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Preterm Infant Incubator Humidity Levels: A Systematic Review

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This is to certify that the doctoral study by

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has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

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Abstract

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MS, Wayne State University, 2009

BS, Case Western Reserve University, 2004

Project Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Nursing Practice

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Abstract

Numerous scholars have reported that inconsistent incubator humidity in the neonatal intensive care unit (NICU) requires attention. Evidence synthesis was needed to assist the identification of optimal incubator humidity levels and duration to decrease transepidermal water loss (TEWL) and the potential for infection. The purpose of this doctoral project was to appraise and synthesize the evidence of preterm outcomes related to incubator humidity. The practice-focused question addressed what patient outcomes were impacted by incubator humidity level and duration in premature infants < 32 0/7 weeks cared for in the NICU. The foundation of this project was the Joanna Briggs Institute method for systematic reviews. Mefford's theory of health promotion for the preterm infant was used to address the wholeness of the preterm infant's body system. Evidence was classified using the Johns Hopkins evidence-based practice levels and quality of evidence. The search was conducted in 8 databases, and citation searching was used to identify 340 articles, 12 of which met the inclusion criteria. The evidence demonstrates that the practice of incubator humidity is warranted; however, it does not come without risks. Microbial growth was increased in high levels of incubator humidity. Unnecessary TEWL was prevented by lowering high levels of incubator humidity after the 1st week, improving skin barrier formation. Incubator humidity of 60%–70% in the 1st week was effective in preventing TEWL in infants born ≥ 26 weeks; however, future research is needed for infants < 26 weeks. When optimal levels and duration of incubator humidity are achieved, positive social change will occur from the improved outcomes of the smallest neonatal patients.

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Dedication

This paper is dedicated to the many preterm infants that have struggled for survival. The strength and will to live in these tiny patients inspired me to pursue one small step in easing their struggle.

Acknowledgments

I would like to sincerely thank Dr. Valdez for the guidance and mentoring throughout this project. I would also like to thank Dr. Balsan for igniting the passion of neonatology in me. In addition, I cannot thank enough my husband, Steve, my mother, Christine, and my four sons, Blake, Easton, Mason, and Steele, for encouraging and supporting me during the completion of this degree. Without all of these aforementioned incredible people, this project would not have been accomplished.

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Section 1: Nature of the Project

Introduction

Concern about the humidity conditions in the care of preterm infants dates back to the 1930s when Blackfan and Yaglou (1933) suggested the importance of humidity in relation to temperature. In the 1950s, Silverman and Blanc (1957) revealed that preterm infants nursed in an incubator set at 80%–90% relative humidity had a markedly lower death rate versus preterm infants nursed in 30%–60% relative humidity incubators. These researchers suggested that humidity played an important role in evaporative losses (Silverman & Blanc, 1957).

As the care of preterm infants improved, preterm infants' immature skin development became a topic of interest. Transepidermal water loss (TEWL) and fluid balance challenges in this population were studied, and it was discovered that incubator humidity was most influential on TEWL in preterm infants (Antonucci, Porcella, & Fanos, 2009). Although 75% relative humidity effectively reduced TEWL during the first days of life, this environment was suggested to prolong skin barrier maturation in preterm infants (Agren, Sjors, & Sedin, 2006).

The immature skin barrier in preterm infants is thought to be a major predisposing factor in neonatal sepsis (Visscher & Narendran, 2014). Along with an immature skin barrier, risk for preterm infant infection and sepsis due to contaminated incubators is an important factor to consider while determining the amount and duration of humidity. Studies have shown that microbes thrive in humid incubator environments (de Goffau et al., 2011). Reported preterm infant deaths due to infection have been linked to humidity chamber contamination (Etienne et al., 2011).

Multiple body systems in the preterm infant benefit from incubator humidity; yet, careful consideration and eliminating unnecessary use of incubator humidity is warranted because risks in this practice exist. Because of the lack of large clinical trials, variations occur in incubator humidity practices (Naka, Freire, & da Silva, 2016; Tengattini, Ferrario, Re, & Bezze, 2015). Currently, there is not a national standardized guideline for the amount and duration of incubator humidity in the care of preterm infants. The goal of this Doctor of Nursing Practice (DNP) systematic review project was to compile and analyze the evidence on preterm infant skin maturation, incubator humidity research, and humidity-related contamination risks to develop provider guidance on the level and duration of incubator humidity in the care of preterm infants.

