EXAMINING THE CONVERGENT CONSTRUCT VALIDITY OF THE BRADEN SCALE'S MOBILITY AND ACTIVITY SUBSCALES IN NURSING HOMES USING TRIAXIAL ACCELEROMETRY

by

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ABSTRACT

Pressure injuries (PrIs) are areas of skin, muscle, and tissue believed to be damaged by external pressure usually due to lack of movement/mobility and remaining in one position. Most PrIs are preventable, yet remain a healthcare problem in nursing homes (NHs) where many residents experience aging related cognitive and physical declines that increase PrI risk. A valid tool is foundational to nursing staff ability to assess and identify individuals at risk in order to prevent PrIs. The Braden Scale for Predicting Pressure Sore Risk© (hereafter, Braden Scale), the most commonly used PrI risk assessment tool in the U.S., has demonstrated reliability and predictive validity in NH settings; however, its construct validity has been challenged and has not been as well studied. This retrospective non-experimental study examined the convergent construct validity of the Braden Scale's Mobility and Activity subscales using secondary analysis of subscale and repositioning movement data collected in nine U.S. NHs during implementation of the 1R01NR016001 (Turn Everyone And Move for Ulcer Prevention [TEAM-UP] cluster randomized controlled trial). Results of bivariate analyses for NH residents' (N = 562) Braden

Scale Mobility, Activity, and Sensory Perception subscale scores and movement parameters (upright, lying, ambulating) revealed consistent correspondence between Braden Scale subscale scores and movement parameters [$r(561) > .16$-$.59$, $p < .0001$] and together accurately predicted movement outcomes ($.0444 < R^2 < .3667$, $p < .005$). Mobility and Activity subscale scores had individual predictive effects ($p < .05$), while Sensory Perception subscale scores were not significant predictors ($p > .05$) of movement parameters. Findings indicate that subscale ratings assigned by nursing staff accurately represented resident movements and reinforce the confidence one can have in nursing staff's ability to use the Braden Scale for PrI risk assessment and to guide care planning of mobility and activity interventions, such as repositioning and walking aimed at preventing PrI.

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DEDICATION

I dedicate my dissertation work to my family. To my parents, Joyce and Lewis, for always believing in me. Thank you for your unconditional love, encouragement, prayers, and support. I am grateful to my brothers, Desmond and Clayton, for keeping me grounded. To my sister, Caroline, you are my greatest cheerleader! Your positivity, energy, and healthy snacks gave me the fuel to keep moving forward when I grew weary. I dedicate my dissertation research in remembrance of my grandmother, Louise, whose grace and steadiness continue to inspire me to never stop looking for ways to use my blessings to help others. My children, Cole and Annabelle, may not have understood my absence but showered me with affection when I returned home from my studies and helped to keep my cup full. This journey would not have been possible without my husband, partner, and rock - Eddie. Your selfless sacrifices provided me with all the time, stability, and support I needed. Your love is limitless. Thank you all for helping me achieve my dreams!

I also dedicate this dissertation to everyone working in healthcare battling the COVID-19 pandemic worldwide. In particular to my colleagues in acute care, whose commitment to doing whatever is necessary to help those in need 24-7 is inspiring. We will persevere!

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CHAPTER 1: INTRODUCTION

Pressure injuries (PrIs) are a serious, costly, and often an avoidable healthcare problem that continues to affect residents in nursing homes (NHs), in spite of enhanced understanding of PrI etiology through research, multidisciplinary and international collaboration, regulation, and technological advances in PrI prevention and treatment over the years. A large amount of empirical and theoretical evidence on the phenomenon of PrI exists and attests to the complexity of PrI development, management, and prevention. Clinical practice guidelines derived from this knowledge endorse PrI risk assessment using validated tools, like the Braden Scale, as an essential first step in PrI prevention (EPUAP et al., 2019); even though, there is a lack of high-quality evidence supporting their use reduces PrI incidence or severity (Moore & Patton, 2019). The validity and reliability of the Braden Scale has undergone more formal evaluations than any other PrI risk assessment scale (Hamilton, 1992); however, little is known about the convergent validity of its Mobility and Activity subscales compared to objective measures of mobility and activity constructs in NH residents. Mobility and activity deficits experienced with aging is associated with an increase PrI prevalence and incidence (National Pressure Ulcer Advisory Panel [NPUAP] et al., 2014) and are factors measured by multiple PrI risk assessment scales. Examination of how well the Braden Scale tool operationalizes theoretically and empirically supported constructs (i.e., measures what it claims to measure) is an important step in advancing understanding about PrI risk assessment measurement in NH residents. Findings from this study of the Braden Scale's Mobility and Activity subscales' convergent construct validity will enhance knowledge of the tool's usefulness in PrI prevention and aid in understanding the practice-evidence gap between PrI risk assessment and the persistence of PrI outcomes in NH residents.

Statement of the Problem

Pressure injury (PrI) prevention guidelines recommend use of a validated tool, such as the Braden Scale, to support clinical judgement when assessing PrI risk and monitoring PrI healing (EPUAP et al., 2019). The lack of strong evidence, however, linking use of structured risk assessment in practice to reduced PrI incidence (Moore & Patton, 2019) has led to questions about the Braden Scale's validity and utility in clinical practice. The Braden Scale subscale scores are used to guide PrI preventive care; yet, there are few studies using objective measures to validate constructs in PrI etiology measured by the scale. Mobility and activity are important factors in PrI development and prevention subject to a diversity of terms, definitions, interpretations, and methods of measurement that contribute to this shortcoming in the literature. The advancement of movement sensor technology now enables the ability to objectively examine the convergent construct validity of the Braden Scale's Mobility and Activity subscale measures of mobility and activity. Study of movement in relation to mobility and activity scores will enhance understanding of the Braden Scale's validity in nursing assessment and implications for guiding prevention care.

Background

Pressure injuries formerly known as ulcers or bedsores, are localized damage to skin and underlying soft tissue, usually over a bony prominence believed to result from intense and/or prolonged pressure (Edsberg et al., 2016) limiting tissue reperfusion, leading to necrosis and eventually tissue death. Pressure injuries are associated with pain, risk for serious infection, longer hospital stays, increased morbidity and mortality, decreased quality of life, and higher healthcare utilization and pose major medical, psychosocial, and financial burdens on affected individuals and healthcare organizations (Agency for Healthcare Research and Quality [AHRQ], 2016).

Prevention has been a primary goal of PrI research (Mervis & Phillips, 2019) given $26.8 billion is spent on treatment costs each year in the U.S. (Padula & Delarmente, 2019) and the vast majority of PrIs are considered to be avoidable (Edsberg et al., 2014). Pressure injuries remain a serious problem in NHs, where the reported national PrI prevalence rate is 5 – 15% (mean = 8.7%) (Centers for Medicare & Medicaid Services [CMS], 2022), despite evidence-based clinical, regulatory, and market approaches for prevention and treatment. Demands and burdens on caregivers and NH facilities grow as aging populations live longer with more comorbidities and experience functional declines that increase dependency on others assistance with activities of daily life. Individuals with impaired mobility and sensation who cannot effectively reposition themselves to relieve pressure or have the inability to feel and communicate the need for repositioning to offload body tissues from pressure are at the greatest risk for PrIs (Mervis & Phillips, 2019). The longer a resident's duration in a position, the more intense the pressure. The conceptual model of intensity and duration of pressure developed by Bergstrom and Braden (1987) identifies mobility, activity, and sensory perception as three of six key factors in PrI development and this tool have been empirically tested. Evidence supports mobility and activity as important protective factors and predictive risk factors in PrI etiology (Lahmann et al., 2015; Lannering et al., 2016; EPUAP et al., 2019). Mobility and activity risk factors measured using PrI risk assessment scales frequently emerge as significant variables (independently predictive of PrI outcome) in studies using multivariable analyses and are commonly classified into the primary risk domain of 'mobility/activity' in literature (Coleman et al., 2013). However, empirical evidence regarding the validity of PrI risk assessment scale scores is inconclusive, and scores contain variable amounts of measurement error (Kottner & Balzer, 2010). The multidimensional nature of mobility and activity can be difficult to quantify solely through an observational means. A variety of instruments and operational definitions for measuring mobility and activity objectively exists, but often these tools are expensive to implement and require technical expertise to use. Additionally, these tools do not consider the influence of potential confounding variables, like sensory perception (a Braden subscale construct), on the degree, type, and timing of mobility and activity for mitigating risk from pressure duration and intensity that is common in the older adult NH resident population.

Standardized PrI risk assessment using validated instruments is foundational to developing an appropriate and individualized care plan for PrI prevention (Gadd & Morris, 2014; Yap et al., 2015; Gadd, 2014). This cost-efficient key best practice can help providers identify which patients may benefit most from preventative measures for allocating critical or limited resources and guide customized interventions to promote health in institutionalized elderly (AHRQ, 2014) and organizational viability through fiscal responsibility. The Braden Scale (Bergstrom et al., 1987) was developed for use in NHs and is the most commonly used risk assessment tool in the U.S. (Ayello & Braden, 2001), although the scale is based largely on subjective and observational data. Further examination of the construct validity of the Braden Scale using objective measures is merited. Movement is an essential component observed in assessment of residents that is guided by the Braden Scale's Mobility and Activity subscales; movement data can serve as an objective point of comparison for the examining convergent validity of the mobility and activity constructs of these subscales.

The Braden Scale (Bergstrom et al., 1987) has six subscales (Mobility, Activity, Sensory Perception, Moisture, Nutrition, and Friction and Shear) quantifying exposure to etiological factors that place a person at risk for PrIs. The six subscales represent independent PrI risk dimensions that are rated 1-3 for friction and shear and 1-4 for the other five subscales using a psychometric scoring system. Summing of the individual subscale scores produces an overall risk score ranging from 6 to 23. The Braden Scale total score provides general information about risk status (Mild Risk 15-18, Moderate Risk 13-14, High Risk 10-12, Severe Risk ≤9) (Briggs Healthcare, n.d.), while its subscale scores are more appropriate for guiding risk-based planning and effective utilization of resources (EPUAP et al., 2019). This study will examine all six subscale scores with primary emphasis on convergent validity of the Mobility and Activity subscales. The Mobility subscale is defined as the ability to change and control body position while in bed. The Activity subscale reflects how much or how little the person moves independently out of bed. Braden Scale Mobility and Activity subscales have been studied (Powers et al., 2004; Oertwich et al., 1995), but these small studies were conducted by Bergstrom and graduate students and were limited by the subjectivity of the nursing staff documentation and observations. Furthermore, variation in nurses' interpretations of Braden Scale subscale operational definitions describing patient characteristics that serve as the criteria for differentiating severity of patient risk may account for inconsistencies in assessment and judgment at the individual parameter level (Choi et al., 2014; Anthony et al., 2010; Kottner & Dassen, 2008).

The Braden Scale's reliability and predictive validity has been demonstrated in NH settings (Kottner & Dassen, 2008; Braden & Bergstrom, 1994); however, its construct validity (i.e., how well the scale measures or correlates with the theorized scientific construct it was designed to measure) has been challenged and has not been objectively studied (Chen et al., 2017). Published literature evaluating the quality of the Braden Scale scores for measuring and quantifying PrI risk often focuses on criterion validity, though no gold standard reference for PrI risk exists (Kottner & Balzer, 2010; National Clinical Guideline Centre [NICE], 2014).

Earlier studies evaluating concurrent validity compare nurses' scores using Braden Scale with other PrI risk assessment scales (RASs), clinical judgement, and expert opinion, which are subjectively-based validated measurement methods. Thus far, validity testing of the Braden Scale constructs using this approach has not been done using robust objective measurement methods.

Evidence of the Braden Scale's predictive validity based on its diagnostic accuracy in predicting the outcome of PrI is commonly used to support its use in clinical practice. This evidence-based approach to validity examines the degree to which the scale's scores are related to performance on a criterion or gold standard assessment administered at some future point (Clemens et al., 2018). The appropriateness of using PrI occurrence as the reference standard for assessing whether its scores accurately indicate presence or absence of PrI risk has generated much debate concerning measurement methods and error. Research focused on this approach is limited because the 'truth' of PrI risk cannot be observed and measurement error may occur as long as the effect of preventive interventions are not taken into account (Kottner & Balzer, 2010). Measures of PrI risk factors identified from Braden Scale assessment and the effectiveness and appropriateness of preventive interventions based on those measured risks are hypothesized factors that should theoretically be able to predict an outcome of PrI. However, PrI development is a multifactorial phenomenon; "true risk is both pervasive and elusive" (Cox, 2017, p. 30). The Braden Scale's clinical utility and effectiveness for measuring PrI risk should therefore be assessed as a screening tool, for which it was developed (Braden, 2012), to aid staff in rationally deploying interventions aimed at PrI prevention that are prescribed according to the level of risk exhibited by individuals (Braden & Bergstrom, 1989).

Inconclusive evidence and a lack of high-quality studies to show use of a risk assessment makes any difference in the prevention of PrIs (Moore & Patton, 2019), despite decades of empirical and theoretically grounded evidence linking risk, raises questions about how the Braden Scale's validity has been studied. The validity of Braden Scale assessment scores and their relationship with PrI prevention cannot be determined without first understanding the validity of the Braden subscale constructs in measuring individuals' susceptibility to known PrI risk factors. A first step to examining the construct validity of Braden Scale's Mobility and Activity subscales is to assess the degree to which these measures of activity and mobility converge with objective measures of movement, which is thought to reduce the intensity and duration of pressure on body tissues. Technology, such as the triaxial accelerometers used to collect NH resident movement data in the larger study 1R01NR016001 (Turn Everyone And Move for Ulcer Prevention (TEAM-UP) embedded pragmatic cluster randomized controlled trial), offers the potential for objective analysis of how movement data compare with the Braden Scale assessment results to address this knowledge gap.

Significance

Structured risk assessment using a validated tool is a key component of standardized PrI prevention protocols aimed at improving nursing compliance with best practice guidelines. Pressure injury research informs practice guidelines that drive nursing care processes and impact patient outcomes; furthermore, research shows that use of evidence-based practice guidelines can lead to decreased incidence of PrIs (Lyder & Ayello, 2008; Kwong et al, 2011; Padula et al., 2016). A connection between structure, process, and outcome described in Donabedian's (1988) triadic model (structure + process = outcome) for assessing care quality and guiding improvement efforts in health organizations is reflected in agency endorsements and policies related to PrI research, regulation, and health coverage payments. Understanding the triad connection between structured risk assessment, preventive care practices, and PrI development provides insight into how Braden Scale's validity has been previously examined and where research opportunities exist to expand and strengthen evidence regarding its value as tool that facilitates nursing staff in assessing PrI risk and informs PrI prevention care planning.

Risk assessment is important for identifying individuals vulnerable to PrI, specific PrI risk factors, and the potential severity of those risks. Valid measures from assessment of PrI factors in risk assessment subscales are essential to help nurses appropriately plan customized care, prioritize tasks, and deploy available resources that address identified risk factors. The complexity of PrIs is reflected in the hundreds of PrI risk factors studied and over 40 different assessment tools developed to address needs of specific populations and settings of care in which PrIs occur (Thompson, 2005; Pancorbo-Hidalgo et al., 2006). The Braden Scale was the first risk assessment scale developed that is supported by a theoretical framework, expert opinion, and empirical evidence (Braden & Bergstrom, 1987), which continues to validate Braden Scale's subscale constructs as significant factors in PrI etiology and prevention. It is considered as having "optimal validation" and balance between sensitivity and specificity compared to other commonly used and studied PrI risk assessment scales (Pancorbo-Hidalgo, 2006, p. 97). The Braden Scale's validity has been judged primarily on findings regarding its predictive validity. Research focuses on the degree to which Braden Scale scoring predicts future PrI development, rather than the degree to which the tool accurately measures risk factors represented in its subscales designed to inform nursing care interventions (EPUAP et al., 2019). This approach to understanding how well the Braden Scale measures obtained from nursing assessments reflect PrI risk is misguided for assessing its accuracy for a couple of reasons.

First, the purpose of the Braden Scale is not to predict a PrI outcome. Its name is a misnomer in that it suggests the scale is for "predicting pressure sore (now referred to as PrI) risk" (Bergstrom et al, 1987, p. 205). The primary uses of the Braden Scale in the care of NH residents are as a screening tool to determine a resident's overall risk for PrI development and to estimate the severity of six risk factors for the purpose of guiding care planning (Kennerly et al., 2015). Braden Scale's performance should be evaluated against a standard criterion for risk prediction that can validate the presence or absence of *risk*, but none exists (Kottner & Balzer, 2010). It has been interpreted by some as a prognostic tool for predicting something related and measurable, i.e., PrI absence or presence, instead of as a screening tool for identifying individuals at-risk of PrI etiological factors that might benefit from preventative care interventions to avoid or reduce consequences from those factors, i.e. progression of PrI development.

Second, care initiated for preventing or treating PrIs, while based on the Braden score, may alter the Braden Scale's predictive performance (e.g., sensitivity and specificity) and effects on outcome and predictor variables (e.g., PrIs and Braden Scale scores) are not known. There is also uncertainty of the effectiveness of interventions in relation to PrI prevention and treatment (Atkinson & Cullum, 2017). It is unethical to withhold preventive care and treatment from individuals needing it, so effectively testing the impact of interventions on PrI risk assessment scoring and PrI development is not feasible.

In summary, structured risk assessment using the Braden Scale is an essential part of PrI prevention, but is not a care process for addressing risks that by itself can prevent PrI development. The Braden Scale is a screening tool used to measure a NH resident's degree of functional impairment and care dependency (Kottner & Balzer, 2010) regarding six risk factors in PrI etiology within its subscales and determine overall risk (severe, high, moderate, mild) for developing a PrI, though there are many other factors that influence PrI development (Halfens, 2000). There is no standard validation criterion for predicting risk; thus, the Braden Scale's validity has primarily been judged and studied based on its prognostic accuracy in predicting a PrI outcome. This approach is not congruent with the tool's design and intended use or compatible with testing in clinical practice situations. Though the constructs of risk represented in the Braden Scale's subscales are validated factors in PrI etiology supported by expert opinion and empirical and theoretical evidence, the convergent construct validity of the subscales has not been adequately examined using objective measurement criterion available.

The practical and clinical significance of the Braden Scale in PrI prevention is not rooted in its predictive validity, rather its subscales' construct validity in guiding accurate measurement of risk factors for planning effective preventative care. The problem associated with existing research on the Braden Scale's validity is that clear connections between constructs of PrI risk assessed in Braden Scale subscale measures and the clinical outcome of PrI cannot be made without accounting for prevention and treatment processes. Structured Braden Scale risk assessment is not directly linked to PrI outcome. Valid measures of PrI risk constructs enhance the validity of risk assessment, which can inform appropriate care intervention processes to achieving desired outcomes (e.g., PrI prevention through care targeted at reducing risk). Targeting interventions to individuals at greatest risk will help reduce PrI incidence and healthcare costs associated with the prevention and treatment of PrIs while conserving resources, so NHs can continue to meet the needs of dependent residents requiring long-term care as aging populations grow.

This proposed study will examine the convergent construct validity of the Braden Scale Mobility and Activity subscales using Braden Scale scores from nursing assessments and movement data of NH residents. International guidelines recommend that PrI screening should "always include risk factors, such as mobility or activity limitations and measures of impaired skin status (especially the presence of a Category/Stage 1 pressure injury) that directly indicate a currently increased and/or insufficiently tolerated exposure toward mechanical loads, and are supported by a high level of evidence" (EPUAP et al., 2109, p. 59). Mobility, activity, and sensory perception are PrI risk factors highly prevalent in older adult NH residents assessed in the Braden Scale's subscales that directly influence the body's response to pressure on skin and tissues. Repositioning and support surfaces are the most common interventions targeting PrI prevention in older adults receiving care in facilities, such as NHs, rehabilitation centers, and others that provide skilled nursing care (Mäki-Turja-Rostedt et al., 2019) aimed at reducing pressure on vulnerable areas of NH residents' bodies to prevent PrIs. Repositioning residents is a nursing intensive process tied to healthcare costs (e.g., time, effort, equipment, staff resources). Identification of a NH resident's level of activity and ability to engage in repositioning can help nursing staff determine the frequency and amount of assistance a resident will require in repositioning and can enable facilities to better target resources needed in care delivery efforts (Coleman et al., 2013). Findings from this study will enhance understanding of the scale's measurement accuracy in NH resident nursing assessment and will have practical and clinical significance to NH staff and health care organizations.

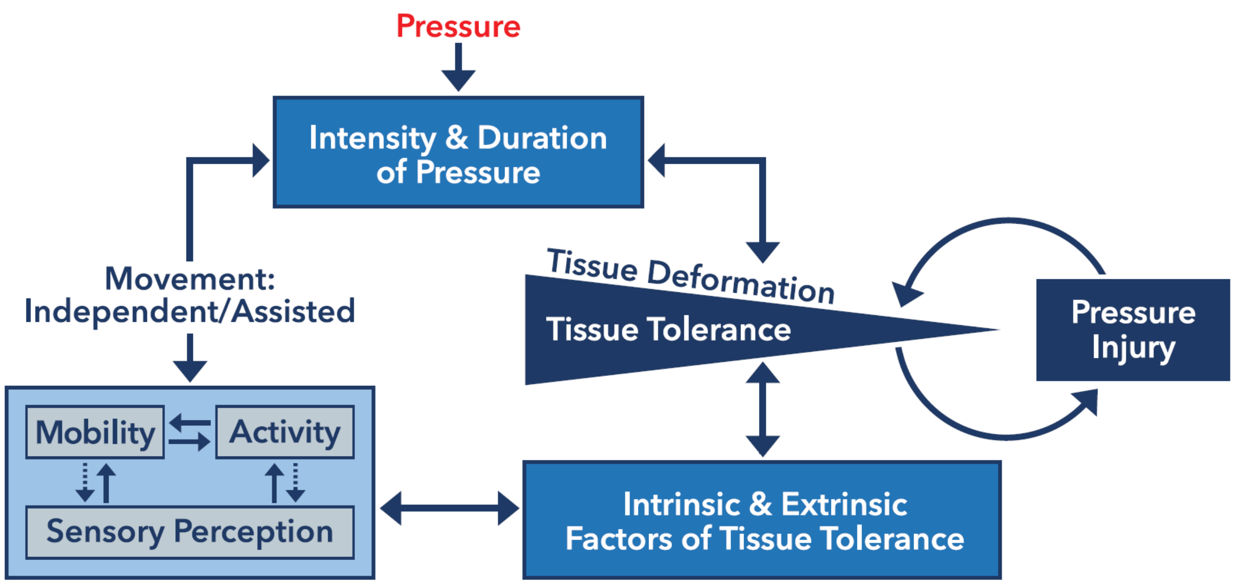
Theoretical Framework

Pressure injury is a phenomenon that has been observed in nursing practice for nearly two centuries and described by varied terms, including pressure sores, ulcers, and bedsores, and most recently internationally termed pressure injuries (EPUAP et al., 2019). The foundational philosopher of modern nursing Florence Nightingale (1859) noted if a patient "has a bed-sore, it is generally not the fault of the disease, but of the nursing" (p. 6). Pressure injury etiology and the relationship between nursing care and the PrI development are not well understood; PrI are often deemed to be related to poor care quality and remain central components in current safety and quality efforts that measure, evaluate, and improve nursing practice (Montalvo, 2007). Early studies of PrI development reported in the 1940s and the creation of a PrI risk assessment tool (Norton et al., 1962) for use in clinical practice underscored the significance of PrI occurrence. Braden and Bergstrom (1987) were the first researchers to develop a framework delineating the components of PrI development. These concepts and relationships proposed by Braden and Bergstrom are operationalized and measured as subscale constructs in the Braden Scale (1988), a widely used PrI risk assessment scale in nursing practice, and generated much research related to PrI since the development of this theory. Braden and Bergstrom's (1987) efforts advanced understanding of PrIs by organizing and examining existing knowledge and identifying knowledge gaps and directions for further research about the etiology, prevention, and treatment of PrIs. The resulting conceptual model for the study of PrI etiology evolved from the theoretical perspective and frame of reference based on their ideas about the origins of PrIs drawn from the literature, clinical practice observations, and inductive reasoning. The theoretical concepts Braden and Bergstrom describe are limited in number and scope and have the ability to vary in their characteristics, which makes the theory testable, yet sufficiently general to be scientifically interesting (Walker & Avant, 2011). Additionally, the broad categories that help to conceptualize and organize the current knowledge and hypothesized relationships are capable of organizing new findings.

