NURSE STAFFING AND PATIENT OUTCOMES IN THE REHABILITATION SETTING: APPLICATION OF PRODUCTION FUNCTION THEORY

By

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This document is dedicated to sagacious and pertinacious advocates for nurses and those entrusted to their care.

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As the United States (US) experienced a sustained nursing shortage, health care policy makers and health care administrators, legislators, and researchers increasingly focused on minimum nurse staffing standards, cost of nursing care, and the relationship between nurse staffing and patient outcomes. A model for nurse staffing that encourages both cost efficiency and outcome effectiveness is elusive. One approach is to use a production function to examine the relationship between nurse staffing and patient outcomes. Production function relationships are used extensively in business to determine a range of resources needed to produce a quality product. There is a paucity of research investigating the impact of nurse staffing on patient outcomes in the rehabilitation setting. Therefore, the specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting . Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined utilizing hierarchical linear modeling. This study was a secondary analysis of a parent study, *Nurse Staffing and Patient Outcomes in Inpatient Rehabilitation Setting* (Nelson, et al., 2007).

The hypothesis that there is a nonlinear relationship between RN HPPD and Non-RN HPPD with patient outcomes of LOS and FIM™ change is supported. Both HPPD estimates indicate that the relationships to LOS and FIM™ change direction. Therefore, the nature of the curvilinear relationship of nurse staffing and patient outcomes approximated a model of production function and diminishing returns.

This study adds to the growing body of knowledge of nurse staffing and patient outcomes in the rehabilitation setting. This study provides further evidence that nurse staffing and patient outcomes have both a "floor" and a "ceiling". These are both inflection points at which quality and efficiency are sacrificed. Further research is imperative to provide leaders in health care the ability to generate data-driven and evidence based practice decisions for optimal quality and efficiency.

CHAPTER 1
INTRODUCTION

Problem Statement

As the United States (US) experienced a sustained nursing shortage; attention to healthcare reform from health care administrators, legislators, and researchers increasingly focused on minimum nurse staffing standards, cost of nursing care, and the relationship between nurse staffing and patient outcomes. Despite this widespread attention, an efficient model for nurse staffing that is both cost efficient and outcome effective has proved to be elusive. Production function relationships are used extensively in business firms to determine a range of resources needed to produce a product at acceptable cost and quality. There is a small body of research that suggests that a production function relationship between nurse staffing and patient outcomes may be plausible. In Chapter 1 the purpose, the background and significance related to the phenomena of focus and theoretical framework will be discussed.

Purpose

The specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting . Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined.

Variables

The predictor variables are nurse staffing levels. The predictor variables are further delineated as staffing levels of Registered Nurse hours per patient day (RN HPPD), Non-RN HHPD: Licensed Practical Nurse/ Nurse's Aide (LPN/NA), total staffing hours per patient day

(THPPD), and skill mix (RN Proportion and non-RNs). The dependent variables are patient outcomes. Patient outcomes are measured in two ways in this study: Length of stay (LOS) and change in Functional Independence Measure FIM™ (FIMCHG). FIM™ change was defined and calculated from the total Functional Independence Measure score on discharge and total FIM™ score on admission.

Background and Significance

Before the interest in medical errors was brought to the forefront in the Institute of Medicine's (IOM) report, *To Err is Human: Building a Safer Health System* (1999), nurses in the United States (US) reported that cost cutting and hospital redesign initiatives by hospitals reduced nurse staffing to unsafe levels (Shindul-Rothschild, Berry, & Long- Middleton, 1996). Subsequently, Congress expressed its concern for the state of health care by mandating the Institute of Medicine to study nurse staffing adequacy in hospitals and nursing homes (Institute of Medicine, 1996). The IOM galvanized the importance of improving the work environment of nurses and nurses' role in safe patient care in its third report, *Keeping Patients Safe: Transforming the Work Environment of Nurses* (2004).

Simultaneously, the impetus for the shift from error orientation ("negative outcomes" such as mortality) to nurse-sensitive outcomes (decreased length of stay or improvement of functional status) occurred when the American Nurses Association (ANA) published its pivotal study: *Implementing Nursing's Report Card: A Study of RN Staffing, Length of Stay, and Patient Outcomes* (1997). The ANA established indicators and outcomes specifically considered "nurse sensitive" which has served as a standard for subsequent research and has further explicated these relationships.

In reaction to the additional growing concern related to nurse staffing and quality of patient care, the American Nurses Association convened a nursing summit of national nursing

organization representatives to develop a strategic and tactical plan. In *Nursing Agenda for the Future: A Call to the Nation,* (American Nurses Association, 2002) evidence based research related to the quality, value, and cost of nursing services was prioritized. The value of nurse staffing to patient outcomes research was emphasized as a primary strategy.

In testimony to the US Senate, the U.S. General Accounting Office (2001) testimony united the concern to evaluate the efficiency of nursing practice, within the context of eroding resources. It also proactively and empirically addressed the impact of the range of nursing care hours at the bedside for optimal patient care. Empirically, national and international systematic reviews of nursing and health services research have demonstrated that identifying the impact of nurse staffing to patient outcomes is paramount to support administrative, fiscal, and political decisions regarding a safe and optimal care environment (Kane, Shamliyan, Mueller, Duval, & Wilt, 2007; Lang, Hodge, Olsen, Romano, & Kravitz, 2004; Lankshear, Sheldon, & Maynard, 2005). In spite of the progress made with health services and nursing researchers providing cogent data to inform evidence based decision making, the current political and fiscal focus on healthcare reform threatens to further erode the core of patient care.

Garnered by the work produced until 2008, the IOM and the Robert Wood Johnson Foundation (RWJF), recognizing nursing as the largest portion of the US healthcare workforce, collaboratively initiated an investigation to assess and make recommendations to transform the future of nursing. Pivotal recommendations charged key stakeholders to expand opportunities for the conduction of research to improve practice environments, improve health outcomes, and reflect the contributions of nurses related to quality of care. More prescriptive recommendations were made related to the data collection for workforce requirements, including projecting for

nursing workforce requirements by role, skill mix, region and demographics (The Institute Of Medicine, 2010, p. 6).

Nursing Home and Acute Care

Within federal mandates as early as 1987, as part of the Omnibus Budget Reconciliation Act (OBRA), the federal Nursing Home Reform Act (NHRA) set minimum staffing levels for registered nurses (RNs) and licensed practical nurses (LPNs) and minimum training requirements for the education of nurses' aides (NAs) in the nursing home setting. California lead the country in 1999 by establishing state mandates for minimum nurse-patient ratios in acute care (Coffman, Seago, & Spetz, 2002). In response to the need for empirical data to support policy and operational decision making regarding these and subsequent mandates, research related to nurse staffing and patient outcomes has grown exponentially since the late 1980's.

Although the volume of research in the nursing home setting and acute care setting is plentiful since the late 1990's, the primary barrier to implementing this research and their conclusions is the inconsistency of the data. Health care settings utilize a variety of software packages and manual systems to capture staffing and patient outcome data. This has led to inconsistencies in the operational definitions and measurement of "nurse staffing". Further complicating this scenario is the varied and sometimes interchangeable use of the definitions and measures of "quality of patient care" and "patient outcomes". These issues have limited the comparability and generalizability of the results.

Rehabilitation

The rehabilitation setting mirrors the circumstances discussed in the nursing home setting previously. Federally mandated staffing standards were implemented without empirical evidence to support the standards. Similar to the nursing home setting, a prospective payment system was implemented for the rehabilitation industry in January 2002. This system was established by the

Centers for Medicare and Medicaid Services (CMS, 2012) and was based on a patient classification system that was generated by research from the RAND Corporation. This patient classification system uses an Inpatient Rehabilitation Facility Patient Assessment Tool that is based on the Functional Independence Measure (FIM™) to classify patients and will be detailed in the review of literature and methodology in Chapters 2 and 3.

Prior to the work of Nelson et al. (2007) there were no published studies examining nurse staffing and patient outcomes in the rehabilitation setting. A collaborative research study between the Uniform Data Systems (UDS), the Association of Rehabilitation Nurse (ARN) and the Veterans Health Administration was convened to investigate the relationship between nurse staffing and patient outcomes in inpatient rehabilitation settings (Nelson, et. al, 2007). This secondary analysis elucidates the production function of quality and nurse staffing as utilized in previous studies. More specifically, it adds to the gap in the literature related to the impact of nurse staffing in the rehabilitation setting on patient outcomes.

Nurse Staffing

There remains a critical lack of coherence in the definitions of what constitutes nurse staffing. In their reviews of national and international nurse staffing and outcomes research evidence, analysts all cited the lack of clear operational definitions of nurse staffing and inconsistencies in defining healthcare personnel as a concern (Heinz, 2004; Lang, Hodge, Olsen, Romano & Kravitz, 2004; Kane, Shamiliyan, Mueller, & Wilt, 2007; Lankshear, Sheldon, & Maynard, 2005; Spetz, Donaldson, Aydin, & Brown, 2008; Unruh, 2008; Unruh & Zhang, 2012). Deepening the concern is emerging evidence that different nurse staffing measures change the association with patient outcomes (Kane et al., 2007, p. 1199). Despite the concerns, Spetz et al. (2008) concluded that recommending a single measurement strategy for studies of nurse staffing was not possible. These authors noted the constraints of data availability as a

limitation. Further, the utilization of nursing personnel based on skill set and patient care need varies with health care settings.

Theoretical Framework

The environment of health care reform threatens the scarce and valued resource of nurses as both human and knowledge capital. Understanding the relationship between nurse staffing and patient outcomes will assist organizations to optimize this critical resource. The utilization of production function theory will provide a conceptual framework for this study and elucidate the key factors that drive nurse staffing for patient outcomes in the inpatient rehabilitation setting.

In spite of healthcare pressures and legislation to implement minimum staffing ratios, there remains a gap in the research providing health care administrators standards to execute "optimum staffing levels" for "optimum care" within the complex environment described previously. Given the inputs (staffing resources), as well as the outputs (patient, financial, and profit outcomes) of health care organizations, it is a logical step to refine the approach of this research to incorporate an econometric methodology. Basic microeconomics principles dictate that a firm must decide on the combination of inputs to produce its outputs, recognizing its constraints (Nicholson, 1978). Further, economic theory explicates that for any set of inputs, the production function is defined as the maximal realizable output or full range of outcomes (Shephard, 1970).