My hope is the results of this systematic review can create a positive impact in neonatology by synthesizing current evidence of incubator humidity in the neonatal intensive care unit (NICU). The comprehensive information provided in this systematic review will be available to assist providers in clinical decision-making regarding optimal incubator humidity levels. The results of this DNP project can promote positive social change by being used to improve preterm infant outcomes through vigilant management of incubator humidity levels.

Problem Statement

The Focus of the Project

An infant born before the 37th week of gestation is considered preterm (World Health Organization [WHO], 2019). Globally, prematurity is the leading cause of infant death (Centers for Disease Control and Prevention [CDC], 2018). Preterm infant births are increasing worldwide, with an estimate of 15 million preterm infants born each year (WHO, 2019). Disparities in preterm births exist with African American women being 50% more likely to delivery preterm infants (WHO, 2019).

As advanced technology enables the survival of infants 23 weeks gestation and above (Boyd, Brand, & Hagan, 2017), evidence on how to best care for this population has become a concern. Preterm infant clinical conditions, such as TEWL, hypothermia, electrolyte imbalance, oxygen consumption, infection, and skin integrity, have shown to be affected by the amount of incubator humidity (Delanaud et al., 2017; Naka et al., 2016; Shlivko et al., 2014; Tengattini et al., 2015; Turnball & Petty, 2013). However, several scholars have identified the inconsistent use of incubator humidity in NICUs (Delanaud et al., 2017; Lim, 2018; Naka et al., 2016; Tengattini et al., 2015).

Local Relevance

The CDC (2018) reported that 382,726 preterm infants were born in the United States in 2017. Although the total birth rate is declining in the United States, the rate of U.S. preterm births has steadily increased each year beginning in 2014 (Martin et al., 2018). The United States was ranked as the sixth leading country in the number of preterm infants born (WHO, 2019).

Variable incubator humidity practices have been identified globally as well as in the United States (Delanaud et al., 2017; Lim, 2018; Naka et al., 2016; Tengattini et al., 2015). Locally, in the northeastern United States, variation also exists. In one large northeastern healthcare organizational system with 13 locations, each neonatal unit has a different incubator humidity practice. One NICU in the organization has varying incubator humidity use, while another NICU in the same organization created and follows an incubator humidity policy. According to several scholars, the unstructured incubator humidity levels in the NICU requires attention (Lim, 2018; Naka et al., 2016; Tengattini et al., 2015). The information provided in this DNP project can be used to guide local leadership teams in making decisions for optimal incubator humidity level and duration in the NICU with the hypothesis of improved patient outcomes.

Significance in Nursing Practice

This doctoral project holds significance and contributes to the advancement of neonatal nursing practice by providing a collection of what is currently known regarding the effects of incubator humidity on preterm infants. Skin development and maturation related to gestational age is discussed, and evidence is summarized regarding the known outcomes, risks, and benefits of incubator humidity in the care of preterm infants. With the completion of this doctoral project, I identified best nursing practices in the use of incubator humidity in the NICU. It is my hope that this document can provide neonatal nurses with inspiration towards practicing consistent usage of incubator humidity. When standardization of care is built on sound evidence, safer patient care practices will follow and lead to improved neonatal outcomes.

This project fulfills the American Association of Colleges of Nursing (AACN; 2006) DNP Essentials I–VIII. In these essentials, the AACN states that the DNP contributes to healthcare with scientific underpinning and scholarship for evidence-based practice (EBP) as well as addresses population health issues to improve outcomes. Use of these project results can assist policy formation and drive the needed future research forward in the area of preterm infant incubator humidity levels and duration.

Purpose

The purpose of this DNP project was to add to the body of knowledge concerning the best incubator humidity practice for preterm infants in the NICU. I hypothesized that by providing those who care for preterm infants with this systematic review of the evidence, optimal incubator humidity levels and duration will improve patient outcomes. These outcomes include decreased hospital costs, length of stay, as well as morbidity and mortality in this population.