The Braden Scale's Mobility and Activity subscales provide the key conceptual focus for investigation of resident movement in and out of bed in the NH setting. The theoretical basis for exploring the dynamic interaction of mobility and activity as factors with potential for reducing pressure intensity and duration is grounded in the framework behind the Braden Scale. Braden and Bergstrom (1987) identify two key concepts as "critical determinants" in PrI development: "(1) intensity and duration of pressure and (2) the tolerance of skin and its supporting structure for pressure" (p.8). Risk dimensions of mobility, activity, and sensory perception are etiological factors considered to influence the skin and exposure of its supporting structures to pressure. These dimensions interact with intrinsic and extrinsic factors influencing tissue tolerance for pressure to determine how and when PrI occurs. Braden and Bergstrom's observations, ideas, concepts, propositions, and assumptions about PrI etiology describe the building blocks of the theory underpinning the Braden Scale and provide the conceptual framework guiding this research study. Figure 1— Conceptual Model for Movement Contribution in the Etiology of Pressure Injuries guiding this study depicts the subconcepts of pressure, the relationships among them, and their contribution to movement in the etiology of PrIs. Intensity and duration of pressure interacts with tissue tolerance to play a central role in whether tissue deformation occurs. This model builds on Braden and Bergstrom's (1987) explanation of how altered mobility, activity, and sensory perception *directly* influence the intensity and duration of pressure in PrI development, while extrinsic and intrinsic factors of tissue tolerance *indirectly* relate to the intensity and duration of pressure in PrI development. Intensity and duration are moderators of pressure that can affect the strength of the relationships between the predictor variables (e.g., factors contributing to pressure) and the criterion variable (e.g., PrI development). More specifically, intensity and duration of pressure moderate the relationship between tissue tolerance and movement that determine whether pressure on tissue results in a PrI outcome.

Figure 1

Conceptual Model for Movement Contribution in the Etiology of Pressure Injuries



Conceptual Framework

External pressure exerts force on skin and tissue. The amount of deformation the tissue experiences is determined by the intensity and duration of the pressure applied to the surface of the skin and underlying tissues and the tolerance of the tissue for pressure. Intrinsic and extrinsic factors influence what magnitude and duration of pressure the tissue can tolerate before PrI occurs. Damage caused by PrI alters tissue tolerance and increases the likelihood of another PrI developing. Factors of tissue tolerance are associated with an individual's sensory perception, mobility, and activity, which influence the intensity and duration of pressure on tissues through independent or assisted movement. The degree, frequency, and duration of movement needed to relieve or remove pressure on tissues is guided by sensory-motor feedback. Information about an individual's pressure and movement changes is integrated by the body as sensory receptors with motor systems that manage the spatial orientation of the head, torso, and limbs communicate with the brain. Movement is a learned behavior through sensory feedback that provides input regarding the success of postural adjustments to gravity or performance of functional tasks (Convaid, 2016); thus, movement can indirectly affect intrinsic and extrinsic factors of tissue tolerance. For example, sacral discomfort sensed from sitting in a hard chair for a long period of time may prompt an individual to get up and walk to remove the pressure source being exerted on the sacrum. This physical activity increases oxygen delivery to the brain and tissues, which increases neuroplasticity, cognitive function, and tissue tolerance as an intrinsic factor (e.g., oxygenation).

The function of intensity and duration of pressure and tissue tolerance in PrI development pathway can be explored by studying the motor and sensory systems that receive, process, interpret, and respond to threats of or direct stimuli associated with the presence of pressure on tissues, such as acknowledgement of risk, repositioning cues, discomfort, and pain. Braden and Bergstrom (1987) describe mobility, activity, and sensory perception as the variable conditions within those systems that contribute to the intensity and duration of pressure through *movement* to avoid, remove, or reduce exposure skin and tissues to pressure. Mobility and activity directly affect movement through repositioning, including ambulating. Sensory perception affects the degree to which mobility and activity are performed and therefore, indirectly affects movement. The Braden Scale Mobility, Activity, and Sensory Perception subscales measure the contributions of these etiological factors to risk of PrI development and are associated with movement to minimize pressure. Examining the constructs of mobility and activity measured through different means (observation versus directly, human compared to machine) and exploring their associations with the construct of sensory perception in Braden Scale risk assessment measurement will deepen our understanding of these important aspects that influence the intensity and duration of pressure in PrI development.

Key Concepts, Definitions, and Relationships

Pressure, tissue tolerance, and movement comprise the key concepts influencing PrI development. The definitions and relationships between these key concepts and the subconcepts comprising them that will be examined in this study are discussed in the following sections.

Pressure

Pressure is conceptualized as someone or something that exerts a force on another person or object. Pressure is regarded to be a primary contributor to PrI development with pressure intensity and duration being crucial factors in PrI formation. Pressure intensity is the magnitude of force per unit of area. Pressure duration is the time during which pressure on the skin and tissue continues or lasts. Internal forces (stress) in the body between particles that make up skin and tissue react to the external forces applied on the system. As the intensity and duration of pressure increases, the force on skin and tissue cells causes them to change. Skin and underlying tissue in the affected area break down from the localized, acute ischemic deformation damage caused by the pressure.

Braden and Bergstrom (1987) theorize that exposure of the skin to intense and prolonged pressure will lead to PrI under any circumstances and that pressure is negatively associated with tissue tolerance. Animal studies (Brooks & Duncan, 1940; Husain, 1953) supported this thinking. Brooks and Duncan (1940) found the duration of pressure was more important than its amount when applying pressures sufficient to produce pathologic changes in tissues in experiments with rats. Groth (1942) and Kosiak (1959) identified an inverse relationship between intensity and duration of pressure. Reswick and Rogers (1976) depicted interface pressure and pressure duration as a hyperbolic curve in their "tissue tolerance guidelines" based on over 980 observations of breakdown at the skin surface of humans. Rogers' (1973) study underlying this pressure-time model also revealed a positive association between increasing time of pressure application and increasing differential temperature. The research aligned with Fisher et al.'s (1978) hypothesis that situations that increase skin temperature, increase tissue metabolism and make tissue more susceptible to ischemic injury described in Braden and Bergstrom's (1987) conceptual model. The etiological factors influencing pressure and tissue tolerance theorized to contribute to PrI development are supported in literature. However, some proposed relationships have been challenged and others have emerged as PrI science and research progressed. Researchers had been unable to identify the precise level of intensity and duration needed for PrI formation in animal studies (Daniel et al., 1981; Lindan, 1961; Nola & Vistnes, 1980) but agreed the relationship was parabolic curve. Contemporary bioengineering methods, such as small animal magnetic resonance imaging (MRI), open MRI, and computational modelling, can determine internal mechanical conditions in loaded muscle tissue in vivo, cell, and tissue culture models, animal models, and living humans and have opened new opportunities in PrI research and advanced efforts to characterize the injury tolerance of tissues to pressure (Gefen, 2009). Recent experimental data patterns in studies exploring the relationship between pressure intensity and duration appear to be more consistent with a sigmoid curve that defines a finite failure strength for muscle tissue at short times (Peeters et al., 2005; Stekelenburg et al., 2007; Linder-Ganz et al., 2006). This model may better explain why an immobilized patient undergoing lengthy surgery and subjected to high peak interface pressures does not develop a

PrI, while another patient with a shorter surgery does. Reswick and Rogers' (1976) curve is based on surface contact (interface) pressure data and does not include internal tissue load distributions, suggesting it is inadequate for studying deep tissue injuries (Gefen, 2009) and other PrIs where deformation is caused by internal tissue load distributions on the skin's supporting structures. The curvilinear nature of the relationship between the intensity and duration of pressure and multitude of factors associated with PrI development continue to present challenges for researchers attempting to define a critical magnitude above which ischemia occurs (Sprigle & Sonenblum, 2011). A more attainable goal for advancing knowledge on the critical determinant of pressure in PrI development may be to study key aspects that influence the intensity and duration pressure, which produce mechanical deformation or stress on the skin's surface or within the tissue.

Tissue Tolerance

Tissue tolerance denotes "the ability of both the skin and its supporting structures to endure the effects of pressure without adverse sequelae" (Braden & Bergstrom, 1987, p. 8). According to Braden and Bergstrom, tissue tolerance is influenced by categories of extrinsic and intrinsic factors. Extrinsic factors influence tissue tolerance from outside of the skin's surface and reflect the degree of moisture and/or to friction or shearing force exposure. Exposure to these primary or management-related external factors weakens the skin's epidermis barrier, decreasing tissue tolerance to pressure and making it more susceptible to breakdown. Intrinsic factors influence tissue tolerance from within the body. These secondary or patient condition-related internal factors, like age, nutrition, and arteriolar pressure, affect the architecture and integrity of the skin's supporting structures and/or the lymphatic and vascular system that serve the skin and underlying structures. Emotional stress, skin temperature, interstitial fluid flow, and smoking are examples of intrinsic factors hypothesized to be negatively associated with tissue tolerance in Braden and Bergstrom's (1987) model that were still in need of testing but whose relationships to PrI have since been studied and recognized in practice guidelines (EPUAP et al., 2019). Intrinsic and extrinsic factors adversely affect tissue tolerance for pressure and enable PrIs to develop at lower pressure intensity and shorter durations (Braden & Bergstrom, 1987).

Research has expanded knowledge on intrinsic and extrinsic factors of tissue tolerance in relation to PrI development (Sala et al., 2021; Kirkland-Kyhn et al., 2017). Structural equation modeling (SEM), a method that includes confirmatory factor analysis, path analysis, and latent growth modeling, has been used to test theoretical models in nursing studies, like Braden and Bergstrom's (1987) PrI etiology framework underpinning the Braden Scale, and found poor nutrition decreased activity (Chen et al., 2017) and tissue tolerance (Schumacher & Mueller, 2021). Multivariate modeling identified that immobility is strongly associated with urinary incontinence, malnutrition, and cognitive impairment (Lahmann et al., 2015). These studies and others suggest relationships among factors influencing tissue tolerance (e.g., moisture, nutrition) and factors contributing to pressure intensity and duration (e.g., mobility, activity, sensory perception) exist. The proposed Conceptual Model for Movement Contribution in the Etiology of Pressure Injuries (Figure 1) could be useful in guiding new studies using movement data to further explore how these factors identified as dimensions of risk in PrI development relate.

Movement

Movement is the act of changing position or physical location or having this change; this can be independent or assisted. Movement "occurs at multiple interacting levels along a continuum" from microscopic to an individual acting in society; each level is influenced by physical, psychological, social, and environmental factors (Allen, 2007, p. 889). This study's conceptual definition of movement refers to the individual level and embodies the relationship between the factors that affect PrI development in the individual, specifically mobility and activity.

Pressure injury can occur anywhere along the movement continuum depending on the interaction of physical, psychological, social, and environmental factors. For instance, elderly individuals with musculoskeletal disease and dementia may be hypoactive and immobile or may experience frequent agitated, uncontrolled, and non-purposeful movements – both of which can increase the intensity and duration of pressure on delicate tissue and result in PrI through either too little or too much movement (Budri et al., 2020).

Pressure injury development or prevention is influenced by the degree, duration, frequency, timing, and type of position or location changes in relation to a pressure source. Appropriately functioning motor and sensory systems enable individuals to move or seek assistance with moving to avoid, remove, or reduce exposure to an unpleasant stimulus, such as discomfort that may occur when pressure is applied to non-weight bearing areas of the body. Movement is a multidimensional concept. Movement in an individual is governed largely by functions of and between the motor and sensory systems. For example, increasing pressure stimulates receptors in the skin that transfer this stimulus via nerves to the spinal cord and then the brain. Individuals with neurological or physical impairments may not be able to feel (sense) or interpret (perceive) pressure on the skin or be capable of moving or asking for help to do so in response to this stimulus. In this case, the skin and tissue cells will remain under pressure. Over time, the external force applied to cells in the affected area causes them to change in response to the increasing intensity of pressure, leading to PrI. An individual with intact sensory perception is cued to reposition, which redistributes pressure within the body; remove the pressure source causing discomfort by moving away from it; or seek assistance from another person or device with those tasks. The degree and frequency of movement needed to relieve pressure is guided by sensory, activity, and mobility feedback loops. For instance, a change in body position that does not provide relief of pain may trigger more active movement, like standing or walking, to remove the pressure source on the skin and tissues. If movement is unsustained or inadequate, the pressure is only temporarily relieved and the risk for PrI remains. Over time, deformation of the skin will occur in response to this stress. Damage caused by PrI alters the tolerance of skin and tissue to pressure and increases the likelihood of another PrI developing. Other internal and external factors to the individual will also contribute to the ability to respond effectively to pressure stimuli, such as an individual's desire to move and to access assistive equipment in their living environment.

Movement or a lack of movement can influence conditions that expose tissues to intense or prolonged pressure. Braden and Bergstrom (1987) theorized conditions contributing to the intensity and duration of pressure in PrI etiology are bound within the subconcepts of mobility, activity, and sensory perception. Mobility is conceptualized as the "ability to change and control body position" (p.8). Activity is an individual's ability to release pressure from or "avoid intense and prolonged pressure over vulnerable skin areas" (p.8); skin areas that are not normally weight-bearing should be avoided. Sensory perception is the "ability to perceive or respond to discomfort by changing position or requesting assistance to change position" (p. 9). Decreases in mobility, activity, and sensory perception increase likelihood of exposure of the skin and its supporting structures to prolonged and intense pressure, and subsequent PrI development. Braden and Bergstrom (1987) describe positive associations among mobility, activity, and sensory perception that have been empirically tested and validated, such as the tendency for diminished activity to be associated with reduced mobility that further lessens the occurrence of activity. Similarly, Chen et al. (2017) found a relationship of low activity to limited mobility when using a structural equation modeling approach was used to investigate the Braden Scale's construct validity. Evidence has validated mobility, activity, and sensory perception as important factors in PrI development. Validity, however, is not a static concept. Conceptual and operational re-examination of how mobility, activity, and sensory constructs are defined and measured as well as interact in relation to pressure intensity and duration must be conducted as new technology, research, and analytics become available. Wearable accelerometers that measure, record, and analyze movement of individuals provides one such opportunity.

Research on movement of NH residents can enhance knowledge of PrI development in older high-risk populations where declines in motor and sensory function are commonly experienced with aging. Relationships among sensory perception, mobility, and activity result in movements (or no movements) that influence the intensity and duration of pressure on tissues in the etiology of PrI will be explored in this study. Mobility will be conceptually defined as the capacity, act, or state of moving while lying or reclining in bed or chair. Activity is the capacity, act, or state of getting up and moving around out of bed or in a wheelchair. Mobility and activity are functions of the motor system that is responsible for voluntary and involuntary movement. Sensory perception is the capability, act, or state of neurophysiological and neuropsychological processing of and responding to stimuli in one's environment. Sensory perception is a function of the sensory system that guides the planning, initiation, and modification of motor functions, like mobility and activity. Motor function is required for movement, while sensory function indirectly drives movement. Thus, this study primarily focuses on the relationship between measures of mobility and activity as motor functions directly influencing movement.

Additionally, the association of Braden Scale risk assessments of mobility and activity with sensory perception will be explored to better understand sensorimotor function measurement of NH residents in PrI prevention.

Braden and Bergstrom's (1987) theory underpinning the Braden Scale Mobility and Activity subscales provides a broad lens for examining mobility and activity in relation to pressure intensity and duration in PrI etiology. Mobility and activity are conceptually distinct subconcepts but have been used interchangeably in the literature to denote how much, how long, how often, or how capable an individual is of moving. The Braden Scale (1988) operationalizes and describes attributes of the mobility and activity constructs within the context of the degree, frequency, or duration their defining characteristics are observed to assess levels of risk for PrI development. Most clinical studies in the literature assess mobility and activity subjectively through direct observation and use of standardized risk assessment tools. Various instruments now exist for objectively measuring mobility and activity of humans but are more expensive and require specialized equipment or training to operate or analyze the results. This may limit their utility in clinical practice but not research. Individuals are living longer with more comorbidities that can negatively affect physical, cognitive, and sensory function that promotes effective movement and place them at greater risk for PrI. Studies investigating how factors influencing motor and sensory systems in older populations are measured, relate, and contribute to PrI development can help nurses better identify individuals that need assistance to move and guide customization of interventions that promote effective movements for reducing pressure on tissues and preventing PrI based on individual needs.

Purpose Statement

The purpose of this study is to examine the convergent construct validity of the Braden Scale's Mobility and Activity subscales using secondary analysis of nursing staff assessments and NH resident movement data from a wireless patient monitoring system collected in nine U.S. NHs facilities during implementation of the 1R01NR016001 TEAM-UP cluster randomized control trial focused on PrI prevention related to repositioning frequency.

Specific Aims and Research Questions

This retrospective non-experimental study will examine the Braden Scale's Mobility and Activity subscales' convergent construct validity in relationship to NH resident movements. The specific aims and research questions are:

Aim 1: Determine how Braden Scale Mobility and Activity subscale scores from nursing staff's risk assessment of NH residents correspond to resident movement data collected via triaxial accelerometer.

Research Question 1: What is the relationship between Braden Scale Mobility and Activity subscale scores and movement data in NH residents?

Exploratory Aim: Explore the interrelatedness of Braden Scale Sensory Perception, Mobility, and Activity subscale scores from nursing staff's risk assessment of NH residents as these independent variables relate to resident movement data.

Research Question 2: What are the associations between Braden Scale Sensory Perception, Mobility, and Activity subscale scores individually and their interaction effects as predictors for the movement outcome variables?

Assumptions and Delimitations

Movement, assisted or independent, is assumed to be a primary contributing factor of pressure intensity and pressure duration in PrI formation. Mobility, activity, and sensory perception are conceptualized as factors that are influenced by movement.

The following are delimitations of the study:

Research design: The retrospective, non-experimental design used existing data originally collected during the TEAM-UP intervention trial that contains variables appropriate for answering the research questions in this study.

Time of the data collection: The primary data were recently collected over an observation period of four weeks during the TEAM-UP intervention trial from 2016 through 2021.

Location of the study: Secondary data used in this analysis were drawn from nine nursing homes located in five states in eastern and central regions of the United States of America.

Sample of the study: The study sample, a convenience sample drawn from the TEAM-UP trial, was examined during data preparation to determine an appropriate sample for answering the research questions. All residents were included in the sample who had full days (at least 22 hours) of movement data and at least one Braden Scale score at the beginning of the TEAM-UP trial intervention start. These inclusion requirements resulted in an effective sample size of N = 562 with adequate power for analyses.

CHAPTER 2: REVIEW OF LITERATURE

The intention of this literature review is to explore the state of evidence as it relates to Braden Scale validity studies, mobility and activity for PrI prevention in older adults, and accelerometry validity as the criterion measurement standard for examining the convergent construct validity of the Braden Scale Mobility and Activity subscales in this study.

Electronic review of the literature was conducted using multiple databases including Cumulative Index for Nursing and Allied Health Literature (CINAHL), PubMed (New), Cochrane Database of Systematic Reviews, Ovid MEDLINE, and Scopus. Google Scholar, Grey literature, government reports, research in progress, and practice guidelines were searched electronically. Review of cited works was performed manually to identify pertinent sources. Combinations of key terms, advanced title search features, and Librarian Liaison consultation was used to develop and refine search strategies. Articles were limited to English language and human studies. No limitations for publication date were applied to the search to identify all relevant articles, show the temporal progression of the research, and minimize bias.

Braden Scale Validity: An Overview of Study Designs

A review of the literature was conducted to better understand the quality of research on the validity of the Braden Scale for Predicting Pressure Sore Risk© (Braden Scale) by exploring the methodological designs used to assess this measurement concept. The aim of this literature review is to describe how Braden Scale's validity has been previously studied, synthesize patterns in knowledge, and identify gaps and weaknesses in evidence to inform future research. Articles retrieved from peer reviewed journals were those whose title contained the keywords "Braden Scale" and "validity". This resulted in review of qualitative, mixed methods, and quantitative studies published from 1987 (the Braden Scale's origination) to 2021 (present day) across multiple journals, mostly the nursing discipline.