Production function, a fundamental economic theory, describes how a firm transforms resources (productive inputs) into outputs (goods, services to be sold to consumers). Decisions made by a firm related to input efficiency is correlated with outcome efficiency. Early studies of efficiency and productivity within the health care arena most commonly addressed cost and financial performance of hospitals (Bazzoli, Chan, Shortell, & D'Annouo, 2000; Garber, 1984; Granneman, Brown, & Pauly 1986). Later, Hendrix and Foreman (2001) clearly describe the

utilization of production function theory in decision making related to staffing and the production and supply of patient care in the long term care setting. They utilized production function theory to "attempt to define an optimum staffing level whereby quality is optimized, personnel are conserved, and public burden is minimized" within the nursing home setting (Hendrix & Foreman, 2001, p. 164).

A fundamental component of production function theory is the law of diminishing returns, also known as the principle of diminishing marginal productivity. This key economic law states that if one input in the production of a commodity is increased while all other inputs are held fixed, a maximum point will eventually be reached at which additions of the input yield progressively smaller, or diminishing, increases in output. (Nicholson, 1995). Further, economists have extended the application of the principle of diminishing marginal productivity to include a point of minimum productivity where productivity and efficiency is decreased, sometimes to the point of inferior or useless product (Nicholson, 1978). Zhang, Unruh, Liu, and Wan (2006) hypothesized that there may be a production function relationship between nurse staffing levels and skill mix in nursing homes, such that an acceptable level of quality outcomes can be achieved within a range of minimum and maximum staffing. They concluded that "efficiency-oriented minimum nurse staffing points exist" (p. 85). Applying the theory of production function places nursing administrators making staffing decisions "at the margin".

In standard economic theory, production function is a model to study how a firm's resources (productive inputs) are transformed into outputs. Nicholson and Snyder (2008) present production function as a statistical model formally expressed as: $q = f(k, l, m, \ldots)$, where q represents the output: amount of product or goods during a period, and k, l, m represent the inputs of capital, labor, raw materials, and the … notation reflects the possibility of other

variables that affect the production process. Application of production function as a statistical model is explicated in Chapter 3, Methods.

While research in both nursing home and acute care settings demonstrated that increased levels of nursing staff have achieved improved outcomes; this approach has supported the concept of "more is better" in relationship to staffing and improved outcomes. However, these data do not assist health care administrators in determining standards that optimize both staffing and patient outcomes. This is further complicated by the influences of declining resources related to the nursing shortage, legislation, financial constraints, and profit incentives.

As evidenced by the aforementioned research studies, nurse staffing levels and staffing skill mix are dynamics influenced by multiple variables. Thus, managing care to achieve acceptable patient outcomes and safety is a challenge for nurse and health care administrators. Most nurse staffing studies have used the terms maximum "ceiling" or "higher levels" and identified relationship with improved patient outcomes. Limited studies have investigated the thresholds of staffing to achieve desired patient outcomes (Lang, Hodge, Olson, Romano, & Kravitz 2004; Lankshear, Sheldon, & Maynard 2005). Discerning if an ideal range of staffing levels and mix exists would support the reliability for staffing decisions to incorporate and influence patient outcomes.

CHAPTER 2
REVIEW OF THE LITERATURE

Purpose

The specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting . Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined. In Chapter 2, the review of literature related to the theory and variables will be discussed.

Production Function Theory

Production Function, a fundamental economic theory, states that the decisions made by a firm related to input efficiency is correlated with outcome efficiency. Early studies of efficiency and productivity within the health care arena most commonly addressed cost and financial performance of hospitals (Bazzoli, Chan, Shortell, & D'Annouo, 2000; Garber, Fuchs & Silverman, 1984; Granneman, Brown, & Pauly 1986). Later, thresholds for optimal staffing levels were identified in the study conducted by Abt Associates (Abt Associates, 2001). In their report to Congress, staffing levels below the threshold demonstrated a negative impact on the quality of care and those above the threshold demonstrated no significant impact on quality outcomes. Leading the foray to incorporate economic theory, health services, and nursing research, are two studies that clearly link the theoretical framework of production function theory to research and conclusions to support the relationship between optimized maximum and minimum staffing resource allocation and optimal patient outcomes (Hendrix & Foreman, 2001;

Zhang, Unruh, Liu, & Wan, 2006). These studies have dealt with the maximum or "ceiling" needed to improve patient outcomes and "floor" or minimum staffing for optimal care.

Hendrix and Foreman (2001) were among the first to utilize production function theory in the health care setting related to nurse staffing. Their study is the most frequently cited in subsequent studies, establishing their research as a seminal work in this area. They clearly describe the utilization of production function theory in decision making related to staffing and the production and supply of patient care in the long term care setting. This study was a secondary analysis of two national data sets commonly utilized in health services research related to nursing homes: Area Resource File (ARF) and the Online Survey Certification and Reporting System (OSCAR). They utilized production function theory to "attempt to define an optimum staffing level whereby quality is optimized, personnel are conserved, and public burden is minimized" within the nursing home setting (Hendrix & Foreman, 2001, p. 164). Where previous studies had generally found that increased nurse staffing improved patient outcomes; the results of this study supported the theoretical model and the concept of diminishing returns.

Zhang, Unruh, Liu, and Wan (2006) utilized the theory of production function in their research to model the relationship between nurse staffing and quality in nursing homes. They sought to empirically identify minimum nurse staffing levels to achieve reasonable quality and efficiency. According to production function theory, the inputs in this study were operationally defined as RN hours per patient day, Licensed Practical Nurses (LPN)/Licensed Vocational Nurses (LVN) hours per resident day, NA hours per resident day, total licensed staff (RN + LPN/LVN) hours per resident day, and total nurse (RN + LPN/LVN + NA + administrator) hours per resident day. The output was operationally defined as a researcher generated quality

index based on the OSCAR measures of the presence of indwelling catheters, pressure sores, physical restraints, and a calculated weight for incidence rate.

Zhang and colleagues (2006) recognized that the most efficient production occurs within the region of decreasing marginal returns to labor. They hypothesized that the desired staffing point (unit of input) to be within the area of diminishing marginal returns in relationship to quality improvement and efficiency (outputs). They defined the ranges of quality improvement within the area at which quality is still improving and efficiency to be where returns to additional staffing are still positive. The minimum point of operation was determined to be "at the point at which marginal returns change from increasing to decreasing" and the maximum point of operation was determined to be "at which the returns go from decreasing marginal to diminishing total returns" (Zhang et al., p. 80). They found diminishing marginal returns to nursing labor in relationship to quality.

Although production function theory was not specified, the results of subsequent studies have revealed a nonlinear relationship between nurse staffing and patient outcomes. Commissioned by the Centers for Medicare & Medicaid Services (CMS) under the Omnibus Budget and Reconciliation Act of 1990, Abt Associates, Inc. (2001) studied the appropriateness of establishing minimum nurse staffing standards in long term care. The report contends that RN, LPN, and NA staffing improves quality to a threshold where there is no further significant improvement. Zhang and Grabowski (2004) purported a nonlinear relationship between nursing home staffing and quality. They state that "initial units of staffing may have a strong influence on quality, but there may be diminishing returns to additional staffing units after some threshold" (Zhang & Grabowski, p. 19).

Mark, Harless, McCue and Xu (2004), in their longitudinal study of 422 hospitals, concluded that "increased RN staffing levels *unconditionally* improves quality care" (p. 279) to the point of marginal return. Staffing increases in the lowest staffed 25% of hospitals showed the largest improvement in patient outcomes. Conversely, increases in staff in the best 25% of hospitals (mean 8.9 hours per patient day) demonstrated marginal returns, and deterioration in some outcomes. With findings consistent with Zhang and Grabowski (2004), their study provides some of the most compelling evidence that a production function for nurse staffing and patient outcomes exists.

An a priori assumption of Nelson and colleagues in their rehabilitation study was that a linear relationship existed between nurse staffing and patient outcomes (Nelson, et. al, 2007). However, their findings suggest a non-linear relationship between nurse staffing and patient outcomes. Their findings were consistent with those studies conducted in long term care settings – a production function relationship explained the diminishing returns of increased nurse staffing on patient outcomes (Hendrix & Foreman, 2001; Zhang, Unruh, Liu & Wan, 2006).

Statistically and clinically significant associations between nurse staffing and patient outcomes were identified in the international systematic review by Lankshear, Sheldon & Maynard (2005). The authors reported that increasing RN levels or RN percentage "tailed off" at higher levels of staffing and that "a curvilinear relationship indicating diminishing marginal returns to increased RN levels and skill mix has more face validity than the linear relationship assumed in most studies and is of considerable policy importance" (p. 172). Further, the systematic review and analysis of Kane and research team (2007) were consistent with identifying a curvilinear association between staffing and outcomes.

More recently, Meyer, Wang, Li, Thompson & O'Brien-Pallas (2009) studied the effects of nurse staffing and work environment variables on patient outcomes in 24 Canadian cardiac and cardiovascular inpatient units. They sought to test the Patient Care Delivery Model, a conceptual model which emphasizes the multiple factors influencing patient outcomes. They hypothesized that staffing levels and patient outcomes were nonlinear. The results demonstrated that patient knowledge, status, and behavior improved as staffing levels increased, then changed direction with a pattern of diminishing marginal return.

The recognition by researchers that a curvilinear relationship between nurse staffing and patient outcomes may exist has evolved over time. In addition, it has been demonstrated in a variety of health care settings. The application of production function theory becomes a logical progression of this area of health services research.

Nurse Staffing

Several early studies used large multi-institutional databases to examine the effects of nurse staffing and mortality along with other characteristics. Three found that higher RN proportion was associated with lower mortality rates (Aiken, Smith, & Lake, 1994; Hartz et al., 1989; Flood, Ewy, Scott, Forrest, & Brown, 1976). Three additional studies found no statistically significant relationships between nurse staffing and mortality (Al-Hider & Wan, 1991; Shortell & Hughes, 1988; Shortell et al., 1994). The measures of nurse staffing and setting varied from study to study. In their later study, Shortell and colleagues (1994) utilized data directly from intensive care units. Unruh (2008), in her literature review of nurse staffing and patient, nurse, and financial outcomes, noted improved research methodologies. Recent studies continue to support that lower nurse to patient ratios (higher RN staffing) were associated with lower mortality (Aiken, Clarke, Sloane, Lake, and Cheney, 2008; Aiken et al., 2010; Needleman et al., 2011).

