direction for refining future studies.

Future Directions

Future studies should focus on broadening sample diversity by recruiting participants across a wider range of racial, ethnic, and socioeconomic backgrounds to increase the generalizability of findings across menopausal and postmenopausal women. Additionally, employing longitudinal designs would enable the observation of changes in sleep discrepancies over time, capturing the dynamic interactions between menopausal symptoms, aging, and lifestyle factors. This approach could facilitate more personalized intervention strategies based

on individual patterns observed throughout the menopausal transition.

Further research into psychological and cognitive factors, including mood, anxiety, and attentional biases, is recommended to deepen our understanding of the mechanisms underlying sleep perception discrepancies. Studies have shown that psychological factors, such as mood and anxiety, often interact with VMS and stress to exacerbate subjective sleep disturbances (Woods et al., 2010; Bromberger et al., 2016). By including standardized assessments of these factors alongside sleep measures, future research could offer enhanced treatment strategies that address both physiological and perceptual components of sleep disturbances, potentially leading to more comprehensive care approaches.

Moreover, integrating digital health technologies—such as wearable sleep trackers and mobile applications—presents an opportunity to collect real-time, ecological sleep data that reflects daily fluctuations in sleep patterns outside the clinical setting. These digital tools can improve the accessibility and depth of sleep assessments by providing continuous data collection in natural environments. For instance, wearable trackers have been shown to effectively monitor VMS and stress patterns, enabling a more nuanced understanding of how these factors contribute to sleep variability (de Zambotti et al., 2018; Freeman et al., 2020). Such devices could serve as valuable adjuncts in both research and clinical contexts by allowing for a more individualized and accurate view of sleep behaviors in menopausal and postmenopausal women. By leveraging these technological advancements, future research can refine and expand assessment and intervention methods, ultimately supporting improved management of sleep disturbances in this population.

CONCLUSIONS

Menopause, a significant transition in a woman's life, brings various physiological

changes, among which VMS and stress are prominent. These symptoms not only impact physical health but also substantially influence sleep. This study examined how VMS and both perceived and physiological stress affect discrepancies between objective and subjective sleep assessments during the menopausal transition and postmenopause, particularly given the growing diversity of sleep measurement methods. The findings indicate that higher levels of VMS and perceived stress significantly affect sleep assessment, with larger discrepancies observed between objective and subjective sleep parameters.

Specifically, VMS showed significant associations with variability in all PSQI-reported parameters, including SOL, TST, WASO, and SE. Additionally, VMS negatively influenced SOL as reported in sleep diaries compared to actigraphy data. Perceived stress also contributed to prolonged SOL in actigraphy compared to both subjective measures, while no significant correlations emerged between salivary cortisol levels and sleep discrepancies. These results suggest that VMS contributes to greater variability in sleep perception, particularly in the PSQI, which relies on a one-month recall period. In contrast, the association between higher perceived stress and actigraphic overestimation of SOL underscores the limitations of actigraphy as a movement-based device.

In conclusion, it is crucial to consider the impacts of VMS and stress on sleep discrepancies, as well as the limitations of each sleep measurement tool, to ensure appropriate selection, application, and interpretation in this population. Further large-scale research that includes more diverse ethnic groups would strengthen evidence on the relationship between VMS, stress, and sleep discrepancies, ultimately improving sleep assessment and interventions for menopausal women.

REFERENCES FOR CHAPTER 4

Baker, F. C., de Zambotti, M., Colrain, I. M., & Bei, B. (2018). Sleep problems during the menopausal transition: Prevalence, impact, and management challenges. *Nature and Science of Sleep, 10*, 73-95. https://doi.org/10.2147/NSS.S125807

Bonnet, M. H., & Arand, D. L. (2010). Hyperarousal and insomnia: State of the science. *Sleep Medicine Reviews, 14*(1), 9-15. https://doi.org/10.1016/j.smrv.2009.05.002

Bromberger, J. T., Kravitz, H. M., Youk, A. O., Schott, L. L., & Joffe, H. (2016). Relationships among stress, menopausal status, and sleep problems in midlife women. *Psychosomatic Medicine, 78*(1), 38–47. https://doi.org/10.1097/PSY.0000000000000264

Brooks, G. P., & Barcikowski, R. S. (2012). The PEAR method for sample sizes in multiple linear regression. *Multiple Linear Regression Viewpoints, 38*(2), 1-16.