Review of the literature reveals the majority of validity studies regarding the Braden Scale are observational, prospective, cohort study designs using primary data obtained from nursing or researcher observations of a variety of patient populations in diverse care settings, though individuals receiving acute care are the most studied. Secondary data sources used include observation data from electronic medical records (EMRs), nationwide PrI prevalence studies, and previous study databases. Sampling methods are generally by convenience with a wide range of sample sizes (45 to 7790 subjects) reported. Data collection methods and frequency vary depending on the research design. Inter-rater reliability is reported most frequently along with validity, though reliability measures are not always assessed. Publications use translation-related and criterion-related construct validation methods to examine Braden Scale's content, predictive, concurrent, convergent, and known-groups validity. Most studies report Braden Scale's predictive validity, specifically accuracy in predicting a PrI outcome, as a measure of its clinical effectiveness as a risk assessment tool (Wilchesky & Lungo, 2015). Braden Scale's concurrent and convergent construct validity is typically examined using other risk assessment scales, such as modifications of the Braden Scale, Norton Scale, Waterlow Scale, Douglas Scale, and Cubbin and Jackson (Seongsook et al., 2004), and structural equation modeling (SEM) using Braden Scale total and subscale scores (Chen et al., 2017; Schumacher & Mueller, 2021). Only one study using actigraphy to explore the construct validity of the Braden Scale Mobility subscale (Powers et al., 2004) provided an objective measure for assessing convergent validity. Known-groups validity studies evaluate performance between risk level groups defined with the Braden Scale as well as different groups determined by study researchers. Statistical analysis techniques like factor loadings using SEM, analysis of variance (ANOVA) and Duncan multiple-range tests are used to determine if differences between two groups were significant. The most frequently reported measures of Braden Scale's validity are sensitivity, specificity, positive and negative predictive values, receiver operating curve, and area under the curve; though, negative and positive likelihood ratios, Youden Index, and standard error of measurement are also used to assess the accuracy of Braden Scale measures. Braden Scale's performance on validity measures varies depending on the study population and total score cut-off points used (9 to 26). Heterogeneity in methods, settings, and populations studied and different cut-off values used contributes to reported variation in the Braden Scale's psychometric performance and inconsistent conclusions about its validity in the literature. Recent meta-analysis studies synthesizing research on the Braden Scale's validity support the findings of this review (Huang et al., 2021; Wilchesky & Lungo, 2015; Park & Park, 2014).

Braden Scale validity research appears to be steady and flux with healthcare event timelines, such as the Institute of Medicine's report on safety issues (1990s), passage of federal standards (Omnibus Reconciliation Act of 1987), and development of other measurement instruments (Minimum Data Set in 1991, risk assessment scales) and care guidelines (AHRQ, EPUAP). Technology, like EMRs mandated by 2014 and new analytical techniques (SEM) may play a role in the increased number of studies published on this topic around 2017. A shift in publications of systematic reviews and meta-analyses in the last decade could contribute to the wane in recent primary studies testing the Braden Scale's validity in literature.

This review of research designs used to study the validity of the Braden Scale identifies multiple gaps in the state of the science. Many Braden Scale studies do not report both reliability and validity, two salient characteristics of any measuring tool or method (Waltz et al., 2017). Use of PrI prevention strategies once risk has been identified alters the predictive ability of a PrI risk assessment scale (Defloor & Grypdonck, 2004; Halfens et al., 2000). Interventions used are seldom stated or measured in the studies and present challenges to examining the validity of the Braden Scale in clinical practice settings. There is a paucity of information pertaining to Braden Scale's validity within the LTC setting (Wilchesky & Lungo, 2015) and examining convergence with objective measures of its subscale constructs. High-quality experimental, qualitative, and mixed method designs on this topic are also lacking in the literature. Rigorous application of these types of research designs could help generate stronger, more holistic evidence to support or refute conclusions from existing observational studies examining the Braden Scale's validity.

Threats to internal, external, and construct validity related to research designs weaken conclusions drawn from previous studies examining the Braden Scale's validity. Temporal ambiguity with retrospective, cross-sectional and case study designs; uncertain temporal sequencing of independent and dependent variables affecting generalized causal inference in quantitative experimental and quasi-experimental designs; group composition effects resulting from pre-existing differences between groups; and confounding variables are threats to internal validity. Convenience sampling, such as the use of highly motivated volunteer nurses as raters, may have influenced the effect results. Interaction effects of sample selection biases and the dependent variable (e.g., PrI development), non-representative sampling, generalizability of findings from acute care to other settings, and replicability of results from single-site or single-country studies pose threats to external validity of findings from the literature. Linguistic bias may have occurred when translating the Braden Scale into other languages in predictive validity studies conducted in Brazil (Serpa et al., 2011) and the Czech Republic (Šateková et al., 2017; Šateková et al, 2015). Another threat to construct validity is the Hawthorne effect (reactivity of subjects to the study situation). Small sample sizes decrease statistical power, increasing the likelihood of a Type II error (Deziel, 2018) and decrease the trustworthiness of findings from studies with smaller samples. Low statistical power threatens statistical conclusion validity. Future studies designed to examine the Braden Scale's construct validity should implement strategies to address such threats.

Mobility and Activity for PrI Prevention in Older Adults

The aim of this integrative review was to ascertain state of the science on mobility and activity (key concepts) as they relate to older adults (target population) and PrI (healthcare problem). This review was carried out from the philosophical perspective and underpinned by Braden and Bergstrom (1987)'s conceptual model for the study of PrI etiology explaining mobility and activity's contributions to pressure duration and intensity. This framework is the basis for the Braden Scale commonly used to assess PrI risk in NHs. The search was guided by the conceptual and operational definitions for mobility and activity discussed in Braden and Bergstrom (1987)'s model. The search strategy used combinations of the key terms: older adults, mobility, activity, and PrI and their MeSH terms, Subject Headings, and related terms. Exclusion criteria included non-primary research, blast injury and spinal cord injury studies, prevalence reports, meeting summaries, education bulletins and theory development literature, and studies performed in home, community, surgery settings, or non-geriatric hospital wards.

The initial search revealed over a thousand qualitative and quantitative studies published between 1976 to 2021 that were further screened to identify relevant empirical studies for quality appraisal. Quantitative research methods are dominant and largely observational in design with more recent shifts toward experimental, quasi-experimental, and feasibility pilot studies reported. Data reduction and management using the Matrix Method (Garrard, 2017) and visual displays enabled discernable patterns and relationships to emerge in analysis: homogeneity of samples, sampling methods, and settings; and heterogeneity in variables and instruments used to measure activity and mobility. Data comparison showed the key concepts are studied as independent and dependent variables and secondary outcomes to PrI incidence. Authors link mobility and activity to PrI prevention, though the relationship is not substantiated in the PrI empirical evidence. Studies focus on measurement of and/or associations between themes of pressure: duration, intensity, injuries, risk factors, and prevention. Mobility and activity were studied as a single concept or as independent variables in risk assessment scales, primarily the Braden Scale. Validity concerns stemming from convenience sampling, poor methodological quality, causal inferences with cross-sectional designs, and conflicting evidence are raised within and across review of the literature.

The temporal progression of scientific inquiry denotes growth in the body of knowledge that builds upon previous studies, i.e., identifying PrI factors then understanding complex interactions between those factors and PrI development and prevention while incorporating new technological advancements to refine data measurement, collection and analysis of those factors and relationship. Early research on mobility, activity, and PrI in older adults described movement patterns that could be used to determine which NH residents would benefit from more frequent repositioning interventions (Schnelle et al., 1993). In the 1990s-2000s, research shifts to identifying individual characteristics contributing to PrI risk (Bergstrom et al., 1996; Gunningberg, 2005). An exploration of the construct validity of mobility, as measured by the Braden Scale, using actigraphy (Powers et al., 2004) supported theory-evidence-practice connections of PrI knowledge, but was limited by the subjectivity of nursing staff observation, small sample size, and device capabilities. Rather than continuing in this direction, studies focused on understanding associations among concepts in PrI etiology in wheelchair-bound adults (Mortenson et al., 2012), scale risk items (Lannering et al., 2016), and trends in nursing care problems in institutionalized elderly (Lahmann et al., 2015). Research centered on prevention practice improvements and gaining a more holistic view of the phenomenon by connecting mobility and activity as risk and protective factors interacting with other key determinants in PrI etiology, like tissue tolerance (Yap et al., 2015) and determining impact of and optimal repositioning-related education (de Oliveria Matos et al., 2016), intervention frequencies (Bergstrom et al., 2014), and protocol effectiveness on preventative care practice (Yilmazer et al, 2019) and reducing pressure on vulnerable tissue (Yoshikawa et al., 2015). Quasi- and experimental designs quantifying effects of repositioning, assessment, and customized interventions with NH residents in wheelchairs on pressure intensity and duration, functional activity, and mobility (Brienza et al., 2018; Zemp et al., 2019) strengthened conclusions in the science. Research of new instruments and monitoring technologies for detecting, classifying, and facilitating movement (Duvall et al, 2019; Yap et al., 2019; Budri et al., 2020) has informed algorithm development for detecting PrI risk in this population (Avsar et al., 2021) to enhance understanding of the relationship between mobility, activity, movement, and PrI development. More opportunity exists to incorporate objective measurement in studying mobility and activity constructs and address validity measurement concerns previously reported in PrI literature to advance science aimed at improving PrI prevention for older adults in NHs.

Accelerometry Validity for Mobility and Activity Measurement in the Elderly

A scoping review of the literature for the time period 1996 to 2021 was conducted to better understand use of triaxial accelerometry as a validated measure of mobility and activity in the elderly. Advantages and challenges with wearable sensor monitoring technology using accelerometers to quantify movement in older adult NH residents was explored in this review. The search strategy used combinations of the following keywords: accelerom*, valid*, elder*, mobility, activity, sensor. Selection focused on literature where the key or related terms (e.g. older adults, geriatric) were included in the article title or abstract.

Monitoring technology is growing field with promising applications to the long-term care of elderly people (Peetoom et al., 2015). Unobtrusive monitoring technology that has the ability to track human mobility and activity can potentially prolong independent living, increase elder well-being, and support care of aging adults in NHs by identifying movement characteristics that place them at greater risk for health issues, such as PrIs, incontinence, falls, and wandering (T'Jonck, et al, 2020). These pragmatic applications for healthcare have fostered widespread research on use of monitoring technologies, such as Passive Infrared, Pyroelectric, or IR (referred to as PIR) motion sensors, body-worn sensors, pressure sensors, sound recognition, and video monitoring (Peetoom et al., 2015). Pertinent aims and methodological features in literature include sensor placement evaluation, activity assessment while wearing sensors, concurrent and convergent validity with clinician observations and patient self-reports/diaries, predictive validity of quantitative evaluation of inertial-based parameters (e.g., gait characteristics, postural sway) for falls and death (Buckinx et al., 2015), development and validation of fall-risk models and activity-monitoring algorithms from movement parameters, quantification of physical frailty phenotypes (Zhou et al., 2019), and levels of mobility and activity and their association with physical function (Corcoran et al., 2016) examined in individuals with stroke-related deficits, chronic diseases (e.g., heart failure, chronic obstructive pulmonary disease), orthopedic surgeries (Lipperts et al., 2017) or amputations, and movement disorders (Parkinson's disease).

Limitations related to methodological designs with small-scale studies, few longitudinal studies, and causality in cross-sectional studies are potential threats to validity identified in the literature.

Direct measurement of human mobility and activity with motion sensors is considered a criterion standard and provides advantages over other alternatives, such as observational measures and self-report questionnaires or diaries (Kochersberger et al, 1996). Quantitative measures of mobility and activity collected from inertial sensors in small wearable devices can provide objective movement information about activities of daily life within real-world environments compared to measures subjectively obtained through simulated activities (e.g., questionnaires or functional assessments) used in clinical risk assessments (Howcroft et al., 2013). Accelerometers use electromechanical sensors to measure static or dynamic acceleration, enabling measurement of parameters along the continuum of movement for a more complete, timely, and accurate picture of the full spectrum of mobility and activity characteristics an individual demonstrates than might be collected from clinical assessment and self-reporting instruments. There is a large amount of growing scientific evidence to support the utility of wearable accelerometer devices for monitoring: (1) energy expenditure and physical activity, including new exploration of measuring mechanical loading related to activities of daily life; (2) the interactions between health-related outcomes and physical activity; and (3) cognitive performance, particularly in the elderly population (Teixeira et al., 2021).

Advantages of triaxial accelerometry over other body-worn sensors, like pedometers, include ability to differentiate between different activities based on intensity and plane of movement based on the three axes (Sumukadas et al., 2008). Use of triaxial accelerometer data to identify orientation and movement has been demonstrated (Lugade et al., 2014) and its importance in quantitatively assessing the functional level of impaired patients through accurate step count measurement among the general population (Fortune et al., 2014) are reported in literature. Challenges to using triaxial accelerometers for measuring mobility and activity of NH residents includes time for education and practice, cost, and comfort-level of residents and staff with e-Health technology. More development and implementation of cost-effective, simple-to-use technological methods of assessment that allow caregivers to make decisions aimed at preventing PrI development is still needed to effectively use real-time health data to improve NH resident self-care and interaction with health care staff (Patton et al., 2018).

Summary

Common themes within and across studies in these three literature reviews of the Braden Scale, mobility and activity, and accelerometry use in NH residents are the use of observational designs, convenience sampling, poor methodical quality, and conflicting results that raise questions about validity of findings. There is heterogeneity in variables, measurement, and definitions of central concepts (mobility, activity) in the existing literature that will be examined in this study of the convergent construct validity of the Mobility and Activity subscales used in NH resident Braden Scale PrI risk assessment with resident movement data from triaxial accelerometers. Despite shifts toward more experimental research designs and objective measurement of movement (mobility, activity) using new technologies in older adults as well as evidence supporting significant differences between PrI and non-PrI groups regarding mobility and activity measures, research examining the convergent construct validity of the Braden Scale continues to focus primarily on the instrument's performance compared to existing or newly developed PrI risk assessment scales. Measurements of mobility, activity, and spontaneous body movement are assessed using subscale items and based on visual observations and interactions of clinicians with individuals under their care (Kohta et al., 2021), rather than objective measurements from wearable sensor monitoring technology in this approach. Concerns regarding geriatric care and health issues are growing with the increases in the elderly population and demands on limited NH resources. New strategies in PrI prevention research that build upon current knowledge from studies of mobility and activity measurement using Braden Scale PrI risk assessment and accelerometry in NH residents will be needed to effectively identify individuals with functional declines that are at risk for PrI development using the resources and tools available in those settings.

CHAPTER 3: RESEARCH DESIGN AND METHODS

This chapter discusses the study's methodology for examining convergent construct validity of the Braden Scale's Mobility and Activity subscales. The purpose of this chapter is to outline the design and methods for answering the study's research questions (RQs):

- **RQ1:** What is the relationship between Braden Scale Mobility and Activity subscale scores and movement data in NH residents?
- **RQ2**: What are the associations between Braden Scale Sensory Perception, Mobility, and Activity subscale scores individually and their interaction effects as predictors for the movement outcome variables?

Research Design

This study used a retrospective non-experimental design to assess the convergent construct validity of the Braden Scale Mobility and Activity subscales using secondary analysis of NH resident movement data from a wireless patient monitoring system and nursing staff assessments collected during the cluster randomized trial 1R01NR016001 TEAM-UP conducted in nine U.S NHs from 2016-2021 (Yap et al., 2022). Secondary data for this study included NH resident demographics (age, gender, race, and ethnicity), nursing staff Braden Scale total scores and subscale risk assessment scores, and triaxial accelerometer movement data (ambulating frequency (how many times in the ambulating position in a day), ambulating durations (how many minutes in the ambulating position per day), and body position frequency and durations) from nine NH facilities randomly assigned a NH-wide 2-, 3-, or 4-hour repositioning interval as standard of care during the larger trial's 4-week intervention period. Selection of key study variables were guided by Bergstrom and Braden's (1987) conceptual model for studying PrI etiology explaining the contributions of mobility, activity, and sensory perception to pressure duration and intensity that impact PrI risk. The TEAM-UP data set contains variables appropriate for addressing the research questions about the convergent validity of Braden Scale's Mobility and Activity theoretical constructs.

The Braden Scale and accelerometers have been used to subjectively and objectively measure characteristics of mobility and activity via nursing observations and motion sensors, respectively. A quantitative approach comparing measures of mobility and activity obtained from two different methods was taken to examine the convergent construct validity of Braden Scale's Mobility and Activity subscales and determine the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences about the Mobility and Activity subscale scores' "meaning or interpretation and about the implications for action that the interpretation entails" (Messick, 1989, p.13). Secondary data collected during the TEAM-UP trial implementation were used to assess the convergent construct validity of the Braden Scale's Mobility and Activity subscales by measuring agreement of Braden Scale assessment scores and resident movement data. "Convergent validity takes two measures that are supposed to be measuring the same construct and shows they are related" (Glen, 2015, para. 1). Testing convergent validity by using two different measurement procedures and research methods (e.g., nurse observation and accelerometer monitoring) in data collection about constructs (e.g., mobility and activity) helps to establish construct validity.

Further, how the Braden Scale Mobility and Activity subscales interface with the Sensory Perception subscale ratings was examined. This study described the nature of mobility and activity concepts in NH residents in relation to sensory perception and determined if significant differences exist in mobility and activity as measured using the Braden Scale and triaxial accelerometers.

Setting

A convenience sample of NH residents (N = 913) from nine Medicare and Medicaid certified skilled nursing facilities in the United States that are clinical sites for the TEAM-UP trial was used. The facilities ranged from 126 – 238 operating beds, offered long-stay and short-stay care, and were located in five different states across central and eastern U.S. regions. The effective sample size drawn from these nine NHs was determined to be N = 562 (refer to Population and Sample) to ensure alignment of Braden Scale scores with movement data in the planned analyses for addressing the study RQs.

Population and Sample

Adult NH residents (> 18 years) that participated in the TEAM-UP clinical trial at the selected NH facilities and had at least one complete Braden Scale assessment documented while wearing a triaxial accelerometer were eligible for this secondary data analysis study. Using an intention-to-treat approach, residents who were discharged, died, or withdrew after the Braden Scale assessment at intervention start were included in data analyses if the resident has ≥ 1 day of 22 hours of movement monitoring data (N = 913). Residents being cared for on a non-viscoelastic (VE) specialty surface or those with adhesive allergies, baseline PrIs, 'no turn' orders, or a Braden score <=9 (severe risk) were excluded from the TEAM-UP trial (estimated at < 10%) and not included in this study. Nursing home residents with full days (at least 22 hours) of movement data were the convenience sample (N = 913) available for analysis in this study of the convergent construct validity of the Braden Scale Mobility and Activity subscales using accelerometry. Sample size estimation and power analyses were used to identify a minimum required sample size to effectively compare different measures of resident mobility and activity in NHs. In a real setting, the parameter of a variable in a targeted population is usually unknown

(Bujang, 2021). Therefore, preliminary analyses were conducted to improve the data consistency and facilitate data analyses, and test and confirm effect sizes for the NH resident measures of interest relative to the study aims.

This study's primary aim was to determine how Braden Scale Mobility and Activity subscale scores from nursing risk assessment of NH residents corresponded to resident movement data collected via triaxial accelerometer. Data preparation for answering the RQ of this aim involved preliminary analyses using available summary statistics from the convenience sample (N = 913 NH residents) to determine if population parameters of interest were adequate for measuring statistically and clinically significant differences between Braden Scale mobility and activity construct measurements and movement data. These analyses determined that consistent representation of the variables of interest would be achieved in an effective sample size of N = 562 NH residents by including all residents who had full days (at least 22 hours) of movement data and at least one Braden Scale score at the beginning of the TEAM-UP trial intervention.

Recruitment

Nursing home residents were not recruited for participation in any portion of this secondary analysis. In TEAM-UP, any resident at intervention start was eligible for participation based on the inclusion/exclusion criteria described above. Residents who were newly admitted to the respective NH after intervention start and who met study criteria were eligible for participation.

Ethical Considerations

A waiver of Health Insurance Portability and Accountability Act (HIPAA) authorization and informed consent was obtained from the Duke University Institutional Review Board (IRB) for the minimal risk EMR and Minimum Data Set (MDS) data extraction performed and movement data gathered for NH residents in the TEAM-UP study.

All residents were adults in the selected NHs and received NH standard care for PrI prevention. Both women and minorities were included in the study population. To protect personal health information (PHI), the NH corporate data manager generated a study identification (ID) number for each NH resident participating in the TEAM-UP study intervention based on medical record number (MRN) replacing it with the corresponding study ID and was responsible for secure storage of study IDs. The corporate data manager extracted and securely transferred EMR and MDS HIPAA-compliant data sets to the TEAM-UP research team. Duke University IRB approved (Reference ID: 314432) adding the East Carolina University (ECU) student investigator of this secondary data analysis study as part of Key Personnel to the TEAM-UP protocol (Protocol ID: Pro00069413). The student's institutional IRB deferred to the Duke University IRB for review and approval under existing Inter-Institutional Agreement and Data Transfer Agreement.

Measures

Nursing home resident Braden Scale and movement data measurements collected in the TEAM-UP trial (Yap et al., 2018; Yap et al., 2022) were used in this secondary data analysis study. Details on the measures, instruments, periods, sources, and performance characteristics for each variable are described below. Concepts measured in this study were comprised of the Braden Scale for Predicting Pressure Sore Risk© (Braden & Bergstrom, 1988) subscales and developed from NH resident movement data collected in the TEAM-UP trial (Yap et al., 2018; Yap et al., 2022).

Braden Scale for Predicting Pressure Sore Risk©

Braden Scale total and subscale score measures collected from weekly nursing assessment documentation of each NH resident participating in the TEAM-UP (Yap et al., 2018) trial's 4-week intervention period were extracted from EMR data. The first Braden assessment score of all Braden assessment scores documented in the EMR for each resident during the TEAM-UP intervention were used for this study. The validity and reliability of the Braden Scale for Predicting Pressure Sore Risk© (Bergstrom et al., 1987) has been tested in a variety of settings and patient populations. This scale is meant to be completed by nursing staff familiar with the resident's physical and functional abilities (Kring, 2007) who use the subscale score descriptors to rate six mutually exclusive PrI risk dimensions: mobility, activity, sensory perception, moisture, nutrition, and friction/shear. Five of the six PrI risk dimensions defined in the Braden Scale subscales are scored 1 to 4 based on descriptors of the level of severity include the following:

- "Sensory perception, ability to respond meaningfully to pressure-related discomfort
- Moisture, degree to which skin is exposed to moisture
- Activity, degree of physical activity
- Mobility, ability to change and control body position
- Nutrition, usual food intake pattern" (Braden & Bergstrom, 1994, pp.460-461)

Friction and shear, the Braden Scale's sixth PrI risk dimension, is described as a problem, potential problem, or no apparent problem, and is scored from 1 to 3, respectively (Braden & Bergstrom, 1994). The subscale scores are summed to produce an overall risk score from 6 to 23; lower scores indicate higher risk for PrI development. The instrument is administered quickly (completed in as little as 1 minute) and interrater reliability established between research staff is $r = 0.95$ to 1.0 (Bergstrom et al., 1998). Kottner and Dassen (2008) found the intraclass correlation coefficients for Braden Scale sum scores ranged from 0.73 (95% CI 0.26-0.91) to 0.95 (95% CI 0.87-0.98); calculated intraclass correlation coefficients for individual items ranged from 0.06 (95% CI 0.31-0.48) to 0.97 (95% CI 0.93-0.99) with the lowest values being measured for the nutrition and sensory perception items. Braden Scale's sensitivity (79%), specificity (74%), and predictive value of a negative test (90%) at a score of 18 among NH residents have been reported (Bergstrom et al., 1998; Braden & Bergstrom, 1994).