The Gap in Practice

In this project, the gap in practice recognized in the care of preterm infants was the lack of a standardized recommendation for optimal incubator humidity levels in the NICU. This gap is indicated by significant inconsistency in practice, leading to multiple effects in preterm body functions associated with TEWL when inadequate incubator humidity is provided. However, when incubator humidity is offered, there is a risk of incubator contamination, which may lead to infection or death (Etienne et al., 2011). This inconsistent practice was a gap in knowledge warranting evaluation and improved management.

Randomized control trials focusing on incubator humidity are limited. In this collection of the body of evidence related to TEWL, skin maturation, and microbe growth, I brought together a compilation of current knowledge to support the amount and duration of incubator humidity levels in the NICU for preterm infants. Incubator humidity effects also need to be considered with clinical practices such as phototherapy and skin-to-skin care.

With this doctoral project, I addressed the gap in practice regarding preterm infant incubator humidity-related patient outcomes. Current variation in the use of incubator humidity supports that clinical expertise and judgment determines each facility's usage of incubator humidity. In my experience, incubator humidity levels and duration have been inconsistent, not only among units, but also among providers. I believe that with the results of this systematic review of quality evidence, neonatal providers will recognize the importance of standardized incubator humidity levels and make EBP changes that will enhance patient outcomes.

With this presentation of a synthesis on all that is currently known about incubator humidity-related patient outcomes, the gap in neonatal practice of how to provide best incubator humidity has been closed until additional research is published.

The goal of this systematic review was to clarify the benefits and risks of incubator humidity levels so that a standardized recommendation for incubator humidity levels can be developed. Consistent, optimal use of incubator humidity in the NICU can then allow for positive patient outcomes.

Practice-Focused Question

The practice-focused question for this doctoral project was: In premature infants < 32 0/7 weeks gestation cared for in the NICU, what impact does incubator humidity level and duration have on patient outcomes? By answering this practice-focused question, I reviewed all aspects of patient care related to incubator humidity, including preterm infant skin development, skin maturation, skin barrier formation, skin integrity, TEWL, preterm infant infections, incubator contamination, phototherapy, and parental care. Neonatal intensive care providers are now presented with a synthesis of evidence that closed the gap in knowledge of best incubator humidity level practice until further clinical trials arise.

Nature of the Doctoral Project

Sources of Evidence

I obtained evidence on incubator humidity by performing a thorough literature review of CINAHL, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, Ovid, Science Direct, and ProQuest databases with search terms of *incubator humidity* in conjunction with *preterm infant, premature infant,* and *NICU*. I evaluated literature related to the terms *TEWL, skin maturity, skin barrier* *formation, and skin integrity*. Due to the narrow subject matter and lack of multiple clinical trials focusing specifically on incubator humidity in the NICU, my search was expanded to literature published within the last 15 years.

Approach

Evidence that is offered in a clear, systematic presentation drives clinical decision-making (Joanna Briggs Institute [JBI], 2019). The approach I took in this doctoral project was a systematic review of evidence on patient outcomes related to incubator humidity levels. All of the presented research studies and literature are relevant to incubator humidity in preterm infants who are cared for in the NICU. The articles were organized in an evidence table that arranges literature that has been analyzed with inclusion and exclusion criteria of international research from JBI (2019).

My appraisal of the included studies adhered to the JBI approach to systematic reviews. I used a flow diagram to clearly display the structured, systematic review format of the literary search process. The relevant data were evaluated and synthesized to summarize the evidence related to the topic of incubator humidity in the NICU. The nature of this project was to address the practice-focused problem by identifying how the recognized gap in practice is closed. The results are presented in a systematic review of evidence accessible to healthcare professionals.

Significance

Stakeholders

The stakeholders identified in this project were neonatal intensive care providers, including nursing staff, nursing directors, nurse educators, nurse practitioners, physicians, as well as NICU patients and their families. Organizational leadership, management, and policy committees may find that this systematic review guides decision makers to determine the optimal incubator humidity levels in their neonatal units. Standardization of nursing practice is known to reduce errors, leading to safer care (Upshaw-Owens, 2019). The consistent, structured management of incubator humidity may have a variety of effects. Offering incubator humidity is the best intervention to prevent TEWL (Antonucci et al., 2009). Early stabilization of the fluid and electrolyte balance can lead to decreased days on intravascular fluids, potentially shortening the length of hospital stay (Antonucci et al., 2009). While discontinuing unnecessary humidity will reduce infection risk (Etienne et al., 2011).