Acute Care

Unruh (2008) conducted a literature review of research exploring the relationship of nurse staffing and patient outcomes in the hospital setting. Of the 45 studies conducted in the United States, she focused on 21 studies conducted since 2002. Her rationale includes the issues presented in the critique above - methodological issues have improved over time. Furthermore, 2002 was a considered a "watershed" year (Unruh, 2008, p. 65).

Aiken et al. (2002) examined patient-nurse ratios and found that each additional patient in a nurses' workload produced a 7% increase likelihood of failure to rescue, defined as death from complications. In their landmark multidisciplinary study, nursing administration researchers collaborated with public health researchers to quantify and elucidate nurse-staffing levels and the quality of care in hospitals (Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). The researchers found that a higher proportion of hours of nursing care provided by registered nurses and a greater number of hours of care by RNs per day are associated with better care for hospitalized patients. Patient outcomes of interest were urinary tract infection, pneumonia, LOS, upper gastrointestinal bleeding and shock in medical patients and failure to rescue for major surgery patients. These studies are considered seminal works for the utilization of patient outcomes that are considered specifically sensitive to nursing care.

Most subsequent studies also utilized hours per patient day and/or nurse to patient ratios. Some studies also addressed the concept of skill mix or proportion of RN to non-RN staffing, finding that higher RN proportion resulted in improved patient outcomes (Cho, Katfian, Barauskas, and Smith, 2003; Hall et al., 2003; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Tourangeau, Giovanetti, Tu, & Wood, 2002; Unruh, 2003). Cho et al. (2003) found that RN proportion significantly reduced pneumonia such that a 10% increase in RN proportion resulted in a 9.5% reduction in pneumonia. Similarly, consistent with Needleman et

al. (2002), Unruh (2003) reported that both higher numbers and proportion of licensed nurses is statistically related to lower incidence of adverse events. This study also supported that an increase in RN proportion significantly reduces pneumonia. A richer RN skill mix was related to a lower 30-day mortality rate for patients with the primary diagnosis of acute myocardial infarction, stroke, pneumonia or septicemia in Canadian hospitals (Tourangeau et al. 2002).

Lang et al. (2004) concluded that the literature offers little support for specific minimum nurse –patient ratios in hospitals and recommends future research include skill mix and case mix adjustment as important variables. To that point, this study is the first to examine the production function relationship between nurse staffing, including skill mix (RN proportion), and patient outcomes. Additionally, case mix adjustment utilizing rehabilitation impairment category (RIC) groups further strengthens this study.

Long Term Care

Two studies of nurse staffing in the nursing home setting utilized production function as the underlying theoretical model. Hendrix and Foreman (2001) examined the number and mix of RNs, LPNs, and NAs in relation to the prevalence and severity of decubitus ulcers as a measure of patient outcome and quality. The results suggest that the number of RNs and NAs reduces the cost of decubitus care, while LPNs tended to increase the cost. These results underscore the importance of clearly defining the various staffing levels of care in the study setting. Additionally, the results also supported that increasing levels of nursing staff only continued to improve outcomes to a point. In doing so, this study was among the first to elucidate that nurse staffing and patient outcomes were functions of marginal productivity and diminishing marginal returns.

Zhang, Unruh, Liu, and Wan (2006) utilized the theory of production function in their research to model the relationship between nurse staffing and a quality index generated from the

incidence rates of indwelling catheters, pressure sores, and physical restraints in nursing homes. Nurse staffing measures utilized were RN hours per patient day (sic), LPN hours per resident day, NA hours per resident day, total licensed staff per resident day, and total nurse (RN, LPN, NA and administrator) hours per resident day. Nurse staffing levels were positively correlated with the quality index.

In their systematic review of studies of nurse staffing and quality in nursing homes, Bostick, Rantz, Flesner, and Riggs (2006) identified three consistent themes in the studies: staffing measures, quality measures, and risk adjustment variables. The authors reported that staffing measures studied included the ratio of staff to residents and the number of hours per resident day (HPRD). In fact, over half the studies used some measure of the two. Staff mix was also identified as an important variable, although the operational definition was inconsistent: ratio of licensed to unlicensed staff, number of RN, LPN and NAs per total nursing staff, and others. These staffing measures most closely align the current study of nurse staffing and patient outcomes in the rehabilitation setting.

Rehabilitation

The rehabilitation setting mirrors the circumstances discussed in the long term care setting previously: in spite of federal mandated staffing standards, there was no empirical evidence to support these standards. Prior to the work of Nelson and colleagues (2007), to our knowledge, there were no published studies examining nurse staffing, minimum staffing levels, or patient outcomes in the rehabilitation setting. Nelson et al. utilized staff mix, defined as RN Proportion and non RN staff, overall nursing HPPD, RN HPPD, and Non-RN staff HPPD as staffing measures. Significant correlations were found between total nursing HPPD and case-mix adjusted FIM™ gain and length of stay. Of importance to the implications and application of

the research findings, as the per cent of nurses certified in rehabilitation increased, the case mix adjusted length of stay decreased.

Outcomes

Length of Stay

Mortality and length of stay were common variables in early outcomes research. These data were consistently generated in hospital registration and administrative databases and therefore readily available. Several early research studies examined the relationship between hospital registered nurse staffing and length of stay. Increased numbers of RNs and RN hours per patient day decreased patient LOS (Flood & Diers, 1988; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002; Schultz, Van Servellen, Chang, McNeese-Smith, & Waxenberg, 1998). In a systematic review of the effect of hospital nurse staffing and patient outcomes published between 1980 and 2003, authors found that few studies included LOS and no clear recommendations were made (Lang, Hodge, Olsen, Romano & Kravitz, 2004).

In a later systematic review Thungjaroenkul, Cummings, and Embleton (2007) encompassed studies published between 1990 and 2006. The effect of hospital nurse staffing on length of stay were variables of interest in 11 studies. Higher ratios of RNs was significantly related to reduced length of stay in hospital settings, including the intensive care unit (Amaravadi, Dimick, Pronovost, & Lipsett, 2000; Barkell, Killinger, & Schultz, 2002; Lassnigg, Hiesmayr, Bauer, & Haisjackl, 2002; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). RN hours per patient day was also statistically related to LOS (Cho, Ketefian, Barkauskas, & Smith, 2003). Further, high RN levels may prevent adverse events that cause an increase in length of stay. Cho and colleagues (2003) reported that each adverse event (falls, adverse drug events, pneumonia urinary tract infection, wound infection and sepsis) resulted in significantly prolonged length of stay. Increases in RN proportion were associated with a

decrease in the probability of pneumonia. Unruh (2003) also attributes higher RN proportion to decrease probability of pneumonia and LOS. These results were corroborated by Kane et al. (2007, p. 1198). In their systematic review and meta-analysis, an increase by one RN per patient day was associated with a decreased LOS of 24% in ICUs (OR, 0.76; 95% CI, 0.62-0.94) and 31% in surgical patients (OR, 0.69; 95% CI, 0.55-0.86).

Synthesizing studies examining the relationship between changes in RN hours per patient day and changes in nurse sensitive outcomes (NSO), Dall, Chen, Seifert, Maddox, and Hogan (2009) reflected the economic value of professional nursing. Using 2005 Nationwide Inpatient Sample (NIS) hospital discharge data along with the RN HPPD, and NSO, they concluded that as nurse staffing levels increase, length of stay decreased. The impact of nurse staffing increases decreased length of stay via mitigation of nosocomial complications. Additionally, the economic value of additional RNs depends on staffing levels, such that, at low staffing levels, incremental additions of RN staff make larger contributions to patient care. As staffing levels improve, the value added is positive, but declining. Although the authors do not explicate it in the presentation of the study, these results underscore that recent research implicates that production function theory applies to nurse staffing and patient outcomes.

Functional Independence Measure

The Uniform Data System for Medical Rehabilitation (UDSMR) developed the Functional Independence Measure (FIM™) to document frequency and severity of disability. The FIM™ measures basic activities of daily living. It is intended to stratify the patient on a continuum from a minimum score, which indicates dependence in all areas evaluated, to a maximum score, representing complete independence. The FIM™ tool is used to establish criteria for admission, discharge, and maintenance of rehabilitation gains (Kelly-Hayes & Phipps, 2008).To that end, the FIM™ tool is a component of the Inpatient Rehabilitation

Facility-Patient Assessment Instrument which is used to determine prospective payment rates for all Medicare rehabilitation patients.

The association between functional status and rehabilitation length of stay is well documented (Harada, Kominski, & Sofaer, 1993; Heinemann, Linacre, Wright, Hamilton, & Granger, 1994; Hosek et al., 1986; Stineman (1995); Stineman & Williams, 1990). Over the years, FIM™ ratings have consistently been a predictor of length of stay. Even as policy and health care reforms have decreased length of stays, national rehabilitation data from 2000-2007 indicate the associations of FIM™ ratings and FIM™ change and LOS have remained constant (Granger et al., 2010). Regardless of patient diagnosis, high functional status is associated with shorter lengths of stay and a low FIM™ score on admission predicts longer length of stays (Atalay & Turhan, 2009; Eastwood, Hagglund, Gordon, & Marino, 1999; Kennedy et al. 2006; McClure et al., 2011; San Segundo, Aguilar, Santos, & Usabiaga, 2007; Yeung, Davis, & Soric, 2010).

The research of the association of nurse staffing and functional status in acute care and in long term care is meager. In their systematic review of evidence on nursing workload and staffing on health work environments, Pearson et al. (2006) cited only one study examining nurse staffing and FIM™. The study by Hall and colleagues (2003) utilized a repeated measures design to examine nurse staffing models and patients' functional status in 19 Canadian hospitals. The higher proportion of "regulated nursing staff" (staff licensed as registered nurses and/or registered practical nurses) was significantly associated with better FIM™ scores. Specifically, staff mix was a significant predictor of functional independence (Hall et al., 2003).

Two studies examined the relationships between staffing intensity and changes in FIM™ scores. Johnston, Wood, and Fiedler (2003) found that correlations between staff hours per

patient day (direct RN and therapy staff) and functional gain in rehabilitation hospitals were small, less than 2% of variance. Similarly, Jette, Warren, and Wirtalla (2004) reported positive associations with higher nursing staff level and therapy intensity and the average change in FIM in skilled nursing facilities. However, the staffing intensity variables contributed only 3% of the variance to the model. Variations in the definitions of nurse staffing in the studies also confound the results. Clearly, these gaps call for current and future research related to nurse staffing and functional health outcomes.