The Braden Scale was used by licensed nurses designated by each NH administration to assess resident risk for PrIs at the TEAM-UP trial's intervention start and weekly thereafter for four weeks. Licensed nursing staff routinely receive standardized training on Braden Scale measurement that is provided by the NH's nurse educator staff:

- For the Braden Scale measurement of mobility, nurses were instructed to assess each resident's mobility in bed with consideration of the individual's motivation to change and sustain changes in position;
- For Braden Scale measurement of activity, nurses were instructed to assess each NH resident's frequency of ambulating; and
- For Braden Scale measurement of sensory perception, nurses were instructed to measure each NH resident's ability to perceive discomfort in a meaningful way whether by movement, communication, or some other action that alerts the caregiver.

Braden Scale sensory perception measurement involved testing at two levels - conscious state and cutaneous state; if the resident had impairment in both, the lower of possible categories was to be assigned.

Measures of levels of consciousness:

1. Completely (Coma);

2. Very limited;
3. Slightly limited;
4. No impairment.

Measures of level of cutaneous sensation:

1. Completely: in-sensate 100% of body;
2. Very: in-sensate ½ of body;
3. Slight: in-sensate 1 or 2 extremities; and
4. No impairment

Resident Movement

Resident movement was comprised of resident mobility (i.e., repositioning) history, including the time, body position orientation, and duration of repositioning while in bed or reclining in a chair, and resident activity history, including the time, body location orientation, number of steps, and duration of lying, sitting, and walking/propelling in a wheeled chair (wheeling) events while out of bed; movement data representing these repositioning events are collectively referred to in this study as movement parameters. Movement data were collected via a triaxial accelerometer personal sensor worn on the anterior chest by each NH resident during the TEAM-UP four-week intervention period and communicated through a wireless system to a patient monitoring (PM) system central server containing monitoring management software. Observational movement data collected from the time of NH resident entry into the intervention to the end of the intervention (up to 4 weeks) was used in this study.

The PM system's wireless sensor has demonstrated validity as a measure of active and passive movement (repositioning) in bench testing and clinical trials with a sensitivity accuracy of +/- 2.5%, consistent with the industry standard for a linear triaxial accelerometer (Yap et al., 2018). Studies and clinical data found the device "effectively detects position changes according to threshold parameters, like degree or angle of position change" (Yap et al., 2018, p. 9). Threshold parameters used in the TEAM-UP study were set at 20 degrees for roll orientation angle, 45 degrees for upright angle, and 10 degrees for tilt angle.

The PM system has 4 main mechanisms: (a) resident sensor; (b) mesh network of relay antennas; (c) network bridges, mesh network software, and Structured Query Language (SQL) database; and (d) "turn management" software. The sensor is comprised of several key components: a 3-axis accelerometer to measure NH resident orientation and activity; a phototransistor that measures ambient light levels and turns on the device when the packaging and/or adhesive liner is removed; a capacitive contact sensor that enables the device to sense when it is attached or removed from skin; a microcontroller for automated data collection, analysis, and storage; an RF radio for transmitting and receiving messages; and a coin-cell battery for providing electrical power (Leaf Healthcare, Inc., 2019). The sensor was affixed to a resident's skin on the anterior chest with a medical grade adhesive sensor backing; placement on the chest established a vertical head-to-toe axis for that resident. The sensor measured the individual's orientation 24-hours per day and communicates that data wirelessly to the mesh network of relay antennas set up in each NH facility. Data were relayed to a network bridge having an RF to USB transceiver and mesh network software running on it that collected the data from the transceiver and sent it to a SQL database for analysis (Leaf Healthcare, Inc., 2019). The turn management software displayed the resident's turn history, current status, alerted staff when the resident needed repositioning, and automatically documented the resident's turn history. The PM system's mesh network provides a secure, "highly redundant data transmission that is fault tolerant" (Leaf Healthcare, Inc., 2019, p. 4). The PM system data was matched with NH system Admission, Discharge, Transfer (ADT) feed to track resident movement.

The PM system measured and recorded NH resident activities 24 hours per day from start to end of NH residents' participation in the trial's 4-week intervention. Changes in body position and location, frequency, and duration were empirically measured, summarized, and categorized using set degree thresholds and time points. This technology offered an advantage over using manually charted position and activity documentation by nursing that can be inaccurate and inconsistent with the actual NH resident behaviors observed or care provided. The PM system's measures reflected direct, continuous monitoring of NH resident mobility and activity over an extended observation period that enabled assessment of the regularity and magnitude of individual movements as well as patterns of movement that are difficult to measure in traditional standardized, documentation options available in EMR packages and with variable nursing practices of EMR charting.

The sensor's triaxial accelerometer measured acceleration along 3 axes in space: the forward and back X-axis, the left and right Y-axis, and the up and down Z-axis (Hawk, 2020). Each sensor recorded and transmitted the body's spatial orientation (body position, including ambulating) in 3-dimensional Euclidean space (Naghshineh et al., n.d.) within the PM system to monitor and track NH resident movement. Active and passive body movements in the PM system data were collapsed and coded into groups representing seven spatial orientations and are labelled as Body Orientations (Ambulating, Back, Back Upright, "Left + Left Prone = Left", Left Upright, "Right + Right Prone = Right", Right Upright) in the TEAM-UP data sets. Thresholds determined the defining parameters of body orientations in the PM system data.

Ambulating was defined with a threshold of ≥ 9 steps of forward movement based on the placement of the sensor on the resident's chest. Steps (walking or wheeling) indicated the resident was changing their location within or outside of the bedroom. Body position was reflected by direction and angle the body was facing based on the accelerometer's three axes. **Upright angle** measured the orientation of a resident's torso to the ground. A threshold of ≥ 50 degrees determined upright orientation for either standing or sitting in a bed or chair; < 50 degrees determined a lying orientation. Prone and back described downward- and upward-facing lying positions, respectively. The system automatically changed from monitoring roll orientation angle (lying in bed positioning) to monitoring tilt angle (seated in bed or chair positioning) when a resident's torso was ≥ 50 degrees upright. **Roll orientation angle (ROA)** measured the change in angle reflecting movement from side-to-side. A threshold of 20 degrees was used to determine the direction of change in position as reflected in a left or right roll position while in a lying orientation. **Tilt angle** measured the vertical or the rotational angle between any two accelerometer readings (Pedley, 2013) and denoted a hip-to-hip weight shift while in an upright orientation. A change in tilt angle to the left or right with a threshold of 10 degrees detected a shift of the body toward the right or left while in the upright position. A body position orientation had to be maintained at least 15 minutes to be recorded by the PM system. Independent and assisted changes in body position and location orientation were not differentiated in the movement data.

Measure Crosswalk

Table 1 depicts a crosswalk that maps the two measurement standards described above (Braden Scale scores, PM system accelerometry) to each other; the crosswalk was created to organize the measurement data and guided data preparation and analyses in this study. The levels of mobility and activity operationalized in the Braden Scale Mobility and Activity subscales (scores 1-4) are depicted in Table 1, which serves as a crosswalk between the subscales, their descriptive categories, and corresponding PM system movement parameters. Table 1 was used to guide identification and grouping of mobility and activity construct attributes for the convergent validity analyses. Both types of measurements (Braden Scale, PM system—triaxial accelerometry) of NH resident activity and mobility included spatial and temporal characteristics of movements that were used to examine the convergent construct validity of the Braden Scale's Mobility and Activity subscales.

The Braden Scale Mobility and Activity subscale measures conceptually define and describe spatial body orientations (e.g., in bed, chair, walking) and temporal attributes (e.g., frequent, occasional, majority of shift) of movement to help nurses assess, distinguish, and score levels of mobility and activity of NH residents. Mobility and Activity subscales construct mobility and activity into four ranked measurement categories (Table 1) based on distinct distinguishing or predominant movement characteristics demonstrated by individuals in each group. The ordinal scale provides a means for quantifying and comparing an individual's performance to determine their level of risk for PrI development in relation to other movement groups within the population. The subscale scores serve as a point of reference for identifying which individuals are at greatest risk for PrIs to customize care plans and effectively utilize resources aimed at preventing PrIs.

Resident movement data from the PM system described spatial and temporal parameters of mobility and activity (e.g., roll orientation angle, number of steps, lying time) derived from numerical quantities continuously collected by accelerometers in sensors worn by the NH residents. Body orientations of NH residents that were used for this analysis were lying, upright,

Table 1

Braden Scale Mobility and Activity Score Descriptors and Corresponding Descriptive Parameters of Resident Movement

Braden Scale			Resident Movement
Subscale	**Descriptor (Score)**	**Descriptive Category**	**PM System Descriptive Parameters Examined**
Mobility	Completely Immobile (Score = 1)	Does not make even slight changes in body or extremity position without assistance.	Lying frequency, Lying duration, Upright frequency, Upright duration
	Very Limited (Score = 2)	Makes occasional slight changes in body or extremity position but unable to make frequent or significant changes independently.	
	Slightly Limited (Score = 3)	Makes frequent though slight changes in body or extremity position independently.	
	No Limitation (Score = 4)	Makes major and frequent changes in position without assistance.	
Activity	Bedfast (Score = 1)	Confined to bed.	Lying frequency, Lying duration, Upright frequency, Upright duration, Ambulating frequency, Ambulating duration
	Chairfast (Score = 2)	Ability to walk severely limited or non-existent. Cannot bear own weight and/or must be assisted into chair or wheelchair.	
	Walks Occasionally (Score = 3)	Walks occasionally during day, but for very short distances, with or without assistance. Spends majority of each shift in bed or chair.	
	Walks Frequently (Score = 4)	Walks outside room at least twice a day and inside room at least once every two hours during waking hours.	

Source: Braden Subscale Descriptors and measures from *Braden Scale for Predicting Pressure Sore Risk©*. Copyright Barbara Braden and Nancy Bergstrom, 1988. All rights reserved. Retrieved March 7, 2020, from https://www.bradenscale.com/images/bradenscale.pdf and ambulating. These parameters measured in the PM system movement data matched the body orientations measured in the Braden Scale Mobility and Activity subscales. The Mobility subscale referred to position changes in bed, which may include lying and upright orientations. The Activity subscale referred to the degree of activity related to changing physical orientation or location to bed, chair, and room (i.e., lying in bed/chair, upright in bed/chair, walking inside/outside of room). The lying, upright, and ambulating body orientation movement parameters indicated to what degree NH residents were mobile or immobile and active or inactive. Residents that spend time ambulating were assumed to be more physically active than residents in lying and upright positions. Temporal characteristics, specifically frequency and duration, of movements were used to measure levels of mobility or activity tolerated by NH residents. *Frequency* measured the rate at which lying, upright, and ambulating body orientations (independent or assisted) occurred or were repeated during an observation period. *Duration* measured the length of time spent lying, upright, and ambulating during an observation period. For example, ambulating frequency was how many times the resident was in the ambulating body orientation per day; ambulating duration was how many minutes the resident spent in the ambulating orientation per day. The measure crosswalk (Table 1) displaying these shared spatial and temporal descriptors of Braden Scale Mobility and Activity subscale and movement parameter measures served as a guide for comparing the mobility and activity construct measurements existing in the two data sets.

Data Preparation and Management

Data files for this retrospective study were comprised of the existing coded limited resident and movement data sets contained in the TEAM-UP study database. Data files merged and cleaned for the secondary analysis were accessed by statisticians from the secure encrypted

Duke share drive for data analyses. This study's Investigator was approved as part of Key Personnel to the TEAM-UP study under the Duke IRB. Data examined in this study included resident demographic variables (gender, age, race, and ethnicity) and intervention resident sensor (patient monitoring system) data and EMR and MDS data for the nine NHs collected by the TEAM-UP investigators. Data management protocols for the collection, access, sharing, storage, security, preparation, and use of data for this secondary analysis study were followed. Data preparation involved processes to clean, format, combine, and analyze the data. These steps created higher quality data containing useful types of information for conducting the RQ1 and RQ2 analyses. Data processes used to improve the data consistency and facilitate data analyses were:

- Fixing or removing incorrect or incomplete data by dealing with missing values and determining whether to impute means, discard data, or recoding data;
- Converting continuous numerical movement data to categorical data;
- Evaluating variability in how data were labeled, reference groups, other representations in the data;
- Matching time periods for data collected at different time intervals;
- Verifying accuracy of data by examining outliers or extreme values that appear to be inappropriate and by reviewing frequency counts associated with each variable; and
- Checking the data assumptions of statistical tests in the study.

Preliminary analyses were performed using SAS/STAT® 15.2 Software run on Version SAS® 9.4M7 (SAS Institute Inc., 2013) to: (1) ascertain whether data collected provided a complete set of variables of interest for this study examining convergence of NH resident Braden Scale Mobility and Activity subscale scores collected from nursing assessments and resident movement parameters from accelerometers; and (2) address variability in the secondary data that could present problems with comparing the different NH resident measurements in the planned study analyses. Primary variables of interest were associated with the Braden Scale scores and movement data. The following section summarizes preliminary analyses conducted to determine effective sample size and establish limitations on movement parameters and Braden Scale and subscale scores that would define the set of data to be included in final data analyses. Nursing home residents with only one score for Braden Scale Mobility or Activity subscales were not included in the preliminary analyses.

Preliminary Analyses: Effective Sample Size

Preliminary analyses included exploration of the population parameters of interest to determine if Braden Scale and movement data variables were adequately represented in the data set in order to be able to answer the research questions of this study of the convergent construct validity of the Braden Scale Mobility and Activity subscales. Univariate and bivariate preliminary analyses using pairwise comparisons of each NH resident's first and last scores of the Braden Scale Mobility and Activity subscales (key study variables) were conducted to assess characteristics and associations between the variables (i.e., effect size) *within* each subscale being studied and determine the true value of those specific variables from the convenience sample (N = 913) to prepare this study's sample. The decision to use first and last subscale scores was deemed optimal for these preliminary analyses based on two assumptions: (1) The duration of resident participation in the TEAM-UP trial (up to 4 weeks) and number of Braden Scale Mobility and Activity scores for each resident (1 up to 4 scores) varied, so excluding only NH residents with one Braden Scale score preserved the sample size to test effect sizes; and (2) the greatest variation in subscale scores would likely occur between the two broadest time points of measurement therefore, first and last Braden Scale scores would be the most useful for detecting differences in how each NH resident was categorized in Mobility and Activity groups (scores 1-4) during the TEAM-UP trial. First, univariate analyses were used to examine data distributions of the Mobility and the Activity first and last subscale scores individually for completeness of data in variable categories (Mobility scores 1-4, Activity scores 1-4), for extreme values, and other variations in data that may signal inconsistencies or absence of clinical plausibility in score ratings of each NH resident. Next, bivariate analyses were performed to assess connections between the first and last scores for each subscale to test and detect effect sizes of the study variables in the sample (N = 913) and define an effective sample for this study. Upon completion of these preliminary analyses, it was determined that data for 351 residents included in the TEAM-UP intervention sample would need to be excluded from analyses to answer research questions; thus, producing an effective sample size of N = 562 NH residents for this study. The preliminary analyses are described in the following sections.

Univariate Preliminary Analyses

Univariate analyses using frequency distributions of each NH resident's first and last Braden Scale Mobility and Activity subscale scores were performed to summarize all of the distinct values (scores 1-4) for each subscale and the number of times those values occurred in the sample (N = 913). These analyses confirmed that the sample was comprised of NH residents who had at least one Braden Scale score at the beginning of the TEAM-UP trial intervention start. Thus, there were no missing Braden Scale Mobility and Activity scores in the data set.

Contingency tables of the first and last Mobility and the Activity subscale score frequencies generated using the SAS® FREQ procedure (SAS Institute Inc., 2013) showed NH resident scores were disproportionately spread across all four categories for each Braden Scale subscale. Mobility subscale score distributions were skewed toward higher score values compared to Activity subscale score distributions. Nursing home residents were most frequently classified as Mobility subscale score 3 (first score 38.23%; last score 36.58%) or score 4 (first score 32.86%; last score 34.83%), indicating their mobility was slightly limited or not limited at the time of Braden Scale assessments. The majority (first score 50.71%; last score 48.96%) of NH residents were categorized as Activity subscale score 2, described as chairfast in the Braden Scale. These preliminary findings showed that the number of times each Mobility and Activity subscale score occurred varied as indicated by differences in the percentage of NH residents who scored each rating (1-4) across the first and last scores. However, there were similar score distributions within each subscale across different repeated Braden Scale measurements (first score versus last score) in the initial N = 913 sample.

Bivariate Preliminary Analyses

Bivariate analyses were performed to examine the significance of the differences in first and last Braden Scale Mobility and Activity subscale score proportions seen in the 4x4 contingency tables and measure associations between the Mobility and the Activity subscales' score pairs (first and last scores) to understand how the scores related to each other within the individual subscales. These preliminary analyses included Chi-square, McNemar-Bowker test of symmetry (Bowker, 1948), Cochran-Mantel-Haenzel (CMH) test for repeated tests of independence (Cochran, 1954; Mantel & Haenszel, 1959), Spearman rank-order correlation, and agreement tests (Cohen's Kappa statistic) (Cohen, 1968) run using the SAS® FREQ procedure (SAS Institute Inc., 2013).

First, Chi-square tests of independence were used to test for differences between each NH resident's Mobility subscale first and last scores and Activity subscale first and last scores.

Results showed the scores were significantly related (i.e., not independent) for both the Braden Scale Mobility subscale [$\chi^2(9, N = 913) = 1131.72$, $p < .0001$] and Activity subscale [$\chi^2(9, N = 913) = 1354.35$, $p<.0001$]. McNemar-Bowker test of symmetry indicated that differences in the first and last scores for the Mobility subscales and the Activity subscales were symmetrical, [$\chi^2(6, N = 913) = 4.20$, $p = 0.65$ for Mobility subscale scores and $\chi^2(6, N = 913) = 4.12$, $p = 0.66$ for Activity subscale scores]. These preliminary tests of confirmed that each NH resident's first and last scores were significantly related and likely to change together.

Next, Spearman rank-order correlation (r_s) analyses were performed to assess the strength of the relationships (i.e., effect size) between each NH resident's (N = 913) <u>first and last scores of the Braden Scale Mobility and Activity subscales</u>. A sample size with stronger relationships between score pairs (larger effect) was desired for quantifying small differences that might exist between the different Braden Scale Mobility and Activity subscales groups (scores 1-4). Results showed first and last scores for both subscales were strongly correlated (Mobility subscale scores, $r_s(9) = .75$; Activity subscale scores, $r_s(9) = .81$), as expected for values (scores 1-4) measuring the same construct. Thus, an effective sample (N = 562) for estimating a small effect size of any meaningful mean differences between the Braden Scale subscale groups examined in this study could be drawn from the NH residents in the convenience sample (N = 913).

Lastly, kappa statistics were performed to test concordance/agreement between the <u>first and last Braden Scale Mobility and Activity subscale pairs of scores</u> collected at the start and end of each NH resident's participation in PM system monitoring during the TEAM-UP trial and used to define the effective sample size and representative measures of the study variables in the sample to use in analyses with resident movement data. Weighted kappa analysis (Cohen, 1968) was used to assess the degree of agreement or disagreement between Braden Scale subscale scores of this ordinal scale and account for situations where differences between score ratings should not be treated as equally important (e.g., disagreement between Mobility subscale scores 1 and 4 is greater than the disagreement between scores 2 and 3). This information and the Braden Scale Mobility and Activity subscale descriptors were used to determine the consistency of observed NH resident mobility and activity characteristics in the sample (N = 913). There was substantial agreement corrected for chance found between the score pairs for both subscale measurements (Mobility subscale scores, $\kappa_w = .68$; Activity subscale scores, $\kappa_w = .75$). Percent actual agreement between each resident's scores was 73% for the Mobility subscale and 79% for the Activity subscale. Complete agreement between the NH resident's first and last scores assumes the variables were consistent measurements of the same Mobility or Activity construct observed by nurses when administering the Braden Scale during the TEAM-UP trial. Therefore, the decision was made to retain only the N = 562 NH residents whose Mobility and Activity subscale scores were internally consistent ($\kappa_w = 1.00$) to enhance the accuracy of results from RQ analyses of the Braden Scale scores. Congruence within subscale score pairs in this effective sample (N = 562) also meant that either first or last scores could be considered true values of the study variables adequate for representing the weekly Mobility and Activity subscale scores of those NH residents. The first scores were determined to be better representative measures than the last scores and the subscale means given the:

- variation and small number of Braden Scale scores (1 up to 4) for each NH resident,
- small standard deviations (*SD* = 0.86), and
- limited range of values (1-4) of the Mobility and Activity subscales.

Therefore, the first Mobility and Activity subscale scores were used in analyses to answer this study's RQs.

Determination of the effective sample size (N = 562) using results from these preliminary analyses helped address variability in the secondary data that presented problems when comparing the different NH resident measurements in this study's planned analyses by: (1) making data collection time windows for the independent (Braden Scale scores) and dependent (movement parameter) variables the same; and (2) removing NH resident cases with inconsistent Braden Scale ratings over the course of monitored 22-hour days from the RQ analyses. All remaining preliminary analyses were performed using the N = 562 effective sample and are discussed in their respective sections below.

Preliminary Analyses: Braden Scale Total and Mobility and Activity Subscale Scores (N = 562)

Preliminary analyses of NH resident Braden Scale data were used to examine characteristics and correspondence between the first Braden Scale Mobility and Activity subscale scores in the study's sample (N = 562) and cross-check the data for accuracy to ensure a high-quality data set for the RQ analyses. The preliminary univariate and bivariate analyses discussed above were repeated using pairwise comparisons of each NH resident's first scores of the Braden Scale Mobility and Activity subscales to assess the data distributions, variations, and associations between the Braden Scale reference groups (scores 1-4) for clinical meaningfulness by comparing scores *across* the subscales (e.g., NH resident's Mobility scores compared to Activity scores). Descriptive statistics were used to analyze characteristics of the first subscale scores relative to Braden Scale total score and movement parameters and remove NH resident cases with clinically implausible data. The preliminary analyses, run using SAS® FREQ and MEAN procedures (SAS Institute Inc., 2013), included a contingency table, Chi-square test of independence, McNemar Bower test of symmetry, CMH test for repeated tests of independence, Spearman rank correlation, weighted kappa, mean, standard deviation, and minimum and maximum values.