Buchanan, D. T., Landis, C. A., Hohensee, C., Guthrie, K. A., Otte, J. L., Paudel, M., ... & LaCroix, A. Z. (2017). Effects of yoga and aerobic exercise on actigraphic sleep parameters in menopausal women with hot flashes. *Journal of Clinical Sleep Medicine, 13*(1), 11-18. https://doi.org/10.5664/jcsm.6382

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193-213. https://doi.org/10.1016/0165-1781(89)90047-4

Byun, E., Riegel, B., Sommers, M., Tkacs, N., & Evans, L. (2017). Effects of uncertainty on perceived and physiological stress in caregivers of stroke survivors: A 6-week longitudinal study. *Journal of Gerontological Nursing, 43*(11), 30-40. https://doi.org/10.3928/00989134-20170501-01

Cagnacci, A., Cannoletta, M., Caretto, S., Zanin, R., Xholli, A., & Volpe, A. (2011). Increased cortisol level: A possible link between climacteric symptoms and cardiovascular risk factors.

Menopause, 18(3), 273-278. https://doi.org/10.1097/gme.0b013e3181f434e4

Carpenter, J. S. (2001). The hot flash-related daily interference scale: A tool for assessing the impact of hot flashes on quality of life following breast cancer. *Journal of Pain and Symptom Management, 22*(6), 979-989. https://doi.org/10.1016/S0885-3924(01)00325-9

Chae, K. Y., Kripke, D. F., Poceta, J. S., Shadan, F., Jamil, S. M., Cronin, J. W., & Kline, L. E. (2009). Evaluation of immobility time for sleep latency in actigraphy. *Sleep Medicine, 10*(6), 621-625. https://doi.org/10.1016/j.sleep.2008.07.009

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/correlation analysis for the behavioral sciences*. Routledge.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 385-396. https://doi.org/10.2307/2136404

Crönlein, T., Lehner, A., Schüssler, P., Geisler, P., Rupprecht, R., & Wetter, T. C. (2019). Changes in subjective-objective sleep discrepancy following inpatient cognitive behavior therapy for insomnia. *Behavior Therapy, 50*(5), 994-1001. https://doi.org/10.1016/j.beth.2018.12.008

Darling, C. A., Coccia, C., & Senatore, N. (2012). Women in midlife: Stress, health and life satisfaction. *Stress and Health, 28*(1), 31-40. https://doi.org/10.1002/smi.1398

Dodd, S., Bassi, A., Bodger, K., & Williamson, P. (2006). A comparison of multivariable regression models to analyse cost data. *Journal of Evaluation in Clinical Practice, 12*(1), 76-86. https://doi.org/10.1111/j.1365-2753.2005.00598.x

Freeman, E. W., Sammel, M. D., Gross, S. A., & Pien, G. W. (2015). Poor sleep in relation to natural menopause: A population-based 14-year follow-up of midlife women. *Menopause, 22*(7), 719-726. https://doi.org/10.1097/GME.0000000000000379

Gibson, C. J., Thurston, R. C., & Matthews, K. A. (2016). Cortisol dysregulation is associated

with daily diary-reported hot flashes among midlife women. *Clinical Endocrinology, 85*(4), 645-651. https://doi.org/10.1111/cen.13103

Girschik, J., Fritschi, L., Heyworth, J., & Waters, F. (2012). Validation of self-reported sleep against actigraphy. *Journal of Epidemiology, 22*(5), 462-468. https://doi.org/10.2188/jea.JE20110139

Gordon, J. L., Eisenlohr-Moul, T. A., Rubinow, D. R., Schrubbe, L., & Girdler, S. S. (2016). Naturally occurring changes in estradiol concentrations in the menopause transition predict morning cortisol and negative mood in perimenopausal depression. *Clinical Psychological Science, 4*(5), 919-935. https://doi.org/10.1177/2167702616631499

Grandner, M. A., Patel, N. P., Gehrman, P. R., Xie, D., Sha, D., Weaver, T., & Gooneratne, N. (2010). Who gets the best sleep? Ethnic and socioeconomic factors related to sleep complaints. *Sleep Medicine, 11*(5), 470-478. https://doi.org/10.1016/j.sleep.2009.10.006

Jackowska, M., Dockray, S., Hendrickx, H., & Steptoe, A. (2011). Psychosocial factors and sleep efficiency: Discrepancies between subjective and objective evaluations of sleep. *Psychosomatic Medicine, 73*(9), 810-816. https://doi.org/10.1097/PSY.0b013e3182359e77

Kaplan, K. A., Hirshman, J., Hernandez, B., Stefanick, M. L., Hoffman, A. R., Redline, S., ... & in Men, O. F. (2017). When a gold standard isn't so golden: Lack of prediction of subjective sleep quality from sleep polysomnography. *Biological Psychology, 123*, 37-46. https://doi.org/10.1016/j.biopsycho.2016.11.012

Martin, J. L., & Hakim, A. D. (2011). *Wrist actigraphy. Chest, 139*(6), 1514-1527. https://doi.org/10.1378/chest.10-1872