The study of nursing staffing and patient outcomes in acute and long term care has progressed exponentially over the past decade. Variables have become more refined. Systematic reviews have identified the concept of diminishing returns as nurse staffing and patient outcomes were examined. The application of production function theory to the relationship between nurse staffing, length of stay and FIM™ change in the rehabilitation setting contributes to the gaps identified in previous studies.

CHAPTER 3
METHODOLOGY

Purpose

The specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting. Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined. Chapter 3 discusses the study design, application of the production function to the study, the empirical specification, the parent study (setting, subjects, sample, and data collection methods), operationalization of variables utilized in the secondary analysis, and data analysis methodologies.

Hypothesis

The following hypothesis was tested: There is a non-linear relationship between nurse staffing levels for RNs, Non-RNs, total nursing staff, and skill mix (RN proportion) with patient outcomes of length of stay (LOS), and FIM™ change in the rehabilitation setting such that a production function relationship is elucidated.

Design

This study was a secondary analysis of data that was collected in the parent study entitled "Nurse Staffing and Patient Outcomes in Inpatient Rehabilitation Settings" (Nelson et al., 2007). It was a collaborative research study between the Uniform Data Systems (UDS), the Association of Rehabilitation Nurses (ARN) and the Veterans Health Administration (VHA) for the purpose of examining nurse characteristics (experience and certification in rehabilitation), nurse staffing, and patient outcomes in the inpatient rehabilitation setting.

Secondary data analysis is defined as "the use of data gathered in a previous study to test new hypotheses or explore new phenomena or relationships" (Polit & Beck, 2006, p. 243). While the use of large data sets has been common in the health services research arena, this approach is recently gaining ground as an accepted methodology for nursing researchers (Kneipp & Yarandi, 2002; Magee, Lee, Giuliano, & Monro, 2006; and Smaldone & Connor, 2003). This study will further elucidate the previous study by applying the theory of production function to the parent study data to estimate a production function with nurse staffing as the predictor variables and patient outcomes as the dependent variables.

Production Function

In standard economic theory, the production function describes how a firm transforms resources (productive inputs) into outputs (goods, services to be sold to consumers) (Nicholson & Snyder, 2008). Formally, a production function can be expressed as: $q = f(x_1, x_2, \ldots, x_n)$ where q represents the output (amount of goods or services produced during a period), and $x_1, x_2, \ldots, x_n$.*where* x_i represents the amount of input i used, for inputs i = 1, …, n. The production function thus measures how much output is obtained from a given set of input.

Total Product

Total product (TP) is another term for the total amount of output that a firm produces from all inputs. (Nicholson, 1978). Most commonly total product is analyzed when one variable input, such as labor, changes while all other inputs are held constant. The upper portion of Figure 3-1 illustrates total product as a function of a variable input: Q = Quantity of outputs as a function of L = Labor (variable inputs).

The TP curve is typically S-shaped, starting at zero when zero units of labor are used. Then, as illustrated in Figure 3-1 and described in Table 3-1, as units of labor are added, TP first

increases at an increasing rate (Stage I), then increases at a decreasing rate (Stage II), and then eventually begins to decrease (Stage III).

Marginal Product

The marginal product (MP) of an input is defined as "the additional output that can be produced by employing one more unit of that input while holding all other inputs constant" (Nicholson & Snyder, 2008, p. 296). When total product is analyzed as a function of one input (typically labor), holding all others constant, marginal product of labor can be expressed as:

$$MP_L = \frac{\partial Q\ (all\ else\ equal)}{\partial L}$$

or

$$MP_L = \frac{\Delta Q\ (all\ else\ equal)}{\Delta L}$$

Thus, marginal product describes how output changes when the labor input changes by one unit.

The lower portion of Figure 3-1 illustrates marginal product and shows the relationship between total product and marginal product. Because MP is the slope of the TP curve at a given point, the shape of the MP curve is determined by the shape of the TP curve. As indicated in Table 3-2, MP initially is positive and increasing (Stage I), then is positive and decreasing (Stage II), and eventually becomes negative (Stage III). Note that a firm would not hire or utilize labor units beyond L3 because in this range using more labor would actually cause a reduction in output.

Diminishing Marginal Returns

A fundamental component of production function theory is the law of diminishing returns, also known as the principle of diminishing marginal productivity. This principle states that if one input in production is increased (i.e. labor) while all other inputs are held fixed, a maximum point of marginal return will eventually be reached, after which additions of the input

yield progressively smaller, or diminishing, increases in output (Nicholson & Snyder, 2008). Note that diminishing returns (Stage II) is different from negative marginal product (Stage III). That is, diminishing returns refers to the situation in which additional units of the input do result in added output, but the marginal contribution declines.

Production Function and Nurse Staffing

While the production function approach is widely used to analyze business firms, Newbold (2008), in his discussion paper regarding production economics of nursing, asserts that there is little adoption of production function theory in mainstream nursing workforce research. Given that nursing is a fundamental input into the production of healthcare services, the approach can readily be adapted to the study of nurse staffing. The standard application of production function would be to examine the effect of nurse staffing (inputs) on the amount of healthcare services produced (output).

Nicholson and Snyder (2008) note that the model is commonly modified in empirical work by measuring output (q) in terms of "value added" (p. 295). In the context of research on nurse staffing, value added can be interpreted as quality, or patient outcomes. Thus, this study examined how additional nurse staffing (labor input) affected quality (patient outcomes). For example, Zhang et al. (2006) took this approach by examining a production function with quality as a function of the number of nurses or nursing hours.

Returning to Figure 3-1, the expectation is that initially as incremental units of nurse staffing are added, patient outcomes will increase at an increasing rate, then increase at a decreasing rate, and eventually will begin to decrease. The implications of this model are that at low levels of staffing, increases in staffing lead to levels of quality that increase at an increasing rate (increasing marginal returns to staffing), where quality is measured by patient outcomes (LOS, FIM™ change). As staffing levels continue to increase, the patient outcome will continue

to improve (LOS, FIM™ change), but at a decreasing rate signifying diminishing marginal returns to staffing. Finally, increases in staffing will result in a decrease in patient outcomes and negative marginal returns to staffing. The maximum level of nurse staffing is exemplified as L3 in Figure 3-1, because adding nurse staffing beyond this point would result in increased LOS and decreased FIM™ change.

Empirical Specification

The next step is to transform the general form of the production function: where Q (patient outcomes) = f [L (nurse staffing); X (covariates)] into the empirical specification to be used in the data analysis. The standard linear specification, which would be: $Q = a + bL + cX$, cannot be used here, because it would not allow the TP curve (patient outcome as a function of nurse staffing) to be S=shaped. To allow for that possibility, a curvilinear model was specified.

Procedure Methods

Following dissertation committee approval, paperwork was processed to gain approval of the University of Florida Institutional Review Board (IRB-01). Exempt review was requested and approved, as subjects were fully de-identified in the data set provided to the recipient-investigators and in compliance with the Health Information and Portability and Accountability Act of 1996. A confidentiality agreement with the primary investigator of the original study was obtained and submitted assuring that the recipient-investigators will not be provided access to the identities of the subjects or to information through which the identities of subjects could be readily ascertained. Included in the packet were copies of the approval letters for the parent study from the Tampa Veterans Administration (VA) Medical Center IRB and the University of South Florida IRB.

Data

The data for this study come from research conducted by Nelson, et al. (2007). That study randomly selected a sample of 54 rehabilitation units from a pool of 806 rehabilitation units in the United States participating in Uniform Data System for Medical Rehabilitation (UDSMR), stratified by the USDMR geographical regions.

Patient- level data were extracted from the USMR database for a one- month period and were de-identified prior to transmission to investigators at the coordinating site, the Tampa Veterans Administration (VA) Medical Center. Nurse level variables were collected via surveys and logs for a one- month period. Data collection occurred over a 24- month period in 2005, staggered by site and reported as unit-aggregated data.

Variables

Study variables and operational definitions are presented in Table 3.3. The predictor variables are nurse staffing and the dependent variables are patient outcomes. The facility staffing variables were further delineated as staffing levels of Registered Nurse hours per patient day (RN HPPD, Non-RN HHPD: Licensed Practical Nurse/ Nurse's Aide (LPN/NA), total staffing (THPPD), and skill mix (PROP-RN). Patient outcomes are measured in two ways in this study: Length of stay (LOS) and change in Functional Independence Measure FIM™ . The Association of Rehabilitation Nurses (2004, 2005) describes the high priority research issues in their second edition of the Rehabilitation Nursing Research Agenda. Under one of the categories, rehabilitation in the changing healthcare system, the ARN identifies individuals' functional outcomes in relation to the type, intensity, and duration of rehabilitation nursing services required as a high priority agenda item. This agenda item supports the selection of both length of stay (duration) and FIM™ change (functional outcome) as key variables in this study. Study variables, data sources, values, and measures are reflected in Table 3-4.

The explanatory patient level variables utilized were gender, age, race, marital status, and Rehabilitation Impairment Category (RIC) groups. Facility level variables were facility types (freestanding rehabilitation hospital versus a rehabilitation unit in an acute care facility) and number of operational beds.

Predictor Variables

Nurse staffing. RN hours for patient day (RNHPPD) is the total number of direct patient-care RN hours during the study month divided by the total midnight census during the study month, Values range from 0 to 36. Non-RN hours for patient day (NONRNHPPD) is the total number of direct patient-care LPN/LVN/NA hours during the study month divided by the total midnight census during the study month, Values range from 0 to 24. Total Hours per patient day (TOTHPPD) is the total number of direct patient-care hours during the study month divided by the total midnight census during the study month, Values range from 1 to 48. Skill mix, proportion of RNs, (PROP_RN) is the per cent of RN and LPN/LVN/NA use.

Nelson et al. (2007) utilized staff mix, defined as proportion of RNs and non RN staff, overall nursing hours per patient day (HPPD), RN HPPD, and Non-RN staff HPPD as staffing measures. This study differs from some previously discussed where licensed staff is defined to include LPNs with RNs when examining skill mix and proportion. For this study, examining RN to non-RN (combining LPN and NA) best addressed the functional roles of the RN and LPN in the rehabilitation setting. This study is further strengthened by the utilization of case-mix adjustment as recommended by Lang et al. (2004). For these reasons, this study utilized the same operational definitions as exemplified by Nelson and colleagues' work.