First, univariate analysis of Braden Scale Mobility and Activity subscale first scores were used to create a contingency table for assessing if NH residents in this study's sample (N = 562) were grouped in appropriate categories according to the Braden Scale descriptors and clinical meaningfulness (e.g., Activity 1 with Mobility 1, Activity 4 with Mobility 4). Table 2 shows how the Mobility and Activity subscale scores were distributed and corresponded with one another in the study sample.

Results of preliminary univariate analyses showed that Braden Scale scores of NH residents were dispersed across all four levels of Mobility and Activity subscale groups (scores 1-4), but with varying frequencies. Nursing home resident subscale scores were expected to be unevenly spread among the four groups to reflect varying levels of independent and assisted movement in the sample. Distribution of Mobility subscale scores were skewed toward a higher rating than the Activity subscale scores. This finding is theoretically and clinically important for differentiating between mobility and activity movements in NH residents. Braden Scale Mobility and Activity subscale scores 1-4 are theoretically conceptualized as position changes when in a lying or an upright sitting position, though Activity subscale scores 3 and 4 also consider ambulating frequency and duration (time). Clinically, it makes sense that more NH residents would be capable of changing body position while lying or sitting than be able to get up and walk occasionally or frequently (Activity subscale scores 3 or 4, respectively). Total energy expenditure standing has been found to be significantly higher than in lying and sitting positions (Amaro-Gahete et al., 2019). Age-associated declines in physiological reserve and function are

Table 2

Correspondence of Braden Scale Subscale Scores Within and Between the Mobility and Activity Subscales (N = 562)

Subscale Distributions						Subscale Associations		
Braden Scale Subscale Scores	**Mobility 1** *N* (%)	**Mobility 2** *N* (%)	**Mobility 3** *N* (%)	**Mobility 4** *N* (%)	**Total** *N* (%)	χ^2	r_s,	κ_w
Activity 1 *N* (%)	6 (1.07)	24 (4.27)	2 (0.36)	1 (0.18)	33 (5.87)	380.72, <.0001	.74	.48
Activity 2 *N* (%)	9 (1.60)	121 (21.53)	119 (21.17)	26 (4.63)	275 (48.93)			
Activity 3 *N* (%)	0 (0.00)	4 (0.71)	62 (11.03)	81 (14.41)	147 (26.16)			
Activity 4 *N* (%)	0 (0.00)	0 (0.00)	4 (0.71)	103 (18.33)	107 (19.04)			
Total *N* (%)	15 (2.67)	149 (26.51)	187 (33.27)	211 (37.54)	562 (100.00)			

Note. % denotes percentage of observations in the given subscale category out of all non-missing observations in the sample and is presented in parentheses.

linked to reduced total daily energy expenditure (Bastone et al., 2019) and would decrease NH residents' capacity to perform higher-energy expending activities, like standing and walking. The majority of NH residents that were classified as chairfast (Activity 2, 48.93%) were also categorized with slight or very limited mobility as is indicated by 21.17% Mobility 3 and 21.53% Mobility 2, respectively. Of the 107 residents classified as frequent walkers (Activity 4), 96% were also categorized as having no limitations with making major and frequent changes in position in bed (Mobility 4). Only 1% of NH residents were rated as completely immobile (Mobility 1) and bedfast (Activity 1), as expected to be lower for non-acute care settings.

Preliminary bivariate analyses including Chi-square test of independence, McNemar Bower test of symmetry, CMH test for repeated tests of independence, Spearman rank correlation, and weighted kappa statistical tests were performed to quantitatively analyze associations between the Mobility and Activity subscale scores displayed in the contingency table (Table 2). Bivariate analyses using pairwise comparisons of each NH resident's first Braden Scale scores for the Mobility and Activity subscales were performed to examine the significance, strength, extent of concordance/discordance, and proportions of subscale score pairs (first Mobility score and first Activity score) in the sample (N = 562). Results from these analyses are presented in Table 2. Statistical significance, strong correlation, and moderate agreement between the Mobility and Activity subscale scores and differences in proportions across the subscale measurements were expected based on the preliminary effective sample size analyses and empirical and theoretical evidence supporting the Braden Scale's subscales as independent, yet related constructs.

A Chi-square test of independence showed there was a statistically significant relationship between the Braden Scale Mobility and Activity subscale scores, $\chi^2(9, N = 562) =$

380.72, $p < .0001$ in this study's sample. A strong, positive Spearman correlation resulting between the Mobility and Activity subscale scores ($r_s(9) = .74$, $p < .0001$) indicated that that the scores of each subscale tended to change in tandem (monotonic relationship). Comparison of the ordinal ratings revealed moderate concordance or agreement corrected for chance ($\kappa_w = .48$) between the paired Mobility and Activity subscale variables. Percent actual agreement between Mobility and Activity subscale scores was 51.95%. Results of the McNemar-Bowker test of symmetry showing the odds ratios above and below the diagonal indicated the contingency table was asymmetric ($p < .0001$) and there was a significant difference between one or more of the row marginal proportions and the corresponding column proportions (lack of marginal homogeneity between changes in first Mobility and Activity subscale scores). A statistical significance of the common odds ratio ([$\chi^2(6, N = 562) = 213.09$, $p < .0001$) in the CMH test denoted that although associated in the combined table, controlling for NH resident revealed that Mobility and Activity subscale scores were conditionally independent, within Braden Scale scorings in the study sample. Findings from these preliminary analyses aligned, as expected, with theoretical and empirical evidence suggesting that the NH resident Braden Scale Mobility and Activity scores of this sample (N = 562) were accurate and valid to use in the RQ analyses examining their relationship with movement parameters from the PM system data. However, there was one outlier that warranted further examination: a NH resident scored Mobility 4 (no limitations) and Activity 1 (bedfast). The descriptive analyses of the subscale scores using movement parameters collected from sensors worn by the NH residents provided a cross-check of the presumed outlier and showed that at least one NH resident in this group did not walk as indicated by the zero Ambulating time (minutes) and Ambulating frequency minimum values. Therefore, this case was not removed from the study sample.

Preliminary Analyses: Braden Scale Total and Mobility and Activity Subscale Scores Correspondence with Movement Parameters (N = 562)

Descriptive statistics of movement parameters (mean lying, upright, and ambulating times and frequencies), mean Braden Scale total score and Mobility and Activity subscale scores were used to ascertain whether movement data and Braden Scale total score means corresponded to the item rating for the Braden scores characterized *within* the Mobility and Activity subscales. Movement parameters were also added to descriptive analyses of Mobility/Activity interaction groups (e.g., Mobility 3-Activity 1, Mobility 2-Activity 2) to cross-check the data for the non-corresponding outliers and further examine resident mobility and activity characteristics *across* the subscale groups of the Braden Scale variables of interest. Results from these analyses showed similarities and differences in movement characteristics among the subscale groups (scores 1-4) of the NH resident sample were clinically meaningful based on the Braden Scale descriptors and mean Braden Scale total score. For example, analyses of Mobility 4 scores indicated that NH residents categorized in this group (N = 211) had the highest mean Braden Scale total score (mean = 21), and walked longer and more often than NH residents categorized as Mobility score 1, 2, or 3 [mean total ambulating time (minutes)/day = 54, *SD* = 78, range 0 to 470 minutes; mean total ambulating frequency/day = 16, *SD* = 14, range 0 to 65 times] during the TEAM-UP trial. No cases were removed from the sample because these findings supported the clinical accuracy of the scores.

Preliminary Analyses: Movement Parameters

Preliminary analyses of the NH resident movements in the PM system data were performed to clean, transform, and examine NH resident movements to prepare the PM system data for analyses with the categorical Mobility and Activity subscale scores in the Braden Scale assessment data. First, the issue of incomplete data was addressed. Then, numerical continuous data were transformed to create reference groups. Next, variation in spatial and temporal orientation parameters (frequency and duration) in the groups were examined to identify outliers or extreme values and improve accuracy of the data. Lastly, a representative measure to match the time period for Braden Scale scores collected at different intervals was determined for use in the comparative analyses to answer the RQ questions in this convergent construct validity study.

Variation in intervention length of stay of NH residents and gaps or missing time periods of movement measurements from the wearable sensors were problems in the PM system movement data that could impact analyses of the study RQs. The decision to include only NH with at least one full day (22 hours) of movement monitoring at intervention start was made to improve the consistency of data and facilitate analyses with the Braden Scale subscale scores collected on one day weekly during the four-week intervention period.

The first step in processing the data was to convert the continuous numerical movement data of NH resident body orientation frequency and duration into categorical data to compare with the categorical Braden Scale Mobility and Activity subscale scores using the measure crosswalk in Table 1. Body orientations in the movement data (up to 7 per resident) were collapsed into three movement parameter categories - lying, upright, and ambulating. The movement data groups are depicted in Table 3. Continuous sensor data with missing variables were collapsed into categorical data. Next, continuous movement data collected from each NH resident by the PM system was further grouped as discrete variables measuring the overall mean frequency and mean duration for the lying, upright, and ambulating orientations experienced by the individual.

Table 3

Resident Movement Parameter Body Orientation Groupings

Resident Movement Data Body Orientations	**Collapsed Resident Movement Parameters**
Back Left (Left + Left Prone) Right (Right + Right Prone)	Lying (in bed or chair)
Back Upright Left Upright Right Upright	Upright (in bed or chair)
Ambulating (present or absent)	Ambulating (walking inside or outside of room)

Frequency was assessed as the overall mean daily rate at which each orientation (independent or assisted) occurred or was repeated during each resident's participation in PM system monitoring during the TEAM-UP intervention. The number of times each resident experienced lying, upright, and ambulating orientations in a day (24 hours) was counted to obtain a daily rate. The daily lying, upright, and ambulating orientation rates for each resident were averaged to determine an overall mean frequency for each of the four orientations during PM monitoring of the TEAM-UP intervention period (one day up to 4 weeks). Using a mean of lying, upright, and ambulating body orientation frequencies in the PM system data helped account for normal daily fluctuations in resident mobility and activity to provide a more holistic picture of resident movement in the NHs.

Duration was assessed as the overall average length of time each resident spent lying, upright, and ambulating during PM system monitoring in the TEAM-UP intervention. Time intervals were measured as the start of a body orientation to the start of a different body orientation and summed daily. Since duration was likely to flux daily, the mean body orientation duration was calculated by averaging daily time intervals of lying, upright, and ambulating orientation experienced by each resident for the duration of PM system. The period of resident movement data for assessing body orientation durations may vary from one day up to four weeks depending on the resident's participation during the TEAM-UP intervention period. Using a mean duration of lying, upright, and ambulating body orientations also helped account for normal daily fluctuations in resident mobility and activity to provide a more holistic picture of resident movement in the NHs.

Means of PM system descriptive parameters created categorical measures for pairing with the Braden Scale Mobility and Activity subscale groups (scores 1-4) to compare measures of mobility and activity constructs at the individual NH resident-level. Therefore, mean was judged to be the most representative of overall movement pattern rather than use of a single day.

Mean movement parameters were examined within the Braden Scale Mobility and Activity subscale scores to cross-check for missing or inaccurate data that did not make sense based on clinical judgement and Braden Scale assessment descriptors. Three NH resident cases had the mean minutes walking imputed to override the "0" minutes as would be expected because of the correspondence between each resident's Activity and Mobility ratings. These preliminary analyses were used to define the movement parameter measurements appropriate for examining the convergent construct validity of the Braden Scale Mobility and Activity subscales.

Statistical Power Analysis

A priori power analyses were performed to estimate a sample size large enough to confidently detect very small differences that might exist between the NH residents' Braden Scale Mobility and Activity subscale groups (scores 1-4). Factors in determining sample size in this quantitative study were based on generally accepted standards for significance level (statistical significance, $\alpha = .05$), power (high, 0.80 and 0.90), and effect size (large correlation, >

.50) reported in Braden Scale studies. Power analyses were performed using the functions Power4Cats and Power3Cats within the R package kappaSize (R Core Team, 2013). A Kappa0 (null hypothesis) of 0.71 was chosen based on reported Braden Scale inter-rater reliability in the literature. Kappa1 (alternative hypothesis) was set at 0.8, denoting substantial excellent agreement (Cohen, 1960). The number of raters was set at 2, the minimum value for this function for studies of interobserver agreement, to calculate the maximum number of subjects required. A conventional power of 0.80 and a two-tailed significance level of $\alpha = .05$ were selected to calculate the minimum number of subjects required when assuming equal distributions of the four Braden Scale subscale scores in the convenience sample (N = 913 NH residents). This initial statistical power analysis estimated the minimum sample size needed to detect a small effect size was approximately 294 subjects. The statistical power is highest when groups have equal sample sizes, such as with random assignment of subjects to groups. However, the grouping in the sample was a natural one, so it was assumed that group sample sizes would be unequal. A second power analysis run at a power of 0.90 and unequal distributions (.4, .4, .1, .1) to reduce chance of a Type II error was used to determine the minimum number of subjects required if group sizes were unequal. Results from this second power analysis suggested a minimum of 457 subjects would be required. If at least two Braden subscales had low frequencies, the categories might need to be combined for the proposed analyses. Therefore, a Power3Cats function using kappa0 = 0.71, kappa1 = 0.80, raters = 2, alpha = .05, power = 0.80, and proportions = .4, .4, .2 was performed, which estimated a minimum of 356 subjects were required for the study. This analysis was repeated at a power = 0.90 and estimated 477 subjects were the minimum sample size required to increase detecting changes in the monitored NH residents from an 80 to 90 percent probability using three Braden Scale subscale categories.

Power analyses indicated that a study sample of 562 NH residents was large enough to detect the target effect sizes with an acceptable margin of error. Therefore, the effective sample size was appropriate to use in the study data analyses to determine if any clinically and statistically significant differences existed between mobility and activity construct measurements of NH residents from Braden Scale assessments and movement data.

Data Analysis

This study of the convergent construct validity of the Braden Scale Mobility and Activity subscales used a research question-driven approach for analyzing existing data from a large clinical trial in NHs. Mobility and activity risk factors consistent with the Braden Scale's etiological conceptual framework and measured using its Mobility and Activity subscales have emerged as statistically significant independent predictors of PrI development in studies using multivariable analyses (Coleman et al., 2013), whose contributions are compounded with increasing age. Data resulting from the recording/monitoring of daily movements (lying frequencies, lying durations, upright frequencies, upright durations, ambulating frequencies, and ambulating durations) of older adults served as an objective criterion for examining Braden Mobility and Activity subscale measures. Analyses of mobility and activity construct measurements from Braden Scale risk assessment data and patient monitoring (PM) system movement data collected for each NH resident during the TEAM-UP trial intervention were used to examine how closely measures of the same construct relate at the individual resident level in this study's sample. The Sensory Perception subscale scores were examined for the potential influence of altered sensory perception on a resident's ability to engage in Mobility or Activity behaviors comprising the constructs and movement pattern predictions. The remaining three Braden subscales (Nutrition, Moisture, and Friction and Shear) were not a focus for analyses since these are thought to be linked to PrI etiology but are not specific to an individual's capacity for movements associated with Mobility and Activity.

The data analysis framework for this study was a person-oriented approach with a variable-oriented approach. The person-oriented approach adopted the NH resident rather than the variables as the unit of analysis. The variable-oriented approach was focused on the relationships between variables. The NH residents were categorized by their ranking on the Braden Scale variables important to this research; in this case, their Braden Scale Mobility, Activity, and Sensory Perception subscale scores.

Descriptive Analyses

Descriptive statistics were first run to assess for any emerging patterns in the NH resident demographic, Braden Scale, and movement parameter characteristics of the study sample (N = 562). Statistics for mean, count, standard deviation, and percentiles of select participant demographic data (age, gender, race, ethnicity) were calculated to describe resident characteristics. Means and standard deviations were calculated to assess the average values and variability across the study measures of the sample for: Braden Scale (Mobility subscale score, Activity subscale score, Sensory Perception subscale score, mean Braden Scale total score) and movement parameters (mean lying time (min)/day, mean upright time (min)/day, mean lying frequency/day, mean upright frequency/day, total ambulating time (min)/day, total ambulating frequency/day).

Research Questions and Analyses

Two research questions (RQs) guided the approach for analyzing Braden Scale and subscale scores and movement parameters to examine the convergent construct validity of the Braden Scale Mobility and Activity Subscales in the NH resident effective sample size (N = 562) determined from the preliminary analyses. Table 4 summarizes the data analysis plan, statistical tests, and variables used to answer this study's two RQs.

RQ1 Analyses: What is the relationship between Braden Scale Mobility and Activity subscale scores and movement data in NH residents?

Nursing home resident Braden Scale Mobility and Activity subscale scores from nursing staff assessments were compared with triaxial accelerometer movement data from a PM system to determine how resident subscale scores and movement parameters corresponded to answer RQ1 and address this study's primary aim. Results from bivariate analyses using statistical tests of difference (Analysis of Variance) and predictive analyses (Ordinary Least Squares Regression) were used to assess if measures of the same constructs of mobility and activity of the NH resident sample collected via different measurement standards (Braden Scale, PM system) converged to examine the convergent construct validity of the Braden Scale Mobility and Activity subscales. Variables in the RQ1 analyses were NH resident Braden Scale subscale scores (analyzed as independent/predictor variables) and movement parameters (dependent/outcome variables). Specifically, mobility variables included resident Braden Scale Mobility subscale scores (1-4) and body orientation positioning movement parameters (mean lying frequency/day, mean lying time (min)/day, mean upright frequency/day, and upright time (min)/day). Activity variables included Braden Scale Activity subscale scores (1-4) and body orientation positioning and ambulating movement parameters (mean lying frequency/day, mean lying time (min)/day, mean upright frequency/day, mean upright time (min)/day, total ambulating frequency/day, and total ambulating time (min)/day). Results of RQ1 analyses were generated using the SAS® GLM Procedure (SAS Institute Inc., 2013).

The initial step in analyzing variables affecting this study's data set was the ANOVA test.

Table 4

Study Research Questions, Data Analysis Plan, Statistical Tests, and Variables for Examining the Convergent Construct Validity of the Braden Scale Mobility and Activity Subscales Using Triaxial Accelerometry

<table>
<tr><th>Research Questions (RQs)</th><th>Data Analysis Plan</th><th>Statistical Tests</th><th>Variables</th></tr>
<tr><td rowspan="2">RQ1: What is the relationship between Braden Scale Mobility and Activity subscale scores and movement data in NH residents?</td><td>Difference analysis to test whether means of movement patterns (upright, lying, and ambulating frequency and duration) for each of the four subscale (Mobility; Activity) scores differ</td><td>One-way analysis of variance (ANOVA)</td><td rowspan="2">Braden Scale scores: (IV)
• Mobility subscale scores
• Activity subscale scores;
Movement Parameters Duration and Frequency: (DV)
• Body orientation positioning (lying and upright) and
• Ambulating (only applied to Activity subscale scores)</td></tr>
<tr><td>Predictive analysis to estimate the relationship between IV(s) and a DV</td><td>Ordinary least squares (OLS) regression (IVs for Activity and Mobility represented as six dummy variables)</td></tr>
<tr><td rowspan="2">RQ2: What is the association between Braden Scale Sensory Perception, Mobility, and Activity subscale scores individually and their interaction effects as predictors for the movement outcome variables?</td><td>Univariate and bivariate analyses of characteristics of relationships between Braden Scale subscale scores and movement parameters</td><td>Descriptive statistics
Pearson correlation</td><td rowspan="2">Braden Scale scores: (IV)
• Mobility subscale scores;
• Activity subscale scores;
• Sensory Perception subscale scores
Movement Parameters Duration and Frequency: (DV)
• Body orientation positioning (lying and upright) and
• Ambulating</td></tr>
<tr><td>Exploratory analysis of relationships to explain any main or interactive effects the Braden Scale Sensory Perception subscale scores (IV) have on the predictive relationship between the Braden Scale Mobility or Activity subscale scores (IVs) and the movement outcomes (DVs) from RQ1.</td><td>OLS regression with and without interactions (first Braden Scale Sensory Perception subscale scores added to regression model with first Braden Scale Mobility and Activity subscale scores as main and interaction term)</td></tr>
</table>

Note: Abbreviations for variable types are independent variable (IV), dependent variable (DV), and covariate variable (CV).

Analysis of variance was used to test for any differences between mean time (minutes) and mean frequency of all resident movement parameter variables and all levels of the Braden Scale Mobility and Activity subscales. The ANOVA tests were used to determine if the subscale scores (1-4) distinguished between NH residents who do and do not exhibit certain characteristics of movement by testing for significant differences in movement data metrics for the Braden Scale Mobility subscale and Activity subscale groups. Post-hoc tests were used to explore any significant results from the ANOVA analyses by comparing all possible pairs of scores within each subscale construct to find out which specific groups' means were different. Tukey's Studentized Range (honestly significant difference) test was used to perform multiple group mean comparisons. Results from this test determined if differences within the Braden Mobility groups and the Activity groups existed (e.g., mean lying time decrease from Mobility 1 to Mobility 4) in relation NH resident movement parameters and whether there were any significant difference(s) that existed among groups of related measurements (e.g., Activity 1 – Activity 2, Activity 3 – Activity 2). The null hypothesis for the ANOVA test was that all group means were equal. Differences between group means were expected within the theoretically-supported independent Braden Scale Mobility and Activity subscale constructs and would provide preliminary evidence of convergence. A significant result of the ANOVA test and significant multiple comparisons differences would indicate that the group means were unequal. If significant differences among pairwise comparisons exist, the findings would support that discretely different constructs are measured in the Braden Subscale subscores as the instrument's theory and developers' purport. Analysis of differences in metrics for the Braden Scale Mobility and Activity groups could be used to describe the accuracy to which the Braden Scale subscale descriptor scores seem to translate constructs of mobility and activity into operationalization (i.e., face validity) and provide preliminary evidence of convergence of each Braden subscale.