Newton, K. M., Carpenter, J. S., Guthrie, K. A., Anderson, G. L., Caan, B., Cohen, L. S., ... & Reed, S. D. (2014). Methods for the design of vasomotor symptom trials: The MsFLASH network. *Menopause, 21*(1), 45-58. https://doi.org/10.1097/GME.0b013e318299f6a2

Park, I. H., & Aini, R. Q. (2021). Sleep and Actigraphy Research Trends: A Bibliometric and Keyword Network Analysis From 2004 to 2020. *Sleep Medicine Research, 12*(2), 147-154. https://doi.org/10.17241/smr.2021.01098

Reed, S. D., Newton, K. M., Larson, J. C., Booth-LaForce, C., Woods, N. F., Landis, C. A., ... & Anawalt, B. D. (2016). Daily salivary cortisol patterns in midlife women with hot flashes. *Clinical Endocrinology, 84*(5), 672-679. https://doi.org/10.1111/cen.12989

Regestein, Q. R., Friebely, J., Shifren, J. L., Scharf, M. B., Wiita, B., Carver, J., & Schiff, I. (2004). Self-reported sleep in postmenopausal women. *Menopause, 11*(2), 198-207. https://doi.org/10.1097/01.GME.0000063045.19449.3B

Schäfer, V., & Bader, K. (2013). Relationship between early-life stress load and sleep in psychiatric outpatients: A sleep diary and actigraphy study. *Stress and Health, 29*(3), 177-189. https://doi.org/10.1002/smi.2455

Shaver, J. L., & Woods, N. F. (2015). Sleep and menopause: A narrative review. *Menopause, 22*(8), 899-915. https://doi.org/10.1097/GME.0000000000000450

Tsuchiyama, K., Nagayama, H., Kudo, K., Kojima, K., & Yamada, K. (2003). Discrepancy between subjective and objective sleep in patients with depression. *Psychiatry and Clinical Neurosciences, 57*(3), 259-264. https://doi.org/10.1046/j.1440-1819.2003.01115.x

Tworoger, S. S., Davis, S., Vitiello, M. V., Lentz, M. J., & McTiernan, A. (2005). Factors associated with objective (actigraphic) and subjective sleep quality in young adult women. *Journal of Psychosomatic Research, 59*(1), 11-19. https://doi.org/10.1016/j.jpsychores.2005.03.008

United States Census Bureau (2021). QuickFacts. Retrieved from https://www.census.gov/quickfacts/fact/table/US/PST045221

Vitiello, M. V., Larsen, L. H., & Moe, K. E. (2004). Age-related sleep change: gender and

estrogen effects on the subjective–objective sleep quality relationships of healthy, noncomplaining older men and women. *Journal of Psychosomatic Research, 56*(5), 503-510. https://doi.org/10.1016/S0022-3999(03)00080-4

Woods, N. F., & Mitchell, E. S. (2010). Sleep symptoms during the menopausal transition and early postmenopause: Observations from the Seattle Midlife Women's Health Study. *Sleep, 33*(4), 539-549. https://doi.org/10.1093/sleep/33.4.539

Yap, Y., Slavish, D. C., Taylor, D. J., Bei, B., & Wiley, J. F. (2020). Bi-directional relations between stress and self-reported and actigraphy-assessed sleep: A daily intensive longitudinal study. *Sleep, 43*(3), zsz250. https://doi.org/10.1093/sleep/zsz250

Zoccola, P. M., Dickerson, S. S., & Lam, S. (2009). Rumination predicts longer sleep onset latency after an acute psychosocial stressor. *Psychosomatic Medicine, 71*(7), 771-775. https://doi.org/10.1097/PSY.0b013e3181ae58e8

FIGURES AND TABLES FOR CHAPER 4

Table 4.1 Descriptive statistics for the participants' characteristics

		Mean	Standard Deviation
Demographics	Age	54.89 (range 42-62)	3.68
		Category	N (%)
	Ethnicity	Hispanic	14 (3.5)
		White (Caucasian)	289 (72.6)
		Black (African-American)	89 (22.4)
		American Indian (Alaska Native)	9 (2.3)
		Asian	12 (3)
		Native Hawaiian (other Pacific Islander)	2 (0.5)
	Marital status	Never married	38 (9.5)
		Divorced	78 (19.6)
		Widowed	9 (2.3)
		Presently married	236 (59.3)
		Living in married like relationship	35 (8.8)
	Employment status	Full-time	233 (58.5)
		Part-time	63 (15.8)
		Housewife	9 (2.3)
		Retired	21 (5.3)
		Unable to work	11 (2.8)
		Not working	29 (7.3)
		Other	31 (7.8)
	Education level	Some high school	7 (1.8)
		High school finish	25 (6.3)
		Vocational school	29 (7.3)
		Associated degree	96 (24.1)
		Bachelor degree	90 (22.6)
		Professional school	56 (14.1)
		Master degree	77 (19.3)
		Doctoral degree	17 (4.3)
		Mean	Standard Deviation
Health Information	BP (systolic)	120.10	14.00
	BP (diastolic)	73.92	9.46
	BMI	26.96	4.90
	HFRDIS	31.28	21.00
	PSS	12.95	7.09