Dependent Variables

Length of stay

Length of stay is the duration of a single episode of inpatient rehabilitation hospitalization. LOS is a continuous measure calculated by subtracting the day of admission from the day of discharge. Values are actual days, ranging from 1 to 32. Descriptive statistics, including means, standard deviations, and ranges (minimum and maximum) are presented.

Functional Independence Measure

The FIM™ instrument is considered the gold standard as a reliable measure of patient outcomes in the rehabilitation setting throughout the United States and the world (Duchene, 2008). This 18 item scale is appropriate for measuring cognitive and motor functions for patients of all ages or diagnoses. FIM™ ratings range from 18 to a maximum of 126, representing the range of complete dependence to independence. The FIM™ has been extensively tested for reliability, validity, and sensitivity. Internal consistency reliability coefficients have been reported as above 0.90 for all subscales, with the exception of 0.68 for the locomotion subscale (Dodds, Martin, & Stolov, 1993).

The discharge FIM™ is the assessment score for the patient within 3 days of discharge. FIM™ change was calculated from the total Functional Independence Measure score on discharge minus total FIM™ score on admission. The higher the values, the greater the improvements in functional independence during the rehabilitation stay. Descriptive statistics, including means, standard deviations, and ranges (minimum and maximum) are presented. Discharge FIM™, adjusted by admission FIM™, is described as a dependent variable in data analysis, later in Chapter 3.

Patient Level Characteristics

Rehabilitation Impairment Category (RIC) classifies patients into one of 21 categories based on inpatient rehabilitation admission reason. The RIC is the highest level of classification for payment groups for CMS. The RIC is considered a proxy measure for patient mix and severity. The proportion of RIC cases in each unit in Nelson's study significantly affected nurse staffing levels (Nelson et al. 2007).

Once initial descriptive statistics were generated, it was determined that the RIC variable values needed to be transformed. Like diagnoses were categorized into eight RIC groups: 1 (Stroke), 2 (Brain Injury), 3 (Spinal Cord Injury), 4 (Neurological), 5 (Replacement lower extremity), 6 (Amputation), 7 (Other, orthopedics) and 8 (Other, miscellaneous). These groupings are consistent with the parent study (Nelson, 2007). Frequency data are presented with a number and percentage for each group.

Additional patient characteristics are age, marital status, race, and gender. Age is presented in descriptive statistics, including means, standard deviations, and ranges (minimum and maximum). Values range from 5 to 101. Marital status, race, and gender are presented as frequency data: number and percentage for each category of variable.

Facility Level Characteristics

The two facility specific variables are the facility type and size. The facility type is categorical: 1 (freestanding rehabilitation hospital) and 2 (rehabilitation unit within an acute care facility). Facility type is reported as number and percentage. Facility size is expressed by number of operation beds, Values range from 8-82.

Data Analysis

SAS version 9.3 (Cary, N.C.) was used for all statistical analyses. A level of significance of .05 was used for all hypothesis testing. Nelson and colleagues (2007) maximized strategies to

limit missing data in the parent study. In spite of stringent steps such as through training of data collectors, minimizing the burden of data collection, and weekly reviews of daily logs with immediate follow up to complete missing data, some data were lost (p. 188). Nurse staffing and facility data utilized in this secondary analysis had a less than 5% missing data rate. Patient data had <1% missing data. The daily FIM™ measures, noted to be the "most burdensome component of the data collection process" had a 9.5% missing data rate (Nelson et al., 2007, p. 188).

Descriptive statistics included means, standard deviations, minimum and maximum ranges for continuous variables. Categorical variables were statistically represented in frequency distributions and percentage distributions.

The following hypothesis was tested: There is a non-linear relationship between nurse staffing levels for RNs, Non-RNs, total nursing staff, and skill mix (RN proportion) with patient outcomes of length of stay (LOS), and FIM™ change in the rehabilitation setting such that a production function relationship is elucidated. First, to allow for a nonlinear relationship in the statistical model, variables representing the means and squared means of the staffing variables RN HPPD and Non-RN HPPD were generated. These staffing variables are referred to as linear and quadratic terms, respectively. Next**,** to allow for a curvilinear result, both the linear and the quadratic staffing variables were utilized in the statistical modeling.

Hierarchical Linear Modeling (HLM) is the most appropriate statistical technique to analyze multilevel data where one level is nested within the other (Raudenbush & Bryk, 2002). In this study, patients are "nested" in facilities. In social science research, it is recognized that subjects may be clustered in organizational units (i.e. students in schools or patients in hospitals) where there may be some influence on one level of analysis that effects the other level of

analysis by virtue of residing within the same organizational context (Hofmann, Griffin, & Gavin, 2000). HLM allows researchers to develop models to adjust for these influences.

HLM was also utilized to account for the hierarchical nature of the data. A key methodological assumption of HLM is that lower level units of data are nested within identifiable higher level units of data (Hofmann, et al.). HLM also allows the researcher to simultaneously model the impact of both individual (patient, lower) and institutional (facility, higher) variables on the dependent variables of interest (McCoach, 2010, p. 125). In this study, patient level characteristics (admission FIM™, gender, race, marital status, and RIC group) are considered level 1 explanatory variables. The facility level characteristics (number of operational beds and facility type) are the level 2 explanatory variables.). The predictor staffing variables were RN hours and non-RN hours. The dependent variables of interest modeled were length of stay and FIM™ change. These are represented in Table 3-3 and 3-4.

Key statistical assumptions for hierarchical linear modeling were examined. Data were checked for outliers and implausible values. For each of the HLM models, the convergence criteria were met. Fit statistics -2 Residual log likelihood, the Bayesian information criterion (BIC) and Akaike's information criterion (AIC, AICC), were examined. Level 1 (patient level) observations are assumed to be independent. The Level 2 (facility) variables are also assumed to independent.

To examine the relationship between patient outcomes (LOS and FIM™ change) and both facility level characteristics and patient level characteristics, separate models were identified. Initially, the nurse staffing predictor variables (level 2 variables) were modeled separately: RNHPPD, Non-RN HPPD, Total HPPD and Proportion RN. HLMs for each of the dependent variables were run with each of the staffing predictor variables and explanatory

variables. All variables were entered and run simultaneously for each model. Nurse staffing variables, (RN HPPD, non-RN HPPD, total HPPD, and RN Proportion) were not significant predictors of length of stay. RN proportion and the proportion RN squared term significantly predicted FIM™ change. The relationship of RN proportion to FIM™ change was such that both the linear and quadratic terms were significantly related to FIM™ change ($p = 0.0169$ and $p = 0.0155$ respectively). Therefore, both the linear and the curvilinear relationships of proportion RN and FIM™ change were statistically significant.

Finally, more parsimonious models were selected. RN HPPD and Non-RN HPPD (controlling for total HPPD and RN proportion) were modeled with each dependent variable. Next, RN HPPD and Non-RN HPPD squared terms were included the models for each DV. For length of stay, the nurse staffing predictor variables (level 2 variables) RN HPPD and Non-RN HPPD were run with explanatory variables of gender, race, marital status, RIC group, operational beds and facility type. A second model was run with the predictor variables RN HPPD, Non-RN HPPD and their quadratic terms with the explanatory variables of gender, race, marital status, RIC group, operational beds and facility type. HLMs for FIM™ change were run with staffing predictor variables of RN HPPD and Non-RN HPPD in one model and RNHPPD, Non-RNHPPD and their quadratic terms in the other. Discharge FIM™ functioned as the dependent variable. The explanatory variables of gender, race, marital status, RIC group, operational beds and facility type were included in both models. In addition, admission FIM™ was included as a covariate to adjust for discharge FIM™. All variables were entered and run simultaneously for each model. The models are presented in Table 3-5.

The last variables entered into each model were selected by the statistical program as the reference variable for each of the categorical patient and facility characteristics. Rehabilitation

Impairment Category group was the only variable with clinical or research rationale for order entry into the model. Stroke was selected as the reference variable because of the volume of patients post stroke was second only to replacement lower extremity. Stroke is a commonly used diagnosis in rehabilitation research literature and is generally considered to be "more acute" than lower extremity replacement surgeries. There was no particular research interest or priority for designating the reference variable for marital status. Age, gender, race and facility type are dichotomous variables with no compelling rationale to enter one variable over the other. The reference variables are identified in the HLM results Tables 4-3 and 4-4.

Table 3-1. Stages of total product.

Stage	Units of labor	Description
Stage I	0, L1, L2	TP of zero when zero units of labor are used, after that TP increases at an increasing rate
Stage II	L2 – L3	TP increases at a decreasing rate
Stage III	>L3	TP decreases

Table 3-2. Stages of marginal product.

Stage	Units of labor	Slope representation
Stage I	0 – L2	MP > 0 and increasing
Stage II	L2 – L3	MP > 0 and decreasing
Stage III	>L3	MP < 0

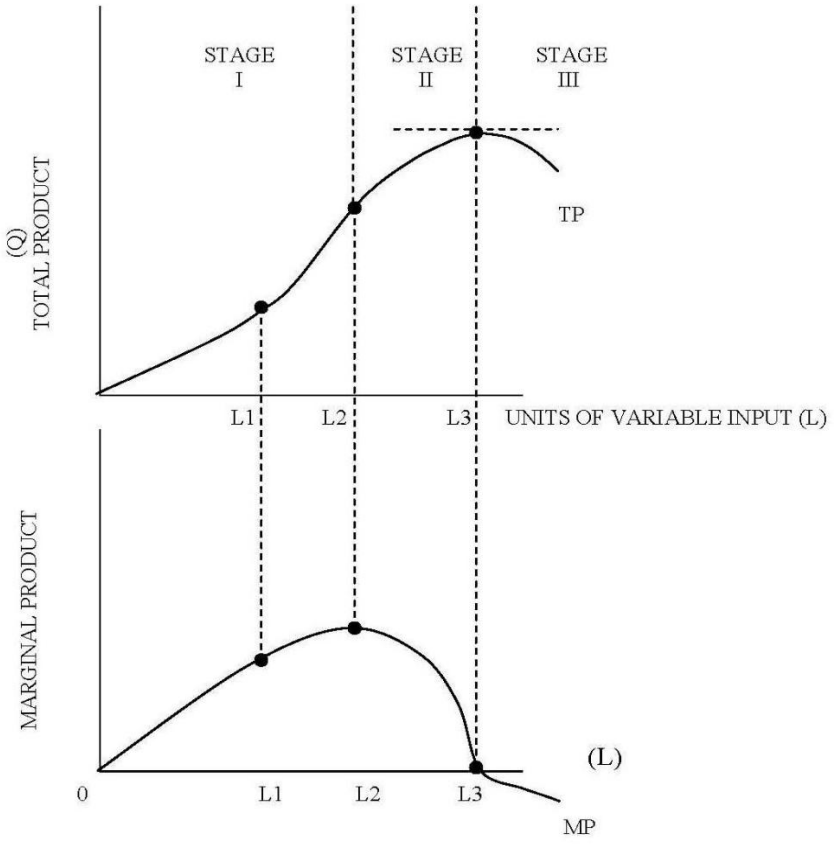

Figure 3-1. Model of Production Function.