Then, ordinary least squares (OLS) regression analyses were performed to measure the effects Braden Scale Mobility and Activity subscale scores collectively and individually as predictors of movement parameters in the NH resident sample. The purposes of the OLS regression analyses were to: 1) test for predictive relationships between NH resident Braden Scale Mobility and Activity subscale scores (independent variable) and PM system movement parameters (dependent variable) data useful for planning PrI prevention care in this population and 2) further examine the convergent validity of the Mobility and Activity subscale constructs. Six dummy variables (three for each subscale construct) were defined and one variable was used as the reference group of the Mobility and Activity subscale 1-4 categories. This analysis method tested whether Braden Scale Mobility and Activity subscale scores and some interactions of their values could significantly predict the amount of mean upright time, upright frequency, lying time, lying frequency, ambulating time, and ambulating frequency of NH residents in the sample. The goal of OLS regression was to establish a linear equation for accurately predicting continuous values of dependent variables that would be useful in determining which NH residents might benefit from preventative interventions targeting mobility and activity. OLS analysis was used to test predictions about performance of the mobility and activity constructs based on the theorized basis for the Braden Scale.

RQ2 Analyses: What are the associations between Braden Scale Sensory Perception, Mobility, and Activity subscale scores individually and their interaction effects as predictors for the movement outcome variables?

Preliminary univariate and bivariate analyses of NH resident Braden Scale and movement parameter data were performed using frequencies and pairwise comparisons to explore the interrelatedness of the NH resident Braden Scale Sensory Perception, Mobility, and Activity subscale scores from nursing staff's risk assessment and how each corresponded with the resident movement data for answering RQ2 and addressing this study's exploratory aim. Results from the RQ2 analyses were generated using SAS® CORR and GLM Procedures (SAS Institute Inc., 2013).

First, contingency tables of Sensory Perception subscale score frequencies and pairwise comparisons with the Mobility and the Activity subscale scores of the NH residents were created to assess distributions and associations among the Braden Scale subscale assessment scores. Univariate analyses of Sensory Perception subscale score frequencies were used to summarize how NH residents were categorized *within* the subscale to assess for subscale groups that were not represented in the study sample. Pairwise comparisons of Sensory Perception subscale scores with the Mobility and the Activity subscale scores showed how Sensory Perception was connected with other Braden Scale study variables. Distribution of Sensory Perception subscale scores was expected to be skewed toward higher score values like the Mobility and Activity subscale scores in the preliminary analysis and based on theoretical connections of Sensory Perception and the Mobility and Activity subscales.

Then, multiple analyses using the SAS® CORR procedure (SAS Institute Inc., 2013) were performed to describe and explore relationships among the 9NH resident study variables (Braden Scale Mobility, Activity, Sensory Perception subscale scores and movement parameters of mean lying time (min)/day, mean upright time (min)/day, mean lying frequency/day, mean upright frequency/day, total ambulating time (min)/day, total ambulating frequency/day) for the sample (N = 562). Descriptive statistics (count, mean, standard deviation, sum, minimum and maximum values) were generated to describe characteristics of the study variables in the sample. Pearson Correlation Coefficients for 9 study variables were used to measure the strength and direction of the associations between the variables. Strong positive correlations were expected among the Braden Scale subscale scores based on the preliminary analyses and evidence in literature. Negative correlations were expected between lying movement parameters and the other parameters ambulating and upright movement in the NH residents.

Lastly, OLS regression using the SAS® GLM procedure (SAS Institute Inc., 2013) performed in the RQ1 analyses was repeated with the NH resident Braden Scale Sensory Perception, Mobility, and Activity subscale scores to explore any main or interactive effects Sensory Perception scores had individually or in combination with Mobility and Activity subscale scores in predicting movement parameters in the sample to answer RQ2. Dummy variables for the Sensory Perception subscale scores were created. The Sensory Perception subscale scores were entered as an interaction term in the regression model to explore associations between the NH resident Braden Scale subscales in relation to movement parameters. Results from the OLS regression analyses for RQ2 were used to evaluate whether the NH resident sample Braden Scale subscale scores' effects on the dependent variables (movement data) differed across Braden Scale Mobility and Activity subscale scores when considering main or interaction effects of Sensory Perception subscale scores. Investigating the main effects of the Braden Scale subscale variables as predictors assumed that the relationship between a given predictor variable (Mobility, Activity, Sensory Perception subscale scores) and the outcome (movement variables) was independent of the other predictor variables (James et al., 2013; Bruce & Bruce, 2017). Conversely, investigating the interaction effects of the Braden Scale Sensory Perception subscale scores (interaction term) with Mobility subscale scores and with Activity subscale scores in relation to movement assumed that the relationships were not independent between the two predictor variables (Braden Scale Sensory Perception and Mobility subscale scores, Braden Scale Sensory Perception and Activity subscale scores) and the outcome (movement variables). Statistically controlling the main and interaction effect of the Sensory Perception subscale variable (scores) in the prediction models allowed for removal of Sensory Perception subscale scores from the list of possible explanations of variance in the dependent variable (NH resident movement data) attributed to the independent variables of interest (Braden Scale Mobility and Activity subscale scores) examined in this convergent construct validity study. This approach would increase statistical power, or the probability that a significant difference between groups is found, when one exists, by reducing the within-group error variance (Tabachnick & Fidell, 2007).

Braden Scale Sensory Perception subscale scores are thought to be associated with Mobility and/or Activity subscale scores because of the hypothesized connection between a NH resident's level of sensory perception and ability to be active and mobile. The statistical techniques described above to answer RQ2 explored the connections between these three theoretically-related Braden Scale variables. Information gained from the RQ2 analyses provided insight into theorized relationships among mobility, activity, and sensory perception construct measures that are considered to be distinct and interacting factors influencing pressure intensity and duration in PrI etiology.

CHAPTER 4: RESULTS

The purpose of this secondary data study was to examine the convergent construct validity of the Braden Scale Mobility and Activity subscales using movement data from PM system sensors worn by NH residents (N = 562) monitored during the TEAM-UP trial (Yap et al., 2022). The primary aim of this secondary study was to determine how Mobility and Activity subscale scores from nursing staff's Braden Scale risk assessments of NH residents corresponded to resident movement parameters. Additionally, an exploratory aim was devoted to exploration of the interrelatedness of three subscale scores (Braden Scale Sensory Perception, Mobility, and Activity). Exploration of associations between the subscale scores individually and their interaction effects as predictors for the movement outcome variables provided additional insight into the convergent construct validity of the Mobility and Activity subscales. The following section describes the statistical tests used to describe the sample and conduct the data analyses for answering the research questions (RQs).

Descriptive Analyses

Descriptive analyses were performed to summarize characteristics of NH residents in the study sample overall and within the different Mobility and Activity subscale score groups (scores 1-4). Results of these descriptive analyses provided important information for interpreting results of inferential statistics used to answer the RQs.

Nursing Home Resident Characteristics

Statistics describing NH resident demographic, Braden Scale total and Mobility, Activity, and Sensory Perception subscale scores, and movement parameter characteristics of the study sample are presented in Table 5. Results are described in separate sections for each set of characteristics.

Table 5

Characteristics for Nursing Home Residents (N = 562)

Demographic, Braden Scale, and Movement Parameter Characteristics	Total Sample
Age: mean (*SD*)	78.28 (11.83)
Gender: Male *N* (%)	201 (35.77)
Race: Black *N* (%)	151 (26.87)
Race: White *N* (%)	385 (68.51)
Race: Other *N* (%)	26 (4.63)
Ethnicity: Hispanic or Latino *N* (%)	13 (2.31)
Ethnicity: Not Hispanic or Latino *N* (%)	549 (97.69)
Braden Scale: Mobility Subscale Score mean (*SD*)	3.06 (0.86)
Braden Scale: Activity Subscale Score mean (*SD*)	2.58 (0.86)
Braden Scale: Sensory Perception Subscale Score mean (*SD*)	3.63 (0.60)
MEAN Braden Scale: Total Score mean (*SD*)	17.53 (3.17)
MEAN Lying Time (min)/Day mean (*SD*)	892.52 (265.03)
MEAN Upright Time (min)/Day mean (*SD*)	481.71 (261.50)
MEAN Lying Frequency/Day mean (*SD*)	104.70 (84.41)
MEAN Upright Frequency/Day mean (*SD*)	218.71 (177.66)
TOTAL Ambulating Time (min)/Day mean (*SD*)	25.46 (55.17)
TOTAL Ambulating Frequency/Day mean (*SD*)	8.37 (12.04)

Note. min denotes minutes and % denotes percentage of total sample.

Demographic characteristics (Table 5). The average age of NH residents in the study sample was 78.28 years (*SD* = 11.83). The sample was largely White (68.51%) and female (64.23%). Most of the NH residents were not of Hispanic or Latino ethnicity (97.69%).

Braden Scale characteristics (Table 5). The mean Braden Scale total score of 17.53 classified the sample's average overall risk for PrIs as mild. The NH residents generally had higher Sensory Perception subscale scores (mean = 3.63, *SD* = 0.60) than Mobility subscale scores (mean = 3.06, *SD* = 0.86) and Activity subscale scores (mean = 2.58, *SD* = 0.86) on average, indicating that sensory perception was more frequently rated as being free of impairment or limitations.

Movement parameter characteristics (Table 5). Nursing home residents averaged more time lying in beds or reclining in chairs with fewer body position changes (mean lying time (min)/day = 892.52, *SD* = 265.03; mean lying frequency/day = 104.70, *SD* = 84.41) compared to sitting up in beds or chairs (mean upright time (min)/day = 481.71, *SD* = 261.50; mean upright frequency/day = 218.71, *SD* = 177.66). On average, the NH residents walked for short durations (mean total ambulating time (min)/day = 25.46, *SD* = 55.17) and infrequently (total ambulating frequency/day mean = 8.37, *SD* = 12.04).

Braden Scale Mobility and Activity Subscale Score Characteristics

Braden Scale Mobility and Activity subscale scores examined in both of the study RQs were analyzed using mean Braden Scale total scores and movement parameters of NH residents classified within each of the subscale score groups (1-4) to assess features of these key study variables. Those characteristics of Mobility and Activity subscale scores are depicted in Table 6.

Braden Scale total scores reflect the overall risk for PrI development. The mean Braden Scale total scores represent the average PrI risk of all NH residents comprising each of Mobility and Activity subscale score groups (Table 6). The higher the mean Braden Scale total score, the lower the PrI risk. Mean Braden Scale total scores increased as Mobility and Activity subscale scores increased, suggesting that NH residents who have no mobility limitations and walk frequently are less likely to be at risk for PrIs. Mean Braden Scale total scores were lower for the Mobility subscale than the Activity subscale in general and when comparing Mobility versus Activity subscale groups with the same subscale score (e.g., mean Braden Scale total score for Mobility 3 = 16.96 and Activity 3 = 19.30). These results indicate NH residents at greater PrI risk were rated as less mobile and/or bedfast while residents with lower PrI risk were more likely to be out of bed. Furthermore, the findings from these descriptive analyses support hypothesized

Table 6

Characteristics of Braden Scale Mobility and Activity Subscale Scores Relative to Braden Scale Total Scores and Movement Parameters (N = 562)

Characteristics	Braden Mobility Subscale Score				Braden Activity Subscale Score			
	1	2	3	4	1	2	3	4
MEAN Braden Scale: Total Score mean (*SD*)	12.43 (4.61)	14.03 (1.55)	16.96 (1.65)	20.76 (1.64)	12.90 (1.14)	15.45 (2.01)	19.30 (1.64)	21.65 (1.22)
MEAN Lying Time (min)/Day mean (*SD*)	1120.21 (332.83)	1039.31 (259.66)	868.79 (232.84)	793.71 (235.42)	1221.81 (234.86)	947.67 (261.07)	798.81 (236.97)	777.98 (196.15)
MEAN Lying Frequency/Day mean (*SD*)	97.27 (95.24)	98.69 (71.66)	107.35 (91.59)	107.12 (85.67)	155.47 (19.10)	100.88 (78.70)	105.61 (98.24)	97.60 (66.73)
MEAN Upright Time (min)/Day mean (*SD*)	263.14 (339.02)	350.74 (263.48)	517.86 (232.83)	556.77 (235.95)	166.27 (220.11)	441.21 (261.77)	578.98 (238.44)	547.63 (202.83)
MEAN Upright Frequency/Day mean (*SD*)	67.50 (92.07)	98.70 (118.04)	214.53 (164.18)	317.91 (168.23)	88.91 (126.23)	157.66 (155.25)	289.36 (173.10)	331.10 (151.81)
TOTAL Ambulating Time (min)/Day mean (*SD*)	4.52 (17.16)	2.81 (12.44)	12.67 (26.23)	54.29 (77.57)	0.86 (13.07)	7.04 (21.24)	26.20 (50.34)	79.39 (86.25)
TOTAL Ambulating Frequency/Day mean (*SD*)	0.67 (2.31)	1.18 (3.60)	5.77 (7.69)	16.29 (14.67)	0.1532 (1.50)	2.87 (7.11)	11.09 (8.02)	21.29 (16.41)

Note. min denotes minutes; standard deviation is presented in parentheses.

relationships between mobility and activity and risk for developing a PrI.

Movement parameter averages varied across the different NH resident score groups of the Braden Scale Mobility and Activity subscales, though followed similar patterns within each subscale (Table 6). Residents with a Mobility or Activity subscale score of 4 presented with higher mean movement parameter values than those rated as subscale scores 1-3. Overall, movement parameters affirmed that the less mobile or less active the resident, according to the Braden Scale subscale score, the lower the value of the respective movement parameter, except in the case of mean lying time (min)/day and mean lying frequency/day. The less mobile or less active the residents per the subscale score, the higher the value of lying times on average. Mean lying frequency/day values did not consistently increase nor decrease with the Mobility or Activity subscale scores of the residents. Residents rated as Activity subscale score 3 (walks occasionally) or 4 (walks frequently) had similar mean lying and upright movement parameter values, though large differences in mean ambulating movement parameters distinguished between residents of these two Activity subscale score groups. Nursing home residents in all the Mobility and Activity subscale score groups averaged more time lying than sitting/standing upright and walking, though made more body orientation position changes while upright compared to lying if rated as a 3 or 4 Mobility or Activity subscale score. Overall, the variation in movement parameter characteristics described statistically and clinically meaningful differences among the subscale score groups (1-4), and patterns in the data highlighted potential relationships among the Mobility subscale, Activity subscale, and movement parameter measurements of NH residents that are consistent with convergence.

Research Question Analyses

The research questions (RQs) for this study of the convergent construct validity of the Braden Scale Mobility and Activity subscales were answered through bivariate statistical analyses. For RQ1, the relationships between NH resident movement parameters and the Mobility and Activity subscale scores were examined to determine if the independently conducted measurements of NH resident mobility and activity from the Braden Scale and movements from the PM system converged. For RQ2, the interrelatedness of the Braden Scale Mobility, Activity, and Sensory Perception subscale scores and their individual and interactive effects with movement parameters of the NH residents were explored to understand whether sensory perception is a potential confounder of the relationships between mobility, activity, and movement in determining PrI risk analyzed in RQ1.

Research Question One Analyses

Bivariate analyses using ANOVA, Tukey's honestly significant difference (HSD) tests, and OLS regression were used to examine how NH resident Braden Scale Mobility and Activity subscale scores related to resident movement parameters, which are thought to be providing an objective measure of those same constructs. Difference analyses and predictive analyses results from those statistical tests to answer RQ1 are reported in the separate sections that follow.

Difference Analyses of Braden Scale Mobility and Activity Subscale Scores and Movement Parameters Using ANOVA and Tukey's HSD Tests

The ANOVA and Tukey's HSD tests were used to analyze variances in mean lying, upright, and ambulating durations and frequencies among and between Mobility and Activity subscale score groups (1-4) in the sample for examining convergence. Results of these difference analyses testing the significance of relationships between the NH residents' Mobility and Activity subscale scores and movement parameters are reported separately for each subscale.

Mobility subscale scores. The Mobility subscale scores of the NH residents collectively explained a small amount of the variance in mean lying and upright movement parameters (.0022 < R^2 < .2580), despite the overall statistical significance of differences in mean movements found between the Mobility subscale score groups in the ANOVA analyses of these Braden Scale and PM system measures (Table 7). There were statistically significant differences in mean lying time (min)/day [$F(3, 558) = 34.42$, $p < .0001$], mean upright time (min)/day [$F(3, 558) = 26.00$, $p < .0001$], and mean upright frequency/day [$F(3, 558) = 64.68$, $p < .0001$] between the Mobility subscale score groups of NH residents. Differences in mean lying frequency averages were not statistically significant [$F(3, 558) = 0.41$, $p = .7469$] among NH residents rated as completely immobile, very limited, slightly limited, or without mobility limitations according to the Mobility subscale.

Results of Tukey's post-hoc analysis of differences in mean lying and upright movement parameters of the Mobility subscale score groups showed the pairwise comparisons among the individual scores varied in significance (Table 7). Nursing home residents with the highest and lowest Mobility subscale scores, i.e., Mobility 1 (completely immobile) and Mobility 4 (no mobility limitations) have, as expected, the largest movement parameter mean differences. Significant differences ($p < .05$) in the mean movement parameters occurred between most Mobility subscale score group comparisons, suggesting there is a strong chance that changes in how long and/or how frequently residents recline in beds/chairs or sit/stand upright measured in actual movement data collected from accelerometers correspond to changes in Mobility subscale scores measured in ratings based on nursing observations of resident movements collected in

Table 7

Examining Differences Between Braden Scale Mobility and Activity Subscale Score Groups Relative to Movement Parameters (N = 562)

Movement Parameters Dependent Variable	**Braden Scale Mobility Subscale Score**					**Braden Scale Activity Subscale Score**				
	ANOVA			**Comparisons**		**ANOVA**			**Comparisons**	
	F	R^2	*p*	Levels	Mean Difference	*F*	R^2	*P*	Levels	Mean Difference
MEAN Lying Time (min)/Day	34.42	.1562	<.0001	1-2	80.90	40.95	.1804	<.0001	1-2	274.15*
				1-3	251.42*				1-3	423.01*
				1-4	326.50*				1-4	443.84*
				2-3	170.52*				2-3	148.87*
				2-4	245.60*				2-4	169.70*
				3-4	75.09*				3-4	20.83
MEAN Lying Frequency/Day	0.41	.0022	.7469	1-2	1.43	4.51	.0237	.0039	1-2	54.59*
				1-3	10.09				1-3	49.86*
				1-4	9.86				1-4	57.88*
				2-3	8.66				2-3	4.73
				2-4	8.43				2-4	3.29
				3-4	0.23				3-4	8.01
MEAN Upright Time (min)/Day	26.00	.1227	<.0001	1-2	87.60	31.73	.1457	<.0001	1-2	274.93*
				1-3	254.72*				1-3	412.71*
				1-4	293.63*				1-4	381.36*
				2-3	167.12*				2-3	137.77*
				2-4	206.03*				2-4	106.43*
				3-4	38.91				3-4	31.35
MEAN Upright Frequency/Day	64.68	.2580	<.0001	1-2	31.20	55.48	.2297	<.0001	1-2	109.31*
				1-3	147.03*				1-3	241.01*
				1-4	250.41*				1-4	282.75*
				2-3	115.82*				2-3	131.70*
				2-4	219.21*				2-4	173.44*
				3-4	103.38*				3-4	41.74

Note. Degrees of freedom for Mobility and Activity were (3,558); min denotes minutes; * indicates comparisons are significant at the .05 level.

Braden Scale assessment. There were a few exceptions to the generally significant findings in the Tukey's test results. Mean lying frequency/day averages of NH residents were not significantly different in any Mobility subscale score group comparisons. No significant differences were found for mean lying or upright movement parameters in comparisons between residents rated as Mobility 1 (completely immobile) and Mobility 2 (very limited) whose subscale scores describe individuals *needing assistance to make significant or frequent changes in body position.* Variances in how long and often movements occurred as measured by accelerometers were not statistically meaningful between residents with these Mobility scores as measured by the Braden Scale. Similarly, the amount of time spent sitting up in beds or chairs did not significantly differ between residents rated as Mobility 3 (slightly limited) and Mobility 4 (no limitations) scores [mean upright time (min)/day mean difference = 38.91, $p > .05$], whose subscale scores describe individuals who *can make frequent and major body or extremity position changes independently.* The statistical and practical significance of variation in movement parameters explained by differences in Mobility subscale scores from the ANOVA and Tukey's tests provided preliminary evidence of the convergent construct validity of the Mobility subscale.

Activity subscale scores. The ANOVA results showed differences among Activity subscale scores collectively explained a small amount of the variance in the mean lying and upright movement parameters ($.0237 < R^2 < .2297$) of the sample (Table 7). There were statistically significant differences in mean lying time (min)/day [$F(3, 558) = 40.95$, $p < .0001$], mean lying frequency/day [$F(3, 558) = 4.51$, $p < .0039$], mean upright time (min)/day [$F(3, 558) = 31.73$, $p < .0001$], and mean upright frequency/day [$F(3, 558) = 55.48$, $p < .0001$] among residents classified as being bedfast, chairfast, walking occasionally, and walking frequently according to the Activity subscale score descriptors.

Pairwise comparisons of Activity subscale score groups in the Tukey's tests resulted in more statistically significant relationships in differences for mean lying time (min)/day and the upright movement parameters than mean lying frequency/day (Table 7). Significant differences ($p < .05$) in mean movement parameters occurred between NH residents with an Activity 1 (bedfast) score compared to all other Activity subscale score groups, indicating the duration and frequency of lying and upright movements were significantly different for residents classified as being bedfast compared to residents classified as chairfast or walking. Alternatively, mean movement parameter differences between NH residents with an Activity 3 (walks occasionally) score and residents with an Activity 4 (walks frequently) score were not significant. Most often, comparison of mean lying and upright movement parameters for residents in the lowest and highest Activity subscale score groups (Activity 1 to Activity 4) yielded large mean differences. These differences were expected; however, there was one exception to this trend. Mean upright time (min)/day mean difference was unexpectedly higher between Activity 1 and Activity 3 score group comparisons [mean difference = 412.71] than Activity 1 and Activity 4 (walks frequently) score group comparisons [mean difference = 381.36], indicating NH residents who walked infrequently spent more time up in chairs or bed than frequent walkers. Shorter average upright times were also explained by the longer and more frequent walking events characterizing NH residents with Activity 4 scores compared to Activity 3 scores found in the movement parameter descriptive analysis results.

The ANOVA and Tukey's tests of significance of relationships between the Activity subscale scores and <u>total ambulating movement parameters</u> are presented in Table 8. The

Table 8

Examining Differences Between Braden Scale Activity Subscale Score Groups Relative to Ambulating Movement (N = 562)

Movement Parameters Dependent Variable	**Braden Scale Activity Subscale Scores**				
	ANOVA			**Comparisons**	
	F	R^2	*p*	Levels	Mean Difference
TOTAL Ambulating Time (min)/Day	61.57	.2487	<.0001	1-2	6.18
				1-3	25.34*
				1-4	78.54*
				2-3	19.16*
				2-4	72.35*
				3-4	53.20*
TOTAL Ambulating Frequency/Day	105.90	.3628	<.0001	1-2	2.72
				1-3	10.94*
				1-4	21.14*
				2-3	8.22*
				2-4	18.42*
				3-4	10.20*

Note. Activity degrees of freedom were (3,558); * indicates comparisons are significant at the .05 level.