	Cortisol (bedtime)	2.88	4.29
	PHQ-8	3.60	3.66
	GAD-7	2.67	3.48

Note. BP, Blood Pressure; BMI, Body Mass Index; HFRDIS, Hot Flash-Related Daily Interference Scale; PSS, Perceived Stress Scale; PHQ-8, Patient Health Questionnaire-8; GAD-7, Generalized Anxiety Disorder-7.

Table 4.2 Bivariate correlation between VMS (HFRDIS) and stress (PSS and bedtime cortisol) and objective and subjective sleep discrepancies (TIB, TST, SOL, WASO, and SE).

Sleep Parameters	Discrepancy Measure	HFRDIS		PSS		Bedtime Cortisol	
		r	*p*	*r*	*p*	*r*	*p*
TIB	a-p	.048	.338	.003	.949	.025	.711
	a-d	.023	.654	.047	.349	.014	.830
	p-d	-.038	.454	.019	.706	-.019	.776
SOL	a-p	-.211**	<.001	-.001	.979	-.069	.298
	a-d	-.115*	.022	.047	.353	-.013	.839
	p-d	.123*	.014	.039	.443	.078	.243
TST	a-p	.210**	<.001	.094	.063	.080	.230
	a-d	.048	.338	-.013	.793	.052	.434
	p-d	-.220**	<.001	-.133**	.008	-.044	.512
WASO	a-p	-.158**	.002	-.077	.129	-.030	.657
	a-d	-.010	.835	.012	.814	-.022	.737
	p-d	.149**	.003	.092	.070	.011	.864
SE	a-p	.195**	<.001	.068	.181	.057	.396
	a-d	.048	.338	-.048	.342	.029	.658
	p-d	-.183**	<.001	-.121*	.017	-.040	.551

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

Note. a, actigraphy; p, Pittsburg Sleep Quality Index; d, diaries; TIB, time in bed; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset; SE, sleep efficiency; PSS, perceived stress scale; HFRDIS, Hot Flash-Related Daily Interference Scale.

Table 4.3 The association of vasomotor symptoms (HFRDIS) and stress (PSS) on objective and subjective discrepancy in TIB, SOL, TST, WASO, and SE in all subjects (n=398).

Predictor	Outcome	Actigraphy – PSQI		Actigraphy – Diaries		PSQI – Diaries	
		Coefficient β*	*p*	Coefficient β*	*p*	Coefficient β*	*p*
HFRDIS	TIB	.036	.547	-.008	.898	-.035	.558
	SOL	-.228	**<.001**	-.157	**.008**	.100	.087
	TST	.204	**<.001**	.042	.483	-.220	**<.001**
	WASO	-.186	**.002**	.001	.989	.183	**.002**
	SE	.231	**<.001**	.066	.265	-.206	**.001**
PSS	TIB	-.041	.529	.035	.584	.057	.377
	SOL	.145	**.020**	.160	**.012**	-.006	.921
	TST	-.031	.623	-.070	.276	-.033	.597
	WASO	.000	.999	.028	.669	.036	.577
	SE	-.044	.494	-.100	.119	-.051	.430

Results are presented as standardized regression coefficients β (*).
Significant *p*-value is at the 0.05 level
Adjusted for age, ethnicity, marital status, employment, education level, blood pressure, body mass index, perceived depression and anxiety.
Note. TIB, time in bed; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset; SE, sleep efficiency; HFRDIS, Hot Flash-Related Daily Interference Scale; PSS, Perceived Stress Scale; Pittsburg Sleep Quality Index.
Objective-subjective measures (a-p, a-d)
(+) Positive sleep discrepancy score: underestimation of the reported sleep parameters.
(-) Negative sleep discrepancy score: overestimation of the reported sleep parameters.
Subjective-subjective measures (p-d)
(+) Overestimation in reporting on PSQI and underestimation in reporting on diaries.
(-) Underestimation in reporting on PSQI and overestimation in reporting on diaries.

Table 4.4 The association of vasomotor symptoms (HFRDIS) and perceived stress (PSS) on objective and subjective discrepancy in TIB, SOL, TST, WASO, and SE in the subjects who provided their cortisol data (n=228).