Table 3-3. Study variables and operational definitions.

Variable level	Variable category	Variable	Definition
Predictor variables	Staffing characteristics	RN hours per patient day	Total number of direct-patient-care nursing hours divided by total midnight census Day, Eve, Night
		Non-RN (LPN/NA) hours per patient day	Total number of direct-patient-care LPN/LVN/NA nursing hours divided by total midnight patient census
		Total hours per patient day	Total number of direct-patient-care nursing hours divided by total midnight patient census
		Skill Mix RN Proportion	Proportion of nursing hours contributed by registered nurses
Dependent variables	Patient outcomes	Length of stay	Duration of single episode of hospitalization (calculated by subtracting day of admission from day of discharge)
		FIM™ change	Functional Independence Measure (FIM™) on discharge adjusted by admission FIM™
Level 1 Explanatory variables	Patient characteristics	Rehabilitation Impairment Category (RIC)	Highest level of classification for payment (case-mix) group categories.
		Age	Actual age in years
		Gender	Gender: male/female
		Marital status	Reported marital status on admission
		Race	Reported race on admission
Level 2 Explanatory variables	Facility characteristics	Facility type	Freestanding rehabilitation hospital Rehabilitation unit in acute care facility
		Size	Number of operational beds

Table 3-4. Study variables, data sources, values, and measures.

Variable level	Variable category	Variable	Data source	Values	Measure
Predictor variables	Staffing characteristics	RN hours per patient day	Daily log	Calculated 0 - 36	Scale
		Non-RN (LPN/NA) hours per patient day	Daily log	Calculated 0 - 24	Scale
		Total hours per patient day	Daily log	Calculated 1 - 48	Scale
		Skill mix RN Proportion	Daily log	Calculated .02 - 1.0	Scale
Dependent variables	Patient outcomes	Length of stay (LOS)	USDMR™ database	Actual days LOS 1 - 32	Continuous Scale
		FIM™ change	USDMR™ database	Discharge FIM™ score 18- 125	Continuous
Level 1 Explanatory variables	Patient characteristics	Admission FIM™ score	USDMR™ Database	Admission FIM™ score 18- 124	Continuous
		Rehabilitation Impairment Category (RIC) Groups	USDMR™ Database	1 = Stroke 2 = Brain injury 3 = Spinal cord injury 4 = Neurological 5 = Replacement lower extremity 6 = Amputation 7 = Other orthopedic 8 = Other miscellaneous	Categorical
		Age	USDMR™ database	5.0 – 101.0	Nominal Continuous
		Gender	USDMR™ database	1 = Male 2 = Female	Categorical Dichotomous
		Marital status	USDMR™ database	1 = Never married 2 = Married 3 = Widowed 4 = Separated 5 = Divorced	Categorical
		Race/ethnicity	USDMR™ database	0 = Other 1 = White	Categorical Dichotomous
Level 2 Explanatory variables	Facility characteristics	Facility type	USDMR™ database	1 = Freestanding rehabilitation hospital 2 = Rehabilitation unit in acute care facility	Categorical Dichotomous
		Size Operational beds	USDMR™ database	8 - 82	Nominal Continuous

Table 3-5. Hierarchical Linear Models.

Model	Dependent variable	Staffing variables	Explanatory variables Level 1 and 2
1	Length of stay	RN HPPD Non-RN HPPD	Age, gender, marital status, race, facility type, operational beds
2	Length of stay	RN HPPD Non-RN HPPD RN HPPD* RN HPPD Non-RN HPPD* Non-RN HPPD	Age, gender, marital status, race, facility type, operational beds
3	FIM™ Change Discharge FIM™	RN HPPD Non-RN HPPD	Admission FIM™, age, gender, marital status, race, facility type, operational beds
4	FIM™ Change Discharge FIM™	RN HPPD Non-RN HPPD RN HPPD* RN HPPD Non-RN HPPD* Non-RN HPPD	Admission FIM™, age, gender, marital status, race, facility type, operational beds

*Squared term for each variable

CHAPTER 4
RESULTS

Purpose

The specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting. Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined. Chapter 4 presents the sample descriptives and results of the hierarchical linear models.

Description of Sample

The descriptive statistics for the nurse staffing characteristics, patient outcomes, patient characteristics, and facility characteristics are presented in table 4-1.

Nurse Staffing Characteristics

The total nursing care hours per patient day averaged 6.9 (*SD* =3.5) with a range of 0.7 - 21.4. The average RN HPPD were 3.6 (*SD* =2.2) and Non-RN HPPD were 3.3 (*SD* =1.9). The proportion of RNs was 50% (*SD* =0.1).

Patient Outcomes

Length of stay

A total of 1529 patients had their full length of stay, admission to discharge, during the data collection period. The average LOS was 9.7 days (*SD* = 5.1).

FIM™ change

The average admission FIM™ rating was 71.4 (*SD* = 16.7). The average discharge FIM™ rating was 91.5 (*SD* = 16.7). The mean FIM™ change, calculated as discharge FIM™ rating minus admission FIM™ rating, was 20.1 (*SD* = 13.3).

Patient Characteristics

The average patient age was 69.7 (*SD* 15.3), with a range from 5 to 101 years. Just over half (57.10%) of the patients were female. The patients were predominantly white (85.22%) with the remaining 14.78% categorized as "other". The largest percent of patients were married (49.17%).

Lower extremity joint replacement (i.e. knee replacement) represented the majority of patients: 25.87%. Next, stroke accounted for 18.14% of the patients. The miscellaneous RIC group (cardiac, pulmonary and pain diagnoses) represented 17.68% of the patients. The "other orthopedic" group (fractured lower extremity, arthritis) was 17.03%. The remainder of the RIC groups, brain injury, spinal cord injury, neurological and amputation accounted for less than 7% of the patients each.

Facility Characteristics

There were 54 rehabilitation facilities included in the study. Of those, 49 (90.74%) were identified as rehabilitation units within acute care facilities. Only 5 facilities (9.26%) were identified as free standing rehabilitation hospitals. The mean number of operational beds was 28.1 (*SD* =17.5). Because of the difference in the nature of the facilities (units within hospitals versus free standing rehabilitation hospitals), the range of operational beds was broad: 8.0 - 82.0.

Hierarchical Linear Modeling Results

Results for the hierarchical linear models for all variables are presented in tables 4-2 through 4-4. Variables, regression estimates, standard errors, and *p* values are presented for each model.

Nurse Staffing and Patient Outcomes

HLM results for nurse staffing and the dependent variables, length of stay and FIM™ change, are presented in table 4-2. Nurse staffing variables, (RNHPPD, NONRNHPPD, and their quadratic terms) were not significant predictors of length of stay or FIM™ change. Therefore, neither the linear nor the curvilinear relationships nurse staffing , LOS and FIM™ change are statistically significant.

Explanatory Variables and Patient Outcomes: Length of Stay

Hierarchical linear modeling results for explanatory variables and length of stay are presented in Tables 4-3. For staffing models (RNHPPD, NONRNHPPD and RNHPPD, NONRNHPPD, RNHPPD*RNHPPD, NONRNHPPD*NONRNHPPD), RIC group, age, and race significantly predicted length of stay. For RNHPPD and NONRNHPPD, operational beds significantly predicted LOS: the more operational beds in a facility, the longer the length of stay. Rehabilitation Impairment Category Group was significantly related to length of stay for all staffing models ($p = <.0001$). When compared to patients with strokes, length of stay was lower than stroke for all RIC groups. Older patients had higher (longer) LOS ($p = <.0009$) than younger patients. There was a statistically significant positive relationship between LOS and patient race ($p <.023$) for all staffing models. White patients had shorter LOS than all patients of other races.

There was a statistically significant positive relationship between length of stay and operational beds ($p < 0.04$) for RNHPPD and NONRNHPPD. In facilities with a greater number

of beds, patients had longer LOS when compared to other facilities with a lower number of operational beds. However, Facility type did not demonstrate a statistically significant relationship with length of stay (p = .42).

Explanatory Variables and Patient Outcomes: FIM™ Change

Hierarchical linear modeling results for explanatory variables and FIM™ change are presented in Table 4-4. For staffing models (RNHPPD, NONRNHPPD and RNHPPD, NONRNHPPD, RNHPPD*RNHPPD, NONRNHPPD*NONRNHPPD), admission FIM™, RIC group, age, gender, facility type, and operational bed size significantly predicted FIM™. Admission FIM™ significantly predicted FIM™ at discharge/FIM™ change (p <.0001). When compared to patients with strokes, FIM™ change was higher for patients post-brain injury, other orthopedic, and replacement lower extremities (e.g. knee replacement) and lower for patient post-amputation extremities and neurological and spinal cord injuries. There was a statistically significant inverse relationship between FIM™ change and patient age (p <.0001). Older patients had lower FIM™ change than younger patients. FIM™ change for males was significantly lower than females (p =.003), such that women had improved functional outcomes.

Additionally, FIM™ change for patients in freestanding rehabilitation hospitals was significantly higher than for patients in rehabilitation units in acute care hospitals (p = 0.018). There was a statistically significant inverse relationship between FIM™ change and operational beds (p = 0.0021). Patients in facilities with a higher number of operational beds had lower FIM™ change.

Production Function

Length of stay

The results show that length of stay decreases as the number of RNHPPD increases. However, the rate of decrease in LOS slows down as more and more RN hours are added, as

evidenced by the positive coefficient for the squared terms. See Table 4-2. The inflection point, x = -10.3969 is the point at which adding more hours would actually lead to longer length of stay. This suggests that there is a U shaped relationship between RN hours and LOS. The inflection point for NONRNHPPD, x = -8.7875, is the point at which adding more hours would actually lead to longer length of stay. This suggests that there is a U shaped relationship between Non-RN hours and LOS.