ANOVA tests showed differences in the Activity subscale scores collectively accounted for 24.87% to 36.28% of the variance in the total ambulating movement parameters of NH residents. There were statistically significant differences in total ambulating time (min)/day [$F(3, 558) = 61.57$, $p < .0001$] and total ambulating frequency/day [$F(3, 558) = 105.90$, $p < .0001$] among NH residents in the Activity subscale score groups. Tukey's test results showed the averages in the total ambulating movement parameters were significantly different ($p < .05$) for Activity subscale score group comparisons with one exception. Differences in mean walking times and number of walking events were not significant between residents with an Activity 1 (bedfast) score and those with an Activity 2 (chairfast) score. This was expected since these residents are generally either unable to walk or are restricted from walking as a part of care. These results showed differences in total ambulating movement parameters were significantly related to Activity subscale scores when comparing NH residents who were rated as Activity 3 (walks occasionally) to Activity 4 (walks frequently), and when comparing these same subscale groups to Activity 1 or 2 score groups describing residents who are bedfast or chairfast, respectively. Overall, the statistical and clinical significance of movement parameter changes associated with the different Activity subscale scores from the ANOVA and Tukey's tests provided preliminary evidence of the convergent construct validity of the Activity subscale.

Results of these RQ1 difference analyses comparing Braden Scale Mobility and Activity subscale scores with PM system movement parameter data provide evidence to support the convergent construct validity of the Mobility and Activity subscales. Comparisons of NH resident mean movement parameters (dependent variables) from two or all four of the subscale score groups for both the Mobility and Activity subscales (independent variables) determined a relationship exists between the PM system and Braden Scale measures. Findings indicate changes in the subscale scores are significantly related to variances in how long and how often NH residents move. The statistical and clinical meaningfulness of variation in characteristics of duration and frequency of movements measured by the Mobility and Activity subscale scores and PM system suggests the two subscales represent discrete dimensions as the Braden Scale purports. The relationships found between the mean movement parameters and Mobility and Activity subscale scores (1-4) when comparing two or more subscale score groups explained a small percentage of variation in NH resident movements.

Predictive Analyses of Movement Parameters Using the Braden Scale Mobility and Activity Subscale Scores in OLS Analyses

The relationships between the Braden Scale Mobility and Activity subscale scores and movement parameters were analyzed using OLS regression models to see how accurately the subscale scores predicted NH resident movement parameters in the sample to further examine the convergent construct validity of the Braden Scale Mobility and Activity subscales. Ordinary least squares (OLS) regression was used to estimate the extent to which Mobility and Activity subscale scores (predictor variables) and mean movement parameters (outcome variables) of NH residents were related and determine how closely the different measurement standards (Braden Scale, PM system) converge as measures of the same constructs of mobility and activity. Results of the bivariate regression analyses testing the predictive effects of the Braden Scale Mobility and Activity subscale scores in relation to movement parameters of NH residents are presented in Table 9.

Significant equations ($p < .0001$ to $p = .0007$, untabled) found for the Braden Scale Mobility and Activity subscale scores and each of the movement parameters in the OLS analyses indicate that knowing these subscale scores could partially help explain or predict different

Table 9

Effects of Braden Scale Mobility and Activity Subscale Scores on Predicting Movement Parameters (N = 562)

Movement Parameters Dependent Variable	**Predictor: Braden Scale Subscale**	**B**	***SE***	***T***	***p***	R^2
MEAN Lying Time (min)/Day	**Mobility 1**	157.18	70.78	2.22	.0278	.2066
	Mobility 2	131.64	36.72	3.58	.0004	
	Mobility 3	23.70	30.25	0.78	.4336	
	Activity 1	318.98	58.50	5.45	<.0001	
	Activity 2	97.26	37.99	2.56	.0107	
	Activity 3	8.14	32.57	0.25	.8028	
MEAN Lying Frequency/Day	**Mobility 1**	-54.23	24.78	-2.19	.0291	.0412
	Mobility 2	-36.18	12.86	-2.81	.0051	
	Mobility 3	-13.00	10.59	-1.23	.2200	
	Activity 1	94.35	20.48	4.61	<.0001	
	Activity 2	26.12	13.30	1.96	.0501	
	Activity 3	14.00	11.41	1.23	.2203	
MEAN Upright Time (min)/Day	**Mobility 1**	-152.85	71.38	-2.14	.0327	.1711
	Mobility 2	-120.60	37.03	-3.26	.0012	
	Mobility 3	-13.09	30.50	-0.43	.6679	
	Activity 1	-265.55	58.99	-4.50	<.0001	
	Activity 2	-43.18	38.31	-1.13	.2601	
	Activity 3	39.66	32.85	1.21	.2278	
MEAN Upright Frequency/Day	**Mobility 1**	-160.94	45.05	-3.57	.0004	.2846
	Mobility 2	-147.35	23.37	-6.30	<.0001	
	Mobility 3	-62.97	19.25	-3.27	.0011	
	Activity 1	-144.86	37.23	-3.89	.0001	
	Activity 2	-78.44	24.18	-3.24	.0012	
	Activity 3	-13.53	20.73	-0.65	.5144	
TOTAL Ambulating Time (min)/Day	**Activity 1**	-78.54	9.55	-8.23	<.0001	.2487
	Activity 2	-72.35	5.46	-13.24	<.0001	
	Activity 3	-53.20	6.09	-8.73	<.0001	
TOTAL Ambulating Frequency/Day	**Activity 1**	-21.14	1.92	-11.02	<.0001	.3628
	Activity 2	-18.42	1.10	-16.78	<.0001	
	Activity 3	-10.20	1.22	-8.33	<.0001	

Note. Degrees of freedom were (3, 558) for Ambulating Time (min)/Day and Ambulating Frequency/Day and (6, 555) for the other movement parameters. Variables were significant at the .05 level. Mobility 4 and Activity 4 were reference groups.

movement outcomes among the NH residents. The Mobility and Activity subscale scores collectively explained about 4.12 – 36.28% of the proportion of variance in movement parameter means for the sample. Overall, there were similar predictive relationships found between the Mobility and Activity subscale scores and the movement parameters. Changes in movement parameter values generally followed logical progressions with changes in the Mobility and Activity subscale score values, increasing or decreasing in the same direction together if there was a direct relationship or moving in opposite directions if there was an inverse relationship. The predominance of negative beta coefficient values showed the degree of change in the movement parameters (outcome variables) typically increased for every decrease in Mobility or Activity subscale scores (predictor variables) with respect to the Mobility 4 (no limitations) and Activity 4 (walks frequently) reference groups in the NH resident sample. Lower scores of the Mobility and Activity subscales describing residents that require assistance with moving were significantly associated with the movement parameters and had the greatest marginal effect on predicting movement parameter outcomes in the OLS regression models. Notable exceptions to these overall trends and differences between the subscale scores in relation to NH resident movement outcomes are discussed in the respective sections below.

Mobility subscale scores 1 (completely immobile) and 2 (very limited) were significant predictors of all lying and upright movement parameters at the .05 level (Table 9). These results provide evidence of a valid relationship between how much and how often NH residents move while lying or sitting in beds/chairs according to PM system and Mobility scores describing an inability to change and control body position without assistance according to the Braden Scale. Similarly, a Mobility subscale score of 3 (slightly limited) was a significant predictor of mean upright frequency/day (p = .0011) in the sample. Overall, Mobility subscale scores were directly related to movement parameters; however, mean lying time (min)/day was inversely related; less mobile NH residents who require repositioning assistance remain in lying positions longer than residents who can move independently. Mobility 1 and 2 beta coefficient estimates were considerably larger than those for Mobility 3 using Mobility 4 as a reference group, indicating lower scores contribute to greater degrees of change in the movement parameter values in the regression models. For example, mean lying time (min)/day increased by 23.70 minutes when changing from Mobility 4 to Mobility 3 and increased by 131.64 minutes when changing from Mobility 4 to Mobility 2. Alternatively, mean upright time (min)/day showed a decrease of 13.09 minutes when changing from Mobility 4 to Mobility 3 and a decrease of 120.60 minutes changing from Mobility 4 to Mobility 2. These results showed lower Mobility subscale scores had a larger impact as predictors of increases or decreases in the movement parameter outcomes.

Activity subscale scores 1 (bedfast), 2 (chairfast), and 3 (walks occasionally) were significant predictors of mean total ambulating time (min)/day and mean total ambulating frequency/day at α = .05 using Activity 4 (walks frequently) as the reference group in the OLS regression analyses (Table 9). These expected results indicate how long or how often NH residents move is linearly related to whether residents were categorized as bedfast, chairfast, and walking using the Braden Scale Activity subscale. Overall, Activity subscale scores 1 and 2 were significant predictors of mean lying and upright movement parameters similar to the Mobility subscale score results, with the exception of Activity 2 subscale scores in relation to mean upright time (min)/day. Changes in upright times of NH residents rated as Activity 1 (bedfast) were significantly different than the Activity 4 subscale score group. Activity subscale scores were directly related to upright and ambulating movement parameters with one exception: mean upright time (min)/day increased by 23.70 minutes when changing from Activity 4 to Activity 3. An inverse relationship between Activity subscale scores and lying movement parameters showed that for every decrease in Activity subscale score, the lying time and frequency increased. Activity 1 scores were the predominant correlates for most of the movement parameters compared to the other Activity subscale and Mobility subscale scores. Activity 1 scores also had significantly larger marginal effects on movement parameters when compared with Activity 2 and Activity 3 scores (e.g., mean lying time (min)/day Activity 1, B = 318.98 and Activity 2, B = 97.26), indicating lower Activity subscale scores had a greater impact as predictors of increases or decreases in the movement parameters of NH residents in the study sample.

Results of the OLS regression analyses showed the relationship between one or more Braden Scale Mobility and Activity subscale scores groups (1-3) and each movement parameter significantly predicted changes in NH resident movement outcomes and estimated the amount of change associated with each subscale score using the Mobility 4 and Activity 4 scores as reference groups (dummy variables) to support construct convergence. The level of significance and contribution of the Mobility and Activity subscale scores' combined and individual predictive effects varied for each movement parameter. Some subscale score values were not significant predictors of NH resident movement outcomes in the model.

Research Question Two Analyses

Multiple analyses were performed to explore the interrelatedness of the Braden Scale Sensory Perception, Mobility, and Activity subscale scores and the movement parameters of NH residents to answer RQ2. First, characteristics and associations of the Braden Scale subscale score variables were analyzed using frequencies and pairwise comparisons to describe the sample regarding Sensory Perception. Then, Pearson-product-moment correlation coefficients were calculated to assess the strength and direction of relationships between the Braden Scale subscale scores and movement parameters. Lastly, predictive analyses using OLS regressions were performed to examine the effects of Braden Scale Sensory Perception, Mobility, and Activity subscale scores on movement parameters. Results of these RQ2 analyses are reported in the separate sections that follow.

Braden Scale Sensory Perception Subscale Score Characteristics and Associations Relative to Mobility and Activity Subscale Scores

The Braden Scale Sensory Perception subscale score frequency distributions and associations relative to the Mobility and Activity subscale scores of NH residents were statistically and clinically significant when performing bivariate analyses (Table 10). Contingency tables showed Sensory Perception ratings of residents were skewed toward higher scores compared to the Mobility and Activity subscale score distributions, and no Sensory Perception 1 (completed limited) scores were present in the sample. Most residents (93.6%) were categorized as a Sensory Perception 4 score (no impairments) or Sensory Perception 3 score (slightly limited) and were dispersed among all Mobility and Activity subscale score groups (1-4). Sensory Perception 2 (very limited) scores were associated with Mobility 1-3 scores and Activity 1-2 scores, indicating NH residents with hindered ability to feel or communicate pain or discomfort had mobility limitations and were constrained to bed and chair activity, not walking activity. Chi-square and CMH repeated tests of independence showed the Sensory Perception subscale scores were conditionally independent and significantly related to the Mobility subscale scores [$\chi^2(6, N = 562) = 133.04$, $p < .0001$] and the Activity subscale scores [$\chi^2(6, N = 562) = 83.69$, $p < .0001$] for each NH resident. Rank-order correlation between

Table 10

Correspondences Between Braden Scale Mobility and Activity Subscale Scores with Sensory Perception Subscale Scores (N = 562)

Mobility and Activity Subscale Scores	Subscale Distributions					Subscale Associations	
	Sensory Perception Subscale Scores				Total		
	1 N (%)	2 N (%)	3 N (%)	4 N (%)	N (%)	χ^2,	r_s
Mobility 1 N (%)	0 (0.00)	2 (0.36)	9 (1.60)	4 (0.71)	15 (2.67)	133.04, <.0001	.45
Mobility 2 N (%)	0 (0.00)	29 (5.16)	58 (10.32)	62 (11.03)	149 (26.51)		
Mobility 3 N (%)	0 (0.00)	5 (0.89)	49 (8.72)	133 (23.67)	187 (33.27)		
Mobility 4 N (%)	0 (0.00)	0 (0.00)	20 (3.56)	191 (33.99)	211 (37.54)		
Activity 1 N (%)	0 (0.00)	6 (1.07)	14 (2.49)	13 (2.31)	33 (5.87)	83.69, <.0001	.38
Activity 2 N (%)	0 (0.00)	30 (5.34)	89 (15.84)	156 (27.76)	275 (48.93)		
Activity 3 N (%)	0 (0.00)	0 (0.00)	26 (4.63)	121 (21.53)	147 (26.16)		
Activity 4 N (%)	0 (0.00)	0 (0.00)	7 (1.25)	100 (17.79)	107 (19.04)		
Total N (%)	0 (0.00)	36 (6.41)	136 (24.20)	390 (69.40)	562 (100.00)		

Note. % denotes percentage of observations in that category out of all non-missing observations in the sample and is presented in parentheses.

Sensory Perception and Mobility subscale scores was moderate (r_s = .45) and Sensory Perception and Activity subscale scores was weak (r_s = .38). The positive monotonic relationships suggest that Braden Scale measures of sensory perception tend to move in the same relative direction as measures of mobility and activity, but not necessarily at a constant rate. Results of these analyses showed similarities in how the Sensory Perceptions subscale scores related to both Mobility subscale scores and Activity subscale scores for the NH residents, which support hypothesized relationships among sensory perception, mobility, and activity in this study's theoretical framework and the Braden Scale's conceptual model for the etiology of PrIs.

Correlation Analyses of Braden Scale Sensory Perception, Mobility, and Activity Subscale Scores and Movement Parameters

Bivariate Pearson-product-moment correlations were estimated to determine the extent to which the NH resident Braden Scale Sensory Perception, Mobility, and Activity subscale and PM system movement parameter measures were associated and explore how the multiple measures of mobility, activity, and sensory perception constructs are related to answer the first part of RQ2. The correlations were expected to be higher among measures obtained from the same measurement method (e.g., *Braden Scale* Mobility and Activity subscale scores, *PM system* upright and ambulating movement parameters) than among measures obtained from different measurement methods (e.g., *Braden Scale* subscale scores and *PM system* movement parameters from indirect, subjective assessment ratings by nurses and direct, objective measurement by accelerometry, respectively). Correlations were expected to be lower among Sensory Perception subscale scores and movement parameters given sensory perception is hypothesized to *indirectly* influence movement.

Braden Scale subscale score results of the Pearson correlation analyses (Table 11) showed there were significant positive associations between Mobility, Activity, and Sensory Perception subscale scores of the sample. Strong correlation between Mobility and Activity subscale scores [$r(561) = .72$, $p < .0001$] indicate these measures of NH resident mobility and activity tended to increase or decrease concurrently. Sensory Perception subscale scores had moderate correlation with Mobility subscale scores [$r(561) = .46$, $p < .0001$] and weak correlation with Activity scores [$r(561) = .37$, $p < .0001$], suggesting that while these subscale measures move together in the same direction, the connection of sensory perception is not strong to either mobility or activity of NH residents using Braden Scale assessment.

Movement parameter Pearson correlation results of the sample showed significant associations among all PM system measures except mean lying frequency/day, which was not significantly related to total ambulating minutes/day [$r(561) = -.04$, $p = .3548$] and total ambulating frequency/day [$r(561) = -.04$, $p = .3537$] (Table 11, exact *p*-values not tabled). Additionally, coefficient sizes less than .30 indicated there were weak correlations between mean lying frequency/day and the other movement parameters. A high, positive, linear relationship resulting between total ambulating time (min)/day and total ambulating frequency/day [$r(561) =.75$, $p < .0001$] was unexpected. It was hypothesized that NH residents who walked for long durations would walk less often, thus ambulating duration and frequency would be inversely related. Conversely, expected high or moderate negative correlations were found between contrasting body orientation parameter measurements [e.g., mean upright time (min)/day versus mean lying time (min)/day, [$r(561) = -.98$, $p < .0001$]. The duration NH residents were lying in beds/chairs was strongly inversely related to how long and how often the residents were upright or walking.

Table 11

Correlations of the Braden Scale Mobility, Activity, and Sensory Perception Subscale Scores and Movement Parameters (N = 562)

Variable	1	2	3	4	5	6	7	8	9
1. **Braden Scale: Mobility Subscale Score**	-	.72**	.46**	-.39**	.04	.33**	.50**	.38**	.51**
2. **Braden Scale: Activity Subscale Score**		-	.37**	-.38**	-.08	.31**	.47**	.47**	.59**
3. **Braden Scale: Sensory Perception Subscale Score**			-	-.19**	.03	.16**	.31**	.38**	.27**
4. **MEAN Lying Time (min)/Day**				-	.25**	-.98**	-.66**	-.28**	-.40**
5. **MEAN Lying Frequency/Day**					-	-.23**	.14**	-.04	-.04
6. **MEAN Upright Time (min)/Day**						-	.65**	.12**	.24**
7. **MEAN Upright Frequency/Day**							-	.27**	.43**
8. **TOTAL Ambulating Time (min)/Day**								-	.75**
9. **TOTAL Ambulating Frequency/Day**									-

Note. $^{*}p < .05$, $^{**}p < .01$

Braden Scale subscale scores and movement parameters of the sample analyzed using Pearson correlation revealed the relationships between the study measures varied in significance, strength, and direction (Table 11). There were significant positive bivariate associations between each of the Braden Scale Mobility, Activity, and Sensory Perception subscale scores and each of the mean upright and total ambulating movement parameters. These results showed that as NH resident subscale scores increased, the durations and frequencies the residents were sitting up/standing or walking also increased. Conversely, decreases in the Mobility, Activity, and Sensory Perception subscale scores separately corresponded with increases in the average lying times of NH residents. While there were significant negative weak correlations found between mean lying time (min)/day and each of the Braden Scale subscale scores, the relationships were not significant between mean lying frequency/day and NH residents' subscale scores for Mobility, $p = .3457$, Activity, $p = .0755$, and Sensory Perception, $p =.5076$ (untabled). Overall, moderate positive correlations resulted between each of the movement parameters and the Mobility subscale scores and between the movement parameters and the Activity subscale scores of the sample. Significant weak correlations were generally found between the Sensory Perception subscale scores and each of the movement parameters, indicating the extent to which NH residents had an ability to feel and communicate discomfort was associated, but not strongly connected, with how much the residents moved. These findings were expected given sensory function indirectly influences movement, whereas motor function (i.e., mobility and activity) directly influences movement. Results of bivariate Pearson-product-moment correlation analyses provided foreshadowing of study variable relationships that were further explored in the OLS regression analyses to understand how the Braden Scale Mobility, Activity, and Sensory

Perception subscale scores individually and collectively predict NH resident movement to answer the second part of RQ2.

Predictive Analyses of Movement Parameters Using the Braden Scale Mobility, Activity, and Sensory Perception Subscale Scores

Ordinary least squares regression analyses were used to determine the extent to which NH resident movement parameters could be predicted by Braden Scale Mobility, Activity, and Sensory Perception subscale score groups individually and explored if the relationships examined in RQ1 were moderated by subscale scores of Sensory Perception, as theorized in this study's conceptual model. The OLS regression analyses tested for main and interactive effects of the Sensory Perception subscale scores using Sensory Perception 4 (no impairment) as the reference group to answer the second part of RQ2.