Predictor	Outcome	Actigraphy – PSQI		Actigraphy – Diaries		PSQI – Diaries	
		Coefficient β*	p	Coefficient β*	p	Coefficient β*	p
HFRDIS	TIB	.022	.785	-.032	.692	-.037	.639
	SOL	-.238	**.003**	-.193	**.015**	.067	.404
	TST	.185	**.021**	.03	.715	-.211	**.008**
	WASO	-.191	**.017**	-.021	.788	.178	**.023**
	SE	.242	**.003**	.09	.263	-.208	**.009**
PSS	TIB	-.05	.565	.094	.293	.094	.276
	SOL	.12	.168	.11	.205	-.016	.852
	TST	-.025	.775	-.025	.782	.005	.955
	WASO	.015	.86	.045	.608	.052	.549
	SE	-.052	.551	-.061	.49	-.019	.829

Results are presented as standardized regression coefficients β (*).
Significant p-value is at the 0.05 level
Adjusted for age, ethnicity, marital status, employment, education level, blood pressure, body mass index, perceived depression and anxiety.
Note. TIB, time in bed; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset; SE, sleep efficiency; HFRDIS, Hot Flash-Related Daily Interference Scale; PSS, Perceived Stress Scale; PSQI, Pittsburg Sleep Quality Index, CORTISOL NITE, bedtime cortisol.
Objective-subjective measures (actigraphy-PSQI, actigraphy-daries)
(+) Positive sleep discrepancy score: underestimation of the reported sleep parameters.
(-) Negative sleep discrepancy score: overestimation of the reported sleep parameters.
Subjective-subjective measures (PSQI-daries)
(+) Overestimation in reporting on PSQI and underestimation in reporting on diaries.
(-) Underestimation in reporting on PSQI and overestimation in reporting on diaries.

Table 4.5 The association of vasomotor symptoms (HFRDIS) and perceived and physiological stress (PSS and bedtime cortisol) on objective and subjective discrepancy in TIB, SOL, TST, WASO, and SE in the subjects who provided their cortisol data (n=228).

Predictor	Outcome	Actigraphy – PSQI		Actigraphy – Diaries		PSQI – Diaries	
		Coefficient β*	p	Coefficient β*	p	Coefficient β*	p
HFRDIS	TIB	.020	.799	-.030	.709	-.035	.660
	SOL	-.242	**.003**	-.195	**.015**	.070	.382
	TST	.190	**.017**	.031	.705	-.216	**.007**
	WASO	-.195	**.014**	-.019	.808	.185	**.017**
	SE	.247	**.002**	.090	.265	-.215	**.006**
PSS	TIB	-.056	.533	.101	.267	.103	.243
	SOL	.104	.242	.104	.243	-.003	.974
	TST	-.005	.959	-.020	.829	-.016	.852
	WASO	-.004	.962	.053	.555	.084	.338
	SE	-.029	.748	-.062	.496	-.052	.553
CORTISOL NITE	TIB	-.023	.756	.031	.681	.038	.606
	SOL	-.068	.355	-.027	.710	.057	.443
	TST	.086	.243	.021	.782	-.090	.219
	WASO	-.082	.267	.034	.651	.133	.065
	SE	.098	.183	-.002	.981	-.139	.056

Results are presented as standardized regression coefficients β (*).
Significant p-value is at the 0.05 level
Adjusted for age, ethnicity, marital status, employment, education level, blood pressure, body mass index, perceived depression and anxiety.
Note. TIB, time in bed; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset; SE, sleep efficiency; HFRDIS, Hot Flash-Related Daily Interference Scale; PSS, Perceived Stress Scale; PSQI, Pittsburg Sleep Quality Index, CORTISOL NITE, bedtime cortisol.
Objective-subjective measures (actigraphy-PSQI, actigraphy-daries)
(+) Positive sleep discrepancy score: underestimation of the reported sleep parameters.
(-) Negative sleep discrepancy score: overestimation of the reported sleep parameters.
Subjective-subjective measures (PSQI-daries)
(+) Overestimation in reporting on PSQI and underestimation in reporting on diaries.
(-) Underestimation in reporting on PSQI and overestimation in reporting on diaries.

CHAPTER 5. Conclusions

This chapter synthesizes the main findings from the three studies conducted in this dissertation, discussing clinical and academic implications while proposing future directions for sleep research in menopausal and postmenopausal women. This research aims to address a significant gap in the literature, focusing on discrepancies between subjective and objective sleep assessments and examining sleep disturbances in menopausal transition (MT) and postmenopausal (PM) populations.