FIM™ change

The results show that as the number of RNHPPD increases, FIM™ change increases. Yet, the rate of increase in FIM™ change is decreasing as more and more RN hours are added, as evidenced by the positive coefficient for the squared terms. See Table 4-2. The inflection point, x = -7.1750 is the point at which adding more hours would actually reduce FIM™ change. This suggests that there is an upside down U shaped relationship between RN hours and FIM™ change. The inflection point for NONRNHPPD, x = -8.7006, is the point at which adding more hours would actually reduce FIM™ change. This suggests that there is an upside down U shaped relationship between Non-RN hours and FIM™ change.

Table 4-1. Sample characteristics.

Variable category	Variable	Frequency	%	Mean	*SD*	Minimum	Maximum
Staffing characteristics	RN hours per patient day			3.6	2.2	0 .2	12.0
	Non-RN (LPN/NA) hours per patient day			3.3	1.9	0.0	9.3
	Total hours per patient day			6.9	3.5	0.7	21.4
	Skill mix RN Proportion			0.5	0.1	.02	1.0
Patient outcomes	Length of stay (LOS)			9.7	5.1	1.0	32.0
	FIM™ score on admission			71.4	16.7	18.0	124.0
	FIM™ score on discharge			91.2	20.9	18.0	125.0
	FIM™ discharge minus admission			20.1	13.3	-77.0	66.0
Patient characteristics	Rehabilitation Impairment Category (RIC) Groups						
	Stroke	277	18.14				
	Brain injury	119	7.79				
	Spinal cord injury	82	5.37				
	Neurological	80	5.24				
	Replacement lower extremity	395	25.87				
	Amputation	44	2.88				
	Other orthopedic	260	17.03				
	Other miscellaneous	270	17.68				
	Age	N = 1529		69.7		5.0	101.0
	Gender						
	Male	656	42.90				
	Female	873	57.10				
	Marital status						
	Never married	186	12.34				
	Married	741	49.17				
	Widowed	421	27.94				
	Separated	16	1.06				
	Divorced	143	9.49				
	Race/ethnicity						
	Other	226	14.78				
	White	1303	85.22				
Facility characteristics	Facility type	N = 54					
	Freestanding rehabilitation hospital	5	9.26				
	Rehabilitation unit in acute care facility	49	90.74				
	Operational beds			28.1	17.5	8.0	82.0

Table 4-2. Results from Hierarchical Linear Models for nurse staffing, length of stay, and FIM™ change.

Variable	Length of stay Estimate	*SE*	*p*	FIM™ change Estimate	*SE*	*p*
RN HPPD	-0.08605	0.1399	0.5414	0.2289	0.3183	0.4754
NONRNHPPD	0.1278	0.1399	0.4272	-0.06554	0.3638	0.8578
RN HPPD	-0.4768	0.5420	0.3835	-1.2549	1.2367	0.3154
RNHPPD* RNHPPD	0.04586	0.06084	0.4548	0.1749	0.1409	0.2207
NONRNHPPD	0.7943	0.6679	0.2403	0.6691	1.5051	0.6587
NONRNHPPD* NONRNHPPD	-0.09039	0.08694	0.3038	-0.07691	0.1960	0.6965

SE = standard error; RNHPPD*RNHPPD, NONRNHPPD*NONRNHPPD = quadratic terms

Table 4-3. Results from Hierarchical Linear Models for Length of Stay.

	RNHPPD NONRNHPPD			RNHPPD NONRNHPPD RNHPPD* NONRNHPPD*		
Variable	Estimate	*SE*	*p*	Estimate	*SE*	*p*
Rehabilitation Impairment Category (RIC) Groups			<.0001*			<0.0001*
Stroke	0	.		0	.	
Brain injury	-0.2525	-0.5371		-0.2734	0.5376	
Spinal cord injury	-0.6917	0.6132		-0.7051	0.6135	
Neurological	-1.2391	0.6192		-1.2520	0.6196	
Replacement lower extremity	-3.347	0.4009		-3.3414	0.4013	
Amputation	-0.05381	0.7796		-0.04536	0.7798	
Other orthopedic	-0.9686	0.4275		-0.9715	0.4278	
Other miscellaneous	-2.0095	0.4271		-2.0156	0.4280	
Age	0.03332	0.01006	0.0009*	0.03341	0.01006	0.0009*
Gender			0.1657			0.1719
Male	-0.3774	0.2685		-0.3719	0.2686	
Female	0	.		0	.	
Marital status			0.6025			0.6189
Never married	06507	0.5528		0.6306	0.5533	
Married	0.4184	0.4415		0.4086	0.4416	
Widowed	0.3335	0.4869		0.3255	0.4870	
Separated	-0.9774	1.2726		-0.9842	1.2728	
Divorced	0	.		0	.	
Race/ethnicity			0.0232*			0.0262*
Other	0.9485	0.4014		0.9294	0.4023	
White	0	.		0	.	
Facility type			0.4253			0.4507
Freestanding rehabilitation hospital	-0.8337	1.0369		-0.7998	1.0516	
Rehabilitation unit in acute care facility	0	.		0	.	
Operational beds	0.03688	0.01716	0.0365*	0.03289	0.01783	0.0713

SE = standard error; RNHPPD*, NONRNHPPD* = quadratic terms; *$p < .05$; 0 or . = reference variable

Table 4-4. Results from Hierarchical Linear Models for FIM™ change.

		RNHPPD NONRNHPPD			RNHPPD NONRNHPPD RNHPPD* NONRNHPPD*	
Variable	Estimate	*SE*	*p*	Estimate	*SE*	*p*
Admission FIM™	0.9303	0.02177	<.0001*	0.9301	0.02177	<.0001*
Rehabilitation Impairment Category (RIC) Groups			0.0002*			0.0002*
Stroke	0	.		0	.	
Brain injury	0.8522	1.4433		0.8368	1.4444	
Spinal cord injury	-2.3992	1.6519		-2.3846	1.6524	
Neurological	-3.0578	1.6658		-3.1313	1.6664	
Replacement lower extremity	3.2887	1.1024		3.2284	1.1025	
Amputation	-0.1566	2.1076		-0.1733	2.1074	
Other orthopedic	0.9525	1.1515		0.8870	1.1519	
Other miscellaneous	-1.0962	1.1550		-1.2167	1.1572	
Age	-0.1470	0.02727	<.0001*	-0.1486	0.02727	<.0001*
Gender			0.0032*			0.0032*
Male	-2.2333	0.7241		-2.2333	0.7243	
Female	0	.		0	.	
Marital status			0.3582			0.3664
Never married	2.5843	1.4856		2.5568	1.4864	
Married	1.7244	1.1894		1.7205	1.1897	
Widowed	2.2468	1.3135		2.2430	1.3135	
Separated	-0.5239	3.4258		-0.5002	3.4253	
Divorced	0	.		0	.	
Race/ethnicity			0.8287			0.7987
Other	-0.2308	1.0595		-0.2722	1.0599	
White	0	.		0	.	
Facility type			0.0176*			0.0256*
Freestanding rehabilitation hospital	5.5193	2.2464		5.1509	2.2346	
Rehabilitation unit in acute care facility	0	.		0	.	
Operational beds	-0.1218	0.03745	0.0021*	-0.1154	0.03818	0.0040*

SE = standard error; RNHPPD*, NONRNHPPD* = quadratic terms; **p* < .05; 0 or . = reference variable

CHAPTER 5
DISCUSSION AND IMPLICATIONS

Purpose

The specific aim of this study was to apply production function theory to examine the nature of the relationship between nurse staffing and patient outcomes in the inpatient rehabilitation setting. Nurse staffing [Registered Nurses (RNs), Non- RNs (Licensed Practical Nurses and Nursing Assistants), total nursing staff, and skill mix (RN Proportion and non-RNs)] and its relationship with patient outcomes measured as length of stay (LOS) and functional independence (FIM™) change was examined. Chapter 5 presents the discussion of the results, limitations, and conclusions of this study and implications for future utilization and research.

Discussion

The following hypothesis was tested: There is a non-linear relationship between nurse staffing levels for RNs, Non-RNs, total nursing staff, and skill mix (RN proportion) with patient outcomes of length of stay (LOS) and FIM™ change in the rehabilitation setting such that a production function relationship is elucidated.

Production Function

The hypothesis that there is a nonlinear relationship between RN HPPD and Non-RN HPPD with patient outcomes of LOS and FIM™ change is supported. The relationships of RN HPPD and Non-RN HPPD with LOS and FIM™ are such that neither the linear or quadratic terms are significant. However, both HPPD estimates indicate that the direction of the relationships to LOS and FIM™ change, as evidenced by the reverse coefficient for the squared terms. This is consistent with published literature indicating that a nonlinear relationship between nurse staffing and patient outcomes exists (Lankshear, Sheldon &Maynard, 2005; Kane et al., 2007; Nelson et al., 2007; Zhang & Grabowski, 2004).

In fact, the inflection points for HPPD and both LOS and FIM™ change indicate the point at which adding more hours would actually change the direction of the relationships. This suggests that there is a U shaped relationship between HPPD and patient outcomes. This result indicates that the relationships are curvilinear and approximate a production function curve.

The seminal work of Aiken et al. (2002) and Needleman et al. (2002) set the stage for robust studies of nurse staffing and nurse sensitive patient outcomes over the past decade. While many studies supported that RN proportion resulted in improved outcomes (more is better) the literature has offered little support for minimum nurse-patient ratios (Lang et al. 2004). This minimum- to more- is- better view is what has commonly been assumed and studied as a linear relationship of nurse staffing to patient outcomes.

The "floor" and "ceiling" for nurse staffing has not been established. A curvilinear relationship of nurse staffing to patient outcomes indicates that a floor and ceiling exists. That is, there is a minimal level of nurse staffing where lower levels result in inferior care or outcomes. Similarly, at some range of staffing, a maximum point is reached such that further increases in staffing no longer produce improved outcomes (ceiling). This is the fundamental principle of production function and diminishing returns: at incremental changes in labor (staffing), variations in productivity (outcomes) occur on the trajectory. The results of this study are important in that there is a curvilinear relationship between HPPD and the patient outcomes of LOS and FIM™ change. This is the first step in indicating that a production function with diminishing returns is plausible.