The relationships between the Braden Mobility and Activity subscale scores and the movement parameters did not significantly change when the main effects of Braden Scale Sensory Perception subscale scores as independent predictor variables were tested in the bivariate OLS regression analyses (Table 12). There were significant regression equations found between the Mobility, Activity, and Sensory Perception subscale and movement parameter measures of the NH residents (p = .0014 for mean lying frequency/day; $p < .0001$ for all other movement parameters, untabled). The regression coefficients estimating the unknown population parameters changed in comparison to the RQ1 OLS regression results when Sensory Perception subscale scores of the sample were added to the models. However, the amount the estimates changed was not significant enough to affect the strength and direction of the relationships between Mobility and Activity subscale scores and mean movement parameters. Sensory Perception subscale scores of the NH residents did not account for any significant differences in

Table 12

Effects of Braden Scale Sensory Perception, Mobility, and Activity Subscale Scores on Movement Parameter Prediction (N = 562)

Movement Parameter Dependent Variable	**Predictor: Braden Scale Subscale Score**	**B**	***SE***	***t***	***p***	***R*²**
MEAN Lying Time (min)/Day	**Mobility 1**	163.42	72.11	2.27	.0238	.2070
	Mobility 2	135.34	38.31	3.53	.0004	
	Mobility 3	25.38	30.47	0.83	.4052	
	Activity 1	320.51	58.70	5.46	<.0001	
	Activity 2	98.58	38.16	2.58	.0100	
	Activity 3	8.88	32.66	0.27	.7857	
	Sensory Perception 2	-3.28	45.11	-0.07	.9421	
	Sensory Perception 3	-13.39	25.56	-0.52	.6005	
MEAN Lying Frequency/Day	**Mobility 1**	-50.01	25.21	-1.98	.0478	.0444
	Mobility 2	-34.50	13.40	-2.58	.0103	
	Mobility 3	-11.75	10.65	-1.10	.2706	
	Activity 1	95.23	20.52	4.64	<.0001	
	Activity 2	26.95	13.34	2.02	.0439	
	Activity 3	14.66	11.42	1.28	.1998	
	Sensory Perception 2	5.08	15.77	0.32	.7474	
	Sensory Perception 3	-10.66	8.94	-1.19	.2335	
MEAN Upright Time (min)/Day	**Mobility 1**	-159.94	72.71	-2.20	.0282	.1717
	Mobility 2	-124.60	38.63	-3.23	.0013	
	Mobility 3	-15.03	30.73	-0.49	.6250	
	Activity 1	-267.26	59.20	-4.51	<.0001	
	Activity 2	-44.66	38.48	-1.16	.2463	
	Activity 3	38.78	32.93	1.18	.2395	
	Sensory Perception 2	1.96	45.48	0.04	.9657	
	Sensory Perception 3	15.58	25.78	0.60	.5457	
MEAN Upright Frequency/Day	**Mobility 1**	-147.45	45.75	-3.22	.0013	.2897
	Mobility 2	-134.22	24.31	-5.52	<.0001	
	Mobility 3	-60.10	19.33	-3.11	.0020	
	Activity 1	-140.60	37.24	-3.78	.0002	
	Activity 2	-75.20	24.21	-3.11	.0020	
	Activity 3	-12.92	20.72	-0.62	.5332	

Movement Parameter Dependent Variable	**Predictor: Braden Scale Subscale Score**	**B**	***SE***	***t***	***p***	R^2
	Sensory Perception 2	-53.07	28.62	-1.85	.0642	
	Sensory Perception 3	-18.62	16.22	-1.15	.2514	
TOTAL Ambulating Time (min)/Day	**Activity 1**	-74.58	9.91	-7.53	<.0001	.2518
	Activity 2	-69.68	5.74	-12.14	<.0001	
	Activity 3	-52.43	6.12	-8.57	<.0001	
	Sensory Perception 2	-8.11	8.74	-0.93	.3540	
	Sensory Perception 3	-6.92	5.01	-1.38	.1677	
TOTAL Ambulating Frequency/Day	**Activity 1**	-20.16	1.99	-10.14	<.0001	.3667
	Activity 2	-17.77	1.15	-15.42	<.0001	
	Activity 3	-10.04	1.23	-8.18	<.0001	
	Sensory Perception 2	-2.62	1.75	-1.49	.1359	
	Sensory Perception 3	-1.41	1.01	-1.40	.1630	

Note. Degrees of freedom were (8,553). Variables were significant at the .05 level in the model. Mobility 4, Activity 4, and Sensory Perception 4 were the reference groups.

the movement parameter outcomes predicted by Mobility and Activity scores as evidenced by the proportion of the variance for the mean movement parameters ($.0444 \leq R^2 \leq .3667$) explained by the Braden Scale subscale scores increasing less than one percent from the results of the RQ1 OLS regression analyses ($.0412 \leq R^2 \leq .3628$). There were no NH residents in the study sample with a Sensory Perception 1 score (completely limited) available for use in these predictive analyses. This meant variations in movement of residents totally unable to feel and communicate discomfort and those with no sensory impairments could not be analyzed. The individual Sensory Perception subscale scores of 2 (very limited) and 3 (slightly limited) were not statistically significant predictors ($p > .05$) of any movement parameters with respect to the Sensory Perception subscale score of 4 (no impairment) reference group and did not have any main effects on the model as independent variables. Therefore, OLS regression analyses using Sensory Perception subscale scores as interactive terms with the Mobility and Activity subscale scores were not performed.

The OLS regression analysis results showed Sensory Perception subscale measures were not significant confounders in predictive relationships between the Mobility and Activity subscale and movement parameter measures of NH residents to answer RQ2. This provided additional evidence to support the convergent construct validity of the Braden Scale Mobility and Activity subscales.

Summary

The results from the analyses performed consistently showed scores of the Mobility and Activity subscales from nursing Braden Scale assessments measure discrete, yet related dimensions that are good at explaining what is actually occurring among NH residents with regard to movement parameters measured using wearable accelerometers. The variation in the degree of movement parameter changes (beta coefficient values) among NH residents within different Mobility and Activity subscale score groups (1-4) followed expected patterns in the OLS regression analyses and were supported by statistically significant differences in movement parameter means among the subscale score groups resulting in the ANOVA and Tukey's tests. Evidence of monotonic relationships observed between the Braden Scale and PM system measurements' values in the bivariate RQ analyses showed the Mobility and Activity subscale scores and movement parameters corresponded with each other and converged as measures of similar mobility and activity constructs. The Braden Scale Sensory Perception subscale scores significantly correlated with Mobility and Activity subscale scores but were not statistically significant predictors of movement outcome variables.

CHAPTER 5: DISCUSSION

This study is the first to demonstrate the convergent construct validity of the Braden Scale Mobility and Activity subscales using triaxial accelerometry and nursing assessment measurements of residents' mobility and activity in U.S. NHs. Valid measures from assessment of PrI risk constructs in the Braden Scale Mobility and Activity subscales are essential to help nurses accurately identify at-risk NH residents and appropriately plan customized care, prioritize tasks, and deploy available resources to prevent PrI development. The Braden Scale is widely used and has been extensively studied as a measure of PrI risk since it was first developed in 1987 to facilitate nursing staff efforts to decrease incidence of PrIs in NHs (Braden & Bergstrom, 1989). Yet, national PrI incidence rates for individuals in aged care have remained relatively stagnant over the years (CMS, 2022), despite increased medical knowledge and new, effective prevention and treatments (Zhang et al., 2021). Growing interest in understanding how the Braden scale measures PrI risk and can be best used in clinical practice has sparked concerns about gaps in evidence that exist regarding validity of the scale. Advancements in movement sensor technology and data analytics enabled investigation of these gaps. This study examined how resident mobility and activity compared to movement data from triaxial accelerometers relate to Braden Scale Mobility and Activity subscale scores from nursing assessments. The new knowledge generated helps to address gaps in validity evidence and respond to questions about the accuracy of PrI risk assessment in NHs. This section discusses key features of the sample, primary findings, and data analytics used in this study about the Braden Scale Mobility and Activity subscale's convergent construct validity.

The composition and size of the study sample was appropriate to effectively answer the research questions and supported the validity and generalizability of the findings. Preliminary analyses determined the effective sample was homogenous with respect to the true values of the Braden Scale variables being studied (i.e., Mobility and Activity subscale scores), which contributed to the consistency of the findings. Additionally, the sample was clinically diverse enough to find statistical differences between the Braden Scale Mobility and Activity subscale scores and PM system movement measurements. Exploration of the NH residents' descriptive characteristics showed that variability in the sample reflected heterogeneous populations common in real life, which lends support to the transferability of findings to other NH settings. Demographic characteristics of the NH residents in this study (N = 562) differed for age, gender, and race but were similar with respect to ethnicity (Table 5). These findings are representative of currently reported U.S. NH resident characteristics: aged 65 years or older (88%), female gender (71%), White race (86%), and not Hispanic or Latino (96%) (National Center for Health Statistics, 2015). Braden Scale characteristics revealed the sample's overall PrI risk was mild (mean Braden Scale total score average = 17.53, Table 5) and this finding is consistent with results from other Braden Scale validity studies of residents in U.S. NHs (Braden & Bergstrom, 1994; Bergstrom & Braden, 2002). The large sample contained NH residents categorized among all of the Mobility and Activity subscale score groups (1-4) enabling the analysis of the full range of mobility and activity characteristics measured by these Braden Scale subscales. Movement parameter characteristics describing lying, upright, and ambulating durations and frequencies of NH residents aligned with the Mobility and Activity subscale characteristics according to the Braden Scale score descriptors and were similar to reported findings in literature. For example, results showing residents spent most of the day lying in a bed or reclining in a chair were expected given it is common to find NH residents sitting or lying down for long periods of time even though capable of ambulating by walking or wheelchair propelling independently (MacRae et al., 1996). Overall, the heterogeneity of the study sample enhanced the quality and trustworthiness of findings from this research.

The novel approach of using objective movement measurements generated new knowledge about mobility and activity constructs of PrI risk measured in the Braden Scale. Movements quantified by triaxial accelerometers provided rich measurements useful for evaluating different categories (1-4) of mobility and activity defined in the Braden Scale Mobility and Activity subscales. The multiple metrics (e.g., roll orientation angles, tilt angles, steps) *simultaneously* measured by the accelerometers and summarized by the PM system coincided with Mobility and Activity subscale category descriptors of body orientations and movement parameters. Thus, the movement measurements were appropriate to compare with Mobility and Activity subscale scores collected from a single Braden Scale assessment that included appraisal of each resident's mobility and activity. Empirical testing of Braden and movement data at the individual resident-level enabled verification of the hypothesized conceptual relationships between the mobility, activity, and movement. New insights were gained about the theorized relationships presented in this study's conceptual model. More specifically, a strong relationship ($r = .72$, $p < .0001$) was demonstrated between mobility and activity, and both concepts were significantly related to all movement parameters ($p < .0001$ except for mean lying frequency/day). The findings suggested that the length of time NH residents spent lying, sitting upright, or walking were better representations of the mobility and activity constructs than how often residents were lying in bed or reclining in chairs during the day. The breadth of measurement detail found in movement parameter data also enabled detection of differences among NH residents in the Mobility and Activity subscale groups (scores 1-4).

To date, no other research has used objective movement data to examine convergent construct validity of the Activity subscale. One prior study by Powers et al. (2004) did examine convergent construct validity of the Braden Scale Mobility subscale using movement data. Powers' work relative to the Mobility subscale only found significant differences when comparing Mobility 4 to Mobility 1, 2, or 3 and may have been constrained, as well, by small sample size and only a 3-day movement data collection period. Significant differences that emerged in the current study between pairwise comparisons of Mobility and Activity subscale 1-4 score categories were likely due to the more granular level of detail (i.e., position duration and frequency) provided by use of a triaxial accelerometer rather than a uniaxial device in the prior research by Powers et al. (2004). Comparisons of measurements of movement on multiple axes afforded by these accelerometers are useful for examining the effectiveness and clinical utility of Mobility and Activity subscale measures in evaluating PrI risk. Mobility and Activity subscale scores were demonstrated to be valid representations of expected movement, thus heightening their potential to inform clinical care decisions nursing staff make about repositioning and length of time one is in a position. Repositioning is a common, resource-intensive intervention aimed at reducing the duration and intensity of pressure over vulnerable areas of the body (NPUAP et al., 2014) and key recommendation of all PrI prevention guidelines. Repositioning is implemented in approximately 16% of residents in daily practice may be attributed to high, physical workloads and the reluctance of staff to disturb the sleep or privacy of residents (Stone, 2020) despite repositioning being a standard prevention procedure in NH residents at risk for PrIs. Staff skill, knowledge, and beliefs about consequences and the NH environment (e.g., finite resources, understaffing, transient workforce) are potential barriers to repositioning (Lavallée et al., 2018). New knowledge about the accuracy of Braden Scale PrI risk measurement from this research can empower staff to have confidence in using residents' Mobility and Activity subscale scores when making important decisions about how often to move or assist residents in repositioning and developing individualized care plans for residents. Furthermore, the mobility and activity subscale scores could form the basis for developing care planning algorithms for the purpose of tailoring prevention care to the individual resident. Burdens placed on NHs are expected to intensify as the numbers of aging adults increase and compound long-standing workforce issues that affect resident care quality and safety, such as PrI prevention. These growing pressures emphasize the importance of accurate risk assessment to ensure residents continue to receive appropriate care services in NHs.

Strong evidence of the convergent construct validity of the Braden Scale Mobility and Activity subscales was demonstrated by consistent empirical findings from multiple statistical analyses confirming the Mobility and Activity subscale scores individually and collectively explained and predicted movement outcomes of NH residents in congruence with the Braden Scale's score descriptors and structure. Nurses' subjective interpretations of the Braden Scale PrI risk assessment score descriptors for each subscale (Mobility scores, Activity scores) were correspondingly differentiated in most pairwise score comparisons (Tukey's tests) for residents with and without mobility and activity limitations. Monotonic relationships found in the OLS regression analyses suggested the Braden Scale Mobility and Activity subscale score definitions and ordinal rankings accurately described different movement parameters and levels of mobility and activity of NH residents. The linkages of empirical findings to concepts and relationships in this research's guiding model (Figure 1) and Braden and Bergstrom's theory (1987) underpinning the Braden Scale's development attested to the truth of the findings about the convergent validity of the Braden Scale Mobility and Activity subscales.

This was the first study to empirically test theorized connections among the Braden Scale Mobility, Activity, and Sensory Perception subscales using objective quantified movement data from accelerometers. The subscale scores emerged as significant predictors of resident movement parameters ($p < .0014$ for mean lying frequency/day and $p < .0001$ for other movement parameters) which supported the hypothesized (Figure 1) interconnections between mobility, activity, sensory perception, and movement relative to the development of PrIs. Sensory perception, first conceptualized by Braden and Bergstrom (1987) as a factor influencing pressure duration and intensity in the etiology of PrIs, is believed to interface with mobility and activity through sensorimotor feedback loops to influence movement. Findings from descriptive and bivariate analyses confirmed NH residents' Sensory Perception subscale scores corresponded with scores of the Mobility ($r = .46$, $p < .0001$) and Activity subscales ($r = .37$, $p < .0001$) and movement parameters ($p < .0001$, except for mean lying frequency/day) and empirically supported conceptualized relationships in this study's model and the theoretical foundation of the Braden Scale (Braden & Bergstrom, 1987). These findings were consistent with scientific evidence showing pressure on the body tissue ultimately leads to discomfort and pain that stimulates an individual to move (Asvar et al., 2020). Examination of predictive relationships among these Braden Scale subscale scores and NH resident movement outcomes facilitated a deeper understanding of how mobility, activity, and sensory perception related to movement and provided additional insights into the connections between these Braden Scale subscale constructs. Differences in the Mobility and Activity subscale scores had significant effects on changes in mean movement parameters ($p < .05$), whereas Sensory Perception subscale scores had no main effect ($p > .05$). Overall, these findings supported mobility and activity were directly connected to each other, sensory perception, and to movement and suggested sensory perception was indirectly connected to movement. Exploration of the interrelatedness of the Braden Scale Mobility, Activity, and Sensory Perception subscale scores was limited to NH residents with a Sensory Perception subscale score of 2, 3, and 4, which indicated residents had at least some ability to respond to discomfort per the Braden Scale, and may explain why sensory perception did not result as a significant predictor of resident movement outcomes in the OLS regression model. More research of how Braden Scale measurements of mobility, activity, and sensory perception are related to movement for residents with a Sensory Perception subscale score of 1 (completely limited) who are described as unresponsive or have limited ability to feel pain may help broaden understanding of sensory perception's exact contribution to movement in relation to mobility and activity motor function of NH residents.

Strengths and Limitations

Multiple methodological strengths enhance the quality of study findings and minimized validity threats posed by using a retrospective, non-experimental design, and previously collected TEAM-UP trial data. Selection of a large, recently collected, existing data set originally obtained from NH residents in different locations in real-life increases the external validity of findings from this secondary analysis study. Rigorous methods applied in designing and performing that research, such as intervention protocols and fidelity checks, and the expertise of the original study's research team minimized the threats to the internal validity of the clinical trial. Strategies to ensure appropriate study design, data management, analysis, and sample size for this study included early involvement of the biostatistician, the PI, co-author of the Braden Scale, and other experienced team members from the TEAM-UP study.

Nursing home resident attrition was expected and taken into consideration when selecting the convenience sample. Limitations of using a convenience sample were minimized through use of effective sample size analyses of Braden Scale Mobility and Activity subscale score characteristics examined in this study. However, the full range of Sensory Perception subscale scores were not present in the sample and may have biased the results of the Sensory Perception subscale characteristics and regression analyses in this study. The exclusion of NH residents with Braden Scale total scores $\leq$ 9 (severe PrI risk) in the TEAM-UP trial may account for the absence of residents rated with a Sensory Perception subscale score 1 (completed limited).

Statistical power analyses and effective sample size analyses confirmed this study's sample size was sufficiently large enough to find clinically and statistically significant relationships for drawing valid conclusions from the results of the statistical tests to accurately answer RQs about the convergent construct validity of the Braden Scale Mobility and Activity subscales. Defining the movement parameters from the PM system by full 22-hour days enabled examination of nighttime behaviors influencing movement that may not be observed by nursing staff (e.g., dementia-related nocturnal agitation, bathroom activity, or sexual activity) to provide a fuller picture of NH resident mobility and activity. Extensive data preparation resolved potential issues with missing data, mismatched time window, removed inaccurate or clinically implausible data, and verified accuracy. The full range of Mobility and Activity subscale values (scores 1-4) in Braden Scale measurement was represented in comparisons with the movement data, which strengthened conclusions about the convergent construct validity of the Braden Scale Mobility and Activity subscales. Imputation of mean walking for three residents with no ambulating minutes represented less than one percent of the sample (0.53%) and was not expected to have biased results. Collectively, these strategies produced a complete data set while preserving the sample size, reducing standard errors, and facilitating accurate estimates of associations in the analyses (Peterson & Martin, 2016). Furthermore, statistical assumptions of tests were met and enhance the validity of inferences drawn from statistical test results of this research.

Future Research

Future research using alternative bivariate and multivariate analyses is needed to further explore the associations among the Braden Scale Sensory Perception, Mobility, and Activity subscale scores and in relation to movement parameters in order to provide new insights into the persistence of PrIs in NH residents. For example, how Sensory Perception interaction varies with movement data compared to variations of Activity and Mobility (e.g., Sensory Perception 2/Activity 1) may be determined through bivariate correlation analyses using binary combinations of the Braden Scale subscale scores. Running multivariate regression analyses with only the Sensory Perception subscale scores as predictor variables with movement parameters as outcome variables could be used to assess any direct effects of Sensory Perception and test theorized relationships (Figure 1); thus, enabling to further refinement the model based on the findings. Future research replicating this study with different samples and in different settings should be performed to see if similar results are obtained. Conducting this study with hospital patients or residents of long-term acute care facilities that are vulnerable to PrI development may facilitate deeper understanding of the Braden Scale's accuracy in measuring PrI risk among individuals with mobility, activity, sensory perception limitations (low subscale scores) or movement restrictions that were not observed in the NH setting. Specifically, Sensory Perception subscale scores of 1 (completely limited) that were not represented in this study's sample are likely to be found in acute care settings where individuals may have diagnoses associated with central sensory impairments or the ability to perceive or respond to pressure-related discomfort (e.g., coma, sedation, anesthesia, paralysis). Individuals with spinal cord injuries have a high risk of developing PrIs due to motor and sensory impairments (Shiferaw et al., 2020). Also, replicating this research with samples comprised of younger and older individuals in the SCI population may enable exploration of any confounding effects of age differences on relationships among sensory perception, mobility, activity.

Conclusion

The unique approach of comparing an objective gold standard for human movement measurement (accelerometers) with Braden Scale measurements (scores) presented in this secondary data analysis study generated theoretically and empirically-supported evidence of the convergent construct validity of the Braden Scale Mobility and Activity subscales. The consistency of findings from the multiple statistical tests analyzing relationships among NH residents' Braden Scale Mobility, Activity, and Sensory Perception subscale scores and PM system movement data in this study strengthens conclusions about the convergent construct validity of the Braden Scale Mobility and Activity subscales. Findings from this study show that when nurses assessed NH resident mobility and activity using Braden Scale Mobility and Activity subscales, the measurements agreed very highly with what sensors worn by the NH residents measured with regard to the duration and frequency of lying, upright, ambulating movements. The Braden Scale Mobility and Activity subscales' category structure and definitions were a good match with the movement parameter sensor data. These findings indicate that subscale ratings assigned by nursing staff accurately represented the movements of NH residents assessed and reinforces the confidence one can have in nursing staff use of the Braden Scale for PrI risk assessments. Mobility and Activity subscale scores are a valid measure for staff to use to guide care planning of interventions aimed at promoting mobility and activity, such as repositioning and walking. Future investigation should further examine what the Sensory Perception subscale is measuring and how that construct is connected to movement associated with PrI etiology.

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APPENDIX A: NOTIFICATION OF DUHS IRB APPROVAL

DukeHealth
Institutional Review Board

DUHS INSTITUTIONAL REVIEW BOARD NOTIFICATION OF AMENDMENT APPROVAL

Protocol ID: Pro00069413
Reference ID: 314432
Principal Investigator: Yap, Tracey
Protocol Title: Preventing pressure ulcers with repositioning frequency and precipitating factors
Sponsor/Funding Source(s): Leaf Healthcare Incorporated, National Institute of Nursing Research
Federal Funding Agency ID:
Date of Declared Concordance with federally funded grant, if applicable:

The Duke University Health System Institutional Review Board for Clinical Investigations has conducted the following activity on the study cited above:
Activity: Amendment **Review Type:** Expedited
Review Date: 04/29/2019
Issue Date: April 30, 2019
Expiration Date: 02/24/2020

DUHS IRB approval encompasses the following specific components of the study:
Protocol, version/date:
DUHS IRB Application version: **1.10**
Consent form reference date:
Investigator Brochure, version/date:
Pediatric Risk Category:
Other: Add Christine Barnes to external KP

The DUHS IRB has determined the specific components above to be in compliance with all applicable Health Insurance Portability and Accountability Act ("HIPAA") regulations.

This study expires at 12 AM on the Expiration Date cited above. At that time, all study activity must cease. If you wish to continue specific study activities directly related to subject safety, you must immediately email Jody Power at jody.power@duke.edu or call the IRB Office at 919-668-5111 and follow the instructions to reach the IRB Chair on call. Continuing review submissions (renewals) must be received by the DUHS IRB office 60 to 45 days prior to the Expiration Date.

No change to the protocol, consent form or other approved document may be implemented without first obtaining IRB approval for the change. Any proposed change must be submitted as an amendment. If necessary in a life-threatening situation, where time does not permit your prior consultation with the IRB, you may act contrary to the protocol if the action is in the best interest of the subject. You must notify the IRB of your action within five (5) working days of the event.

The Duke University Health System Institutional Review Board for Clinical Investigations (DUHS IRB), is duly constituted, fulfilling all requirements for diversity, and has written procedures for initial and continuing review of human research protocols. The DUHS IRB complies with all U.S. regulatory requirements related to the protection of human research participants. Specifically, the DUHS IRB complies with 45CFR46, 21CFR50, 21CFR56, 21CFR312, 21CFR812, and 45CFR164.508-514. In addition, the DUHS IRB complies with the Guidelines of the International Conference on Harmonization to the extent required by the U. S. Food and Drug Administration.

DUHS Institutional Review Board
2424 Erwin Rd | Durham, NC | 919.668.5111
Federalwide Assurance No: FWA 00009025Suite 405 |