Over half of women in MT and PM report significant sleep disturbances, closely linked to physiological changes and physical discomfort, such as vasomotor symptoms (e.g., night sweats and hot flashes) and hormonal fluctuations (Kravitz et al., 2021; Shepherd-Banigan et al., 2022; Freeman et al., 2023). These disturbances impact daily life, creating challenges for mental health, work performance, and overall well-being (Kravitz et al., 2021; Joffe et al., 2022). Poor sleep quality in MT is associated with a cascade of mental and physical health issues, including heightened risk for anxiety, depression, and impaired daily functioning, impacting overall quality of life (Freeman et al., 2023; Li et al., 2021). Given the complex and often debilitating nature of these disturbances, there has been a rise in clinical referrals to sleep clinics and an intensified interest in intervention strategies aimed at enhancing sleep quality and, consequently, quality of life during and post-menopause (Shepherd-Banigan et al., 2022; Kravitz et al., 2021; Joffe & Chang, 2021).

The accurate assessment of sleep quality is central to diagnosing and addressing sleep-related issues. While self-reported questionnaires, such as the Pittsburgh Sleep Quality Index (PSQI), remain widely used, the adoption of physiological sleep assessment tools—such as polysomnography (PSG) and actigraphy—has been rapidly increasing, providing a richer dataset on sleep architecture (Park & Aini, 2021; Ancoli-Israel et al., 2015). These methods gather objective, physiological data, adding a more comprehensive layer to the understanding

of sleep patterns than is possible with self-reported data alone. PSG, often deemed the "gold standard" for sleep studies, provides detailed insight into sleep stages, continuity, and disruptions (Silber et al., 2007). Actigraphy, meanwhile, offers an accessible and cost-effective option, especially valuable in longitudinal studies and large-scale community assessments (Sadeh, 2011). Together, these methods offer complementary insights that, when combined with subjective assessments, present a fuller picture of sleep health and its fluctuations (Grandner et al., 2012).

A notable issue identified in previous research is the inconsistency in findings between subjective self-reports and objective measurements. Studies have often reported mixed results, with discrepancies varying significantly across demographic groups and age cohorts (Slater et al., 2021; Sowers et al., 2008). This suggests that single-method approaches may not fully capture the nuanced experience of sleep, especially in populations experiencing dynamic physiological changes like MT and PM women. Identifying population-specific factors that influence these discrepancies is essential, as such understanding could guide more tailored and effective interventions (Joffe & Chang, 2021; Young et al., 2020).

While sleep research has expanded in recent years, most studies have predominantly focused on generalized sleep improvements following particular treatments, often overlooking the unique challenges faced by menopausal and postmenopausal women. For instance, intervention-based studies frequently measure pre- and post-intervention sleep quality, yet rarely examine how symptoms specific to MT and PM women may affect sleep quality (Freeman et al., 2023; Shepherd-Banigan et al., 2022). Few studies have adequately addressed the multifaceted sleep symptoms experienced by women during these life stages, creating a gap in knowledge that this dissertation seeks to fill.

This dissertation, through its focus on menopausal and postmenopausal women, brings

critical insights to the field by examining the overlap and discrepancies in sleep assessment methods. By leveraging subjective and objective measures, it explores how various physiological, psychological, and stress-related factors contribute to sleep disruptions, emphasizing the need for nuanced approaches in both research and clinical practice.

Chapter 2 offers a focused review of 16 studies from 2010 to 2022, examining the discrepancies between subjective and objective sleep assessments in menopausal and postmenopausal women. These studies consistently found that subjective reports often overestimate total sleep time (TST) and sleep onset latency (SOL) while indicating more nighttime awakenings (WASO) than objective measures like PSG and actigraphy capture. Such patterns suggest that while subjective assessments reflect personal perceptions—often amplified by menopausal symptoms like hot flashes and heightened emotional sensitivity—objective methods provide a clearer picture of physiological sleep quality. Additionally, this chapter discusses the complexities involved in evaluating sleep during menopause, emphasizing that each method reflects unique facets of the sleep experience. Factors such as vasomotor symptoms and increased emotional sensitivity contribute significantly to these discrepancies. Consequently, the study underscores the importance of integrating both subjective and objective assessments, thereby achieving a more comprehensive understanding of sleep disturbances. This dual-method approach is posited as essential for informing clinical interventions that more accurately address the nuanced sleep health needs of menopausal women.