When the nature of the relationships between HPPD with LOS and FIM™ change are further examined in this study, both gave evidence of the increasing or decreasing slope patterns typical of production function models. The existence of diminishing marginal returns to

additional HPPD was supported, although the relationship was not statistically significant. This is consistent with the published literature utilizing production function to model the relationship of nurse staffing and patient outcomes which found increased nurse staffing improved quality and patient outcomes to the point of diminishing returns (Hendrix & Foreman, 2001; Zhang et al. 2006; Mark, Harless, McCue & Xu, 2004; Meyer, Wang, Li, Thompson, & Obrien-Pallas, L., 2009).

The lack of statistically significant estimates in this study does not mean that a production function curve does not exist. The results are in keeping with the traditional slopes of a typical production function model. The lack of statistical support for a model of diminishing returns may have been influenced by the limitations of this study. Decisions related to centering of the variables could have influenced the results. In the same way, different approaches for modeling production function may produce statistically significant results.

FIM™ Change

HLM models including admission FIM™ as a covariate demonstrated a curvilinear relationship between RNHPPD and patient outcomes. As the number of RNHPPD increases, FIM™ change increases. The relationship between RNs and FIM™ change is consistent with previous studies in the acute care setting. Hall et al., 2003 found that proportion of "regulated" nursing staff in Canadian hospitals was found to be a significant predictor of functional status.

In this study, as the number of RNHPPD increases, FIM™ change increases. However, the rate of increase in FIM™ change is decreasing as more and more RN hours are added, as evidenced by the positive coefficient for the squared terms. The inflection point, x = -7.1750 is the point at which adding more hours would actually reduce FIM™ change. This suggests that there is an upside down U shaped relationship between RN hours and FIM™ change.

This is consistent with the results of with Meyer et al. (2009), where the linear relationship between nurse staffing and Omaha Scale knowledge and status changed direction at 88%. As staffing levels exceeded 88%, there were diminishing returns on patient Omaha Scale knowledge, status, and behavior scores. Additionally, Meyer and colleagues reported increasing levels of nurse staffing had an increasing influence on status change to a point of marginal returns. These findings suggest that further investigation into production function modeling as applied to functional status and positive patient outcomes such as knowledge achievement is warranted.

Length of Stay

Nurse staffing levels for RNs and Non-RNs were not significant predictors of length of stay. Nelson (2007) found a significant relationship between hours of total nursing care and RN HPPD with LOS in the rehabilitation setting. The difference in results may be related to an adjustment of the length of stay (n=304): deleting patients with immediate discharge from the sample. In addition, the researchers utilized an iterative process for model development, deleting independent variables found to be nonsignificant. The scope of this current study did not allow for the adjustments in LOS and could be considered for future investigation of these data.

This is in contrast to a large volume of literature supporting the relationship between nurse staffing and LOS. Higher ratios of RNs and RN HPPD were significantly related to reduced length of stay in hospital settings, including the intensive care unit (Amaravadi, Dimick, Pronovost, & Lipsett, 2000; Barkell, Killinger, & Schultz, 2002; Cho, Ketefian, Barkauskas, & Smith, 2003; Lassnigg, Hiesmayr, Bauer, & Haisjackl, 2002; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002). One explanation may be that the nature of the rehabilitation setting is not as amenable to changes in length of stay as acute care setting. Also, economic

pressures encourage early transfer to rehabilitation facilities having the effect of reducing the LOS in acute care setting may be reduced.

When examining the relationship of RN HPPD and LOS, the hypothesis of a production function curve of diminishing marginal returns was supported. The results of this study show that length of stay decreases as the number of RNHPPD increases. Additionally, the rate of decrease in LOS slows down as more and more RN hours are added, as evidenced by the positive coefficient for the squared terms. The inflection point, the point at which adding more hours would actually lead to longer length of stay, suggests that there is a U shaped relationship between RN hours and LOS. This shape approximates the shape of a typical production function curve.

Limitations

Several limitations of this study should be acknowledged. First, hierarchical linear modeling was utilized to address the "nested" nature of the variables in this study. Variables were not centered in the HLM models in the current study. There are many considerations for the selection of variables to center and which centering method to use (e.g., group centering, grand mean centering, etc.). Centering selection choices can affect statistical results. In future work, selection of variables to center and centering method will be incorporated in the development of HLM models.

Second, the HLM modeling results have shown a curvilinear relationship of RN HPPD and Non-RN HPPD with patient outcomes of LOS and FIM™ change.. The methodology for examining diminishing marginal returns with nurse staffing and patient outcomes is limited, but approaches are varied. For the scope of this study, one approach to approximate the inflections points of the curvilinear relationship was utilized. The HLM estimates for HPPD and the

squared terms were calculated for the value of x. Further exploration of the nature of the curvilinear relationships will be part of future investigation.

Third, an argument may be made that the sample consisted exclusively of rehabilitation centers, possibly affecting generalizability of the results. However, nurse staffing has been identified as having a curvilinear relationship and diminishing returns with patient outcomes in the literature in the acute and long term settings. This study of the rehabilitation setting is additive to that body of work.

Implications

Implications for Nursing Practice

Nursing administrators are once again challenged to justify registered nurse staffing in lean economic times. With nurse staffing being one of the largest budget expenses of health care facilities, historical staffing models and hours per patient day are called into question. Empirical data to support staffing decision is needed. In particular, higher costs related to higher RN staffing must be justified. Hall et al. (2003) and Meyer et al. (2009) support that higher RN proportion/ staff utilization is a significant predictor of functional independence. These studies help elucidate the unique nature of nurses' influence on the outcomes of patients in their care.

The evidence to support optimizing both minimum staffing and maximum staffing resource allocation and optimal patient outcomes is growing. Since Hendrix & Foreman, (2001) and Zhang, Unruh, Liu and Wan (2006) the body of literature revealing diminishing returns to nurse labor in acute and long term care has grown. This study indicates that the pattern of diminishing returns also exists in the rehabilitation setting. This adds to the conundrum for health care administrators and policy makers that, in addition to concerns related to minimal nurse staffing, there is a point at which additional staffing no longer promotes quality or

efficiency. Further research is needed to continue to provide evidence to demonstrate the "floor" and the "ceiling" for nurse staffing for all settings.

Implications for Theory

Production function theory was utilized to provide the underpinnings and guide this research study. This theory has been utilized to address staffing resources and patient outcomes (Hendrix & Foreman, 2001; Zhang et al., 2006). As previously stated, the existence of diminishing returns has been demonstrated repeatedly in a variety of settings over the past decade. Nonetheless, the volume of research has not reached a tipping point at which decision makers and policy makers are convinced by the evidence. This theory can provide the conceptual framework for utilizing alternate statistical approaches to the questions of staffing efficiency as it relates to quality of care and patient outcomes, as well as other efficiency concerns in the health care setting today. Perhaps Hendrix and Foreman portended the future when in 2001 they utilized production function theory to "attempt to define an optimum staffing level whereby quality is optimized, personnel are conserved, and public burden is minimized" (p. 164).

Implications for Future Research

In their study of nurse staffing and patient outcomes, Meyer, Wang, Li, Thompson, & Obrien-Pallas, L. (2009) noted a "ceiling effect" where patient with higher admission Omaha knowledge, behavior and status scores were less likely to show improvements at discharge. Further analysis of the rehabilitation data may reveal a similar effect of admission FIM™ scores on discharge FIM™ scores and therefore, FIM™ change. This could be an important factor for consideration in future analysis for other outcomes, as well.

Although research of nurse staffing and patient outcomes has surged in the last decade, few studies have applied the theory of production function to examine the nature of those

relationships. Methodological issues in nurse staffing research continue to be refined, including which statistical approaches best address the "nested" nature of nurse staffing and patient outcomes within facilities. Studies including large data sets in all settings (acute care, long term care, and rehabilitation) could further substantiate if the relationship of nursing labor and patient outcomes consistently demonstrates diminishing returns. These data are important to support decision makers and policy makers in tight fiscal environments such as health care today.

"Nurse sensitive" patient outcomes are another growing body of work for researchers and quality measurement specialists. For example, higher RN proportion decreased probability of pneumonia and a subsequent reduction in LOS (Cho et al., 2003; Unruh, 2003). They attribute RN proportion as specifically influencing the interventions aimed at the prevention of pneumonia and are therefore particularly "nurse sensitive". Nelson et al. (2007) noted that further research is needed to articulate the rehabilitation RN work processes that affect patient outcomes. The work of Hall et al. (2003) reported RN proportion/staff mix as a significant predictor of functional independence. Further research is needed to continue to substantiate the influence rehabilitation RN staffing and interventions have on functional outcomes.

Conclusions

The hypothesis that there is a nonlinear relationship between RN HPPD and Non-RN HPPD with patient outcomes of LOS and FIM™ change is supported. The relationships of RN HPPD and Non-RN HPPD with LOS and FIM™ are such that neither the linear or quadratic terms are significant. However, both HPPD estimates indicate that the relationships to LOS and FIM™ change direction, as evidenced by the reverse coefficient for the squared terms. Therefore, the nature of the curvilinear relationship of nurse staffing and patient outcomes approximated a model of production function and diminishing returns was demonstrated.

This study provides further evidence that nurse staffing and patient outcomes have both a "floor" and a "ceiling". These are both inflection points at which quality and efficiency are sacrificed. Concerns about the economy and the state of health care in general have reached a Zeitgeist in the United States. Further research is imperative to provide leaders in health care the ability to generate data-driven and evidence based practice decisions for optimal quality and efficiency.

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BIOGRAPHICAL SKETCH

Mary Margaret Nason graduated from the University of Alabama, Huntsville with her Bachelor of Science in Nursing, with high honors in 1979. Upon graduation, she served as an officer in the United States Naval Nurse Corps until 1984. She received her Master of Science in Nursing from the University of Florida in 2001. She received her Ph.D. from the University of Florida in the spring of 2014. Her minor course of study for her doctorate was Health Services Research, Management, and Policy. During her Ph.D. program she earned a research grant from Sigma Theta Tau, Lambda Rho Chapter-at-large. Her nursing experience includes a broad range of progressive clinical, administrative, research, educational, and informatics roles. She has served as a member University of Florida Institutional Review Board (2006-2008). Her research interests are nursing workforce, patient outcomes, and exploration of organizational effectiveness.