In the NICU, family members are a significant part of the NICU care team. In this review, I identified known recommendations of family involvement practices, such as skin-to-skin care during incubator humidity. Incubator humidity stabilization has also been shown to prevent skin injury in the fragile skin of this patient population (Tengattini et al., 2015). Decreasing injury and scarring from interrupted skin integrity will positively affect the preterm infant as well as increase provider and family satisfaction.

Transferability

The findings of this project may be transferable to other areas of nursing practice where skin integrity is compromised such as burn units. Preterm infant skin resembles mature skin that has been wounded (Visscher & Narendran, 2014). In this doctoral project, I discuss skin maturation and barrier development. Incorporating humidity into the healing process of compromised mature skin could benefit areas outside the field of neonatology. In this document, I conclude that future humidity research opportunities exist, not only in the care of preterm infants, but also in patients where skin is compromised.

Social Change

Infant morbidity and mortality are global health issues with prematurity being the leading cause of death (CDC, 2018). As the care of preterm infants evolves and infants born at the threshold of viability are surviving, it is crucial to determine best practices to prevent TEWL while enhancing skin barrier formation and reducing the risk for infection. This DNP project promotes positive social change by providing a systematic review of incubator humidity evidence that neonatal providers can use in the care of preterm infants, resulting in improved management of electrolytes, thermoregulation, and skin integrity. Providers that create standards and guidelines might use this document to work towards ensuring positive neonatal outcomes.

One of these outcomes is to preserve the skin integrity of this population. Neonates have an incomplete skin structure at the time of delivery (Shlivko et al., 2014).

Endotracheal tube tape, securing of umbilical lines, and electrocardiogram electrodes can cause tape-stripped epidermis in this vulnerable population of premature infants (Tengattini et al., 2015). Compromised skin and immaturity of the epidermal barrier puts the preterm infant at risk for infection (Visscher & Narendran, 2014).

Along with improving patient outcomes, positive social change is promoted by this project through decreasing skin scarring in premature infants with consistent incubator humidity at optimal levels. The evidence reviewed in this project has the potential to standardize preterm incubator humidity levels. This project aligns with the mission of Walden University to promote social change by identifying optimal incubator humidity levels for the preterm infant population according to the available evidence.

Summary

The inconsistency of incubator humidity found in NICUs is an addressable problem that when attended to will lead to the advancement of nursing practice. Without a systematic review of the evidence on this topic, many scholars have found this inconsistency to be problematic (Delanaud et al., 2017; Lim, 2018; Naka et al., 2016; Tengattini et al., 2015). Positive social change is promoted by this project through delivering a collection of evidence suggesting the need for the development of standardized incubator humidity level protocols or guidelines that decrease the sole reliance on individual professional judgment for humidity use in the NICU. In the following section of this systematic review, I detail the background and importance of incubator humidity in the NICU. Models and theories used as the framework for this project are discussed and relevance to nursing practice is explained.

Section 2: Background and Context

Introduction

This section relates the practice problem of inconsistent use of incubator humidity in the care of preterm infants in the NICU to nursing theories and models. McEwen and Wills (2014) explained that theory is the framework used to guide all aspects of research. Theory adds scientific value to the results of scholarly work by connecting knowledge concepts (McEwen & Wills, 2014). This doctoral project was based on the concept of EBP, which is vital in nursing to achieve empiricism. When EBP is based on theory, it engages nursing staff and provides a structure to guide the process of implementing the evidence into practice. Mefford's (2004) theory of health promotion for preterm infants was the theory I chose as the theoretical framework for this project. The EBP model that was appropriate for addressing this practice problem was the JBI (2019) approach to evidence-based healthcare, which provided additional detailed guidance on completing the steps of this systematic review. Scholarly work published on this topic was classified using the Johns Hopkins EBP levels and quality of evidence. In this evaluation of existing scholarship, I explain what has developed thus far in the care of preterm infants. This section also includes a clarification of relevant terms, discussion of existing scholarship relevant to nursing practice, and explanation of the role of the DNP student in this project.