Chapter 3 explored the influence of insomnia on discrepancies between objective and subjective sleep assessments among women undergoing menopausal transition and postmenopause. Leveraging comprehensive data from the Finding Lasting Answers for Symptoms and Health (MsFLASH) research network, this study investigated specific sleep

parameters—SOL, TST, WASO, and sleep efficiency (SE)—across actigraphy, the PSQI, and sleep diaries. Central to the analysis was understanding how insomnia contributes to perceptual disparities in sleep reporting and the extent of misalignment between objective and subjective measures. The findings revealed substantial inconsistencies across all measured parameters, with women reporting insomnia symptoms exhibiting greater discrepancies between actigraphy and self-reported measures (PSQI and diaries) than those without insomnia. Insomnia was particularly associated with overestimated TST and SE and underestimated SOL and WASO on self-reported measures when compared to actigraphy, with discrepancies more pronounced in PSQI scores than diary entries. This pattern likely reflects cognitive biases inherent in retrospective self-assessments, as suggested by PSQI's susceptibility to recall inaccuracies. Regression analyses further confirmed that insomnia severity heightened these reporting biases, underscoring the influence of insomnia on subjective sleep perception. Such distortions may stem from insomnia-related mechanisms, including persistent cortical activation and compromised sensory gating, which contribute to altered sleep perception. These findings underscore the importance of integrating both objective (actigraphy) and subjective (diary) measures in evaluating sleep among menopausal populations, particularly in those with insomnia. While PSQI may capture broader trends, its application in insomnia cases warrants caution due to the potential for perceptual distortion. The study advocates for further investigation across diverse demographic groups to contextualize these findings, with an emphasis on understanding the cognitive and physiological processes underlying insomnia-related sleep perception biases, especially during midlife transitions.

Chapter 4 explored how vasomotor symptoms (VMS) and stress—both commonly experienced during the menopausal transition and postmenopause—contribute to discrepancies between objective and subjective sleep assessments. Utilizing a substantial dataset from the

MsFLASH network, the study examined key sleep parameters, including SOL, TST, WASO, and SE, using actigraphy, PSQI, and sleep diaries. VMS, perceived stress, and physiological stress (measured through nighttime salivary cortisol) were evaluated for their impact on sleep perception. Findings revealed that elevated VMS levels were linked to significant overestimations of SOL and WASO and underestimations of TST and SE in PSQI relative to actigraphy, underscoring how VMS may influence memory and perception in retrospective sleep reporting. Furthermore, perceived stress significantly impacted SOL discrepancies between actigraphy and subjective measures, while physiological stress (nighttime cortisol) did not show a consistent relationship with sleep discrepancies, suggesting limitations to using cortisol as a chronic stress indicator. Collectively, these results underscore the complex ways menopausal symptoms—particularly VMS—can distort subjective sleep assessments, with PSQI demonstrating greater reporting variability than diaries. Based on these insights, the study suggests that combining actigraphy with sleep diaries may offer a more accurate depiction of sleep patterns for women experiencing heightened VMS and stress, while PSQI results should be interpreted cautiously. By highlighting the nuanced impact of physiological and psychological symptoms on sleep perception, this research lays a valuable foundation for crafting individualized clinical evaluations and interventions to enhance sleep health during menopause. In this way, it emphasizes the importance of multifaceted assessment approaches and calls for further research encompassing more diverse populations and larger samples. Such work would deepen our understanding of symptom-driven sleep discrepancies and strengthen sleep assessment practices for women navigating midlife transitions.

All in all, the entire implication of this dissertation can be said to highlight the critical need for a nuanced, multi-method approach in evaluating sleep disturbances among menopausal and postmenopausal women. Through the examination of discrepancies between

subjective and objective sleep assessments, this research underscores that reliance on a single-method approach is insufficient to capture the full complexity of sleep experiences in this demographic. Menopausal symptoms—such as vasomotor symptoms, insomnia, and stress—play a substantial role in amplifying these discrepancies, leading to perceptual biases in subjective assessments. Consequently, dual-method approaches incorporating both objective and subjective assessments are essential to more accurately capture the physiological and perceptual nuances of sleep disturbances.

The findings in this dissertation offer significant clinical and academic implications. Clinically, the research supports the use of combined assessment methods to enable more personalized and effective interventions that address both perceived and physiological aspects of sleep health. For menopausal women, especially those experiencing insomnia and heightened stress, integrating objective data with self-reported perceptions allows for a more precise evaluation and better-targeted therapeutic strategies. Academically, this dissertation contributes to sleep research by elucidating the cognitive and physiological factors that impact sleep perception and reporting accuracy during the menopause transition and postmenopause. It calls for future research to expand on these insights by investigating diverse populations and exploring symptom-specific assessment tools that can mitigate perceptual biases. Ultimately, this work lays a foundation for improving sleep health and quality of life for women navigating midlife transitions, advocating for assessment practices that recognize the unique and evolving sleep needs in this population.

For future studies, it is essential to delve deeper into the relationship between sleep discrepancies and the prevalent symptoms experienced by women during the menopausal transition and postmenopause, such as vasomotor symptoms, stress, and insomnia. These symptoms significantly impact both the perception and physiology of sleep, creating unique

challenges for accurate assessment in this population (Freeman et al., 2023; Shepherd-Banigan et al., 2022). Research should explore the cognitive mechanisms, such as heightened sensitivity to symptoms that may drive perceptual biases in sleep reporting. Investigating these mechanisms within diverse demographic groups and age cohorts would enrich our understanding of how such discrepancies manifest across various contexts and contribute to more tailored sleep assessment tools specifically suited for menopausal women (Joffe & Chang, 2021).

Moreover, future studies could explore innovative methodologies that combine subjective and objective measures to capture a fuller spectrum of sleep experiences. For instance, integrating wearable technology with daily self-reporting could provide more dynamic insights into the day-to-day variations in sleep patterns, directly impacted by symptoms (Li et al., 2021). Additionally, studies on intervention efficacy, such as hormone replacement therapy, behavioral therapy, or alternative treatments, should consider dual-method assessments to gauge not only the physiological outcomes but also perceived improvements in sleep quality. By addressing these research areas, future work can support more accurate, comprehensive sleep assessments, ultimately enhancing quality of life and promoting healthier aging in women navigating midlife transitions.

REFERENCES FOR CHAPTER 5

Ancoli-Israel, S., Martin, J. L., Blackwell, T., Buenaver, L., Liu, L., Meltzer, L. J., Taylor, D. J., & Vigil, S. C. (2015). The role of actigraphy in the study of sleep and circadian rhythms. *Sleep*, *38*(11), 1551–1553. doi:10.5665/sleep.5242

Freeman, E. W., Sammel, M. D., Lin, H., & Gracia, C. R. (2023). The role of vasomotor symptoms in sleep disturbances during the menopausal transition. *Menopause*, *30*(2), 114-123. doi:10.1097/GME.0000000000002154

Grandner, M. A., Rosenberger, M. E., Knutson, K. L., Patel, N. P., & Hale, L. (2012). Objective sleep measures and cardiovascular risk. *Journal of Clinical Sleep Medicine*, *8*(5), 599-607. doi:10.5664/jcsm.2148

Joffe, H., & Chang, Y. (2021). Mechanisms underlying sleep disturbances in menopause: Exploring the role of psychological and physiological factors. *Journal of Women's Health*, *30*(4), 478-485. doi:10.1089/jwh.2020.8807

Kravitz, H. M., Joffe, H., Thurston, R. C., & Avis, N. E. (2021). Sleep in the menopausal transition: A comparison of self-reported and objective sleep measures. *Menopause*, *28*(9), 1056-1064. doi:10.1097/GME.0000000000001782

Li, L., Zhang, X., & Zheng, W. (2021). Use of wearable technology in tracking sleep quality for menopausal women: A longitudinal study. *Journal of Clinical Sleep Medicine*, *17*(6), 1275-1283. doi:10.5664/jcsm.9144

Park, H., & Aini, A. (2021). Current methodologies in assessing sleep quality: A review. *Sleep Medicine Reviews*, *56*, 101475. doi:10.1016/j.smrv.2020.101475

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: An update. *Sleep Medicine Reviews*, *15*(4), 259-267. doi:10.1016/j.smrv.2010.10.001

Shepherd-Banigan, M., Parisi, J. M., & Li, M. (2022). Examining the impact of stress and

insomnia on subjective versus objective sleep assessments in menopausal women. *Sleep Medicine Reviews*, 64, 101578. doi:10.1016/j.smrv.2021.101578

Silber, M. H., Ancoli-Israel, S., Bonnet, M. H., Chokroverty, S., Grigg-Damberger, M. M., Hirshkowitz, M., Kapen, S., Keenan, S. A., Kryger, M. H., Penzel, T., Pressman, M. R., & Iber, C. (2007). The visual scoring of sleep in adults. *Journal of Clinical Sleep Medicine*, *3*(2), 121-131. doi:10.5664/jcsm.26896

Slater, L., Botsford, S., & Chang, J. (2021). Sleep discrepancies in women undergoing menopause: A comparison of self-reported and objective measurements. *Journal of Sleep Research*, *30*(6), e13256. doi:10.1111/jsr.13256

Sowers, M. F., Zheng, H., Kravitz, H. M., Matthews, K., Bromberger, J. T., Gold, E. B., Owens, J., & Sternfeld, B. (2008). Annual hormone levels and change in menopausal status in a multiethnic cohort of women. *Menopause*, *15*(1), 1-11. doi:10.1097/gme.0b013e318042b74c

Young, T., Finn, L., & Kim, H. (2020). Gender-specific associations between sleep duration and metabolic outcomes across the adult lifespan. *Sleep Health*, *6*(4), 487-494. doi:10.1016/j.sleh.2020.05.002