Concepts, Models, and Theories

Mefford's Theory of Health Promotion for Preterm Infants

This DNP project was based on Mefford's (2004) midrange theory of health promotion for preterm infants. Theoretical parsimony was achieved by structuring this theory on Levine's conservation model (McEwen & Wills, 2014). This theory was created during Mefford's (1999) dissertation work, at which time the researcher recognized the gap in knowledge for a theoretical framework to use in the care of preterm infants. The validity of Mefford's theory of health promotion for preterm infants was achieved through a descriptive correlation study that later followed (Mefford & Alligood, 2011). This identification of findings, validated through research, provided evidence that this theory achieved structural consistency with inductive reasoning (Fawcett & Garity, 2009). For the preterm infant to achieve health attainment, all concepts of health in the model must be met (Mefford, 2004). This concreteness confirms the testability of the theory (Fawcett & Garity, 2009). The validated theory provides NICU nurses with a framework to minimize injury, promote a stable family system, protect and enhance neurodevelopmental competence, and achieve physiologic stability (Mefford & Alligood, 2011). Mefford (2004) linked intrauterine and extrauterine environments to the preterm infant's immature body system as well as to the disruption of the family system. These aspects contribute to the well-being and wholeness of health in the preterm infant (Mefford, 2004).

Evaluating a collection of evidence was required to connect the use of incubator humidity to each of the four theoretical aspects described by Mefford (2004). Ultimately, this project contributes to empiricism by aligning what is known in each of these aspects of health in the preterm infant. Through this process, I also discovered that evidence is lacking in the use of incubator humidity, leading to suggestions for future research. Using this theory as a foundation in this doctoral project allowed me to formulate a plan that concisely addressed the wholeness of health by administering precision and thoroughness to each aspect of health in the preterm infant.

Joanne Briggs Institute Approach for Evidence Analysis

I used the JBI (2019) approach to evidence-based healthcare as the method to establish inclusion and exclusion criteria. The JBI approach is composed of multiple checklists for those to follow in the creation of a systematic review. I employed these checklists to complete this project. Aromataris and Pearson (2014), published authors from the JBI, explained that systematic reviews that are internationally accepted are defined by the following seven criteria:

- Identifying a practice problem,
- Determining the eligibility of studies by explaining inclusion and exclusion criteria,
- Thoroughly searching all relevant evidence,
- Appraising the quality of the studies,
- Analyzing the data found in the included studies,

- Synthesizing and presenting the findings, and
- Expressing the methodologies used.

The Johns Hopkins EBP Model and Levels of Evidence

The following steps in the Johns Hopkins EBP model provide scholars with a clear structure to base EBP on: (a) identifying a practice question, (b) searching for evidence, (c) appraising the evidence, and (d) determining if the evidence is supportive of the practice change (Newhouse, Johns Hopkins University, Sigma Theta Tau International, & Johns Hopkins Hospital, 2007). Having a foundation in EBP that answers nursing practice issues through an organized approach can validate current practice or find evidence that suggests practice change is needed (Newhouse et al., 2007).

I used the Johns Hopkins EBP model to determine the strength of the evidence by assigning each included article with a level of evidence and quality rating suggested by Dang and Dearholt (2017). Level I evidence was determined by articles that were randomized controlled trials or systematic reviews of randomized controlled trials (see Dang & Dearholt, 2017). Articles that were assigned as Level II evidence were quasi-experimental studies and systematic reviews of quasi-experimental studies (see Dang & Dearholt, 2017). Level III evidence was assigned if the article was nonexperimental or if a systematic review synthesized studies with mixed-method designs (see Dang & Dearholt, 2017). I determined evidence to be Level IV if the included evidence was the opinion of respected authorizes or was the opinion of nationally recognized committees, such as clinical practice guidelines (see Dang & Dearholt, 2017). Lastly, Level V was assigned to the evidence if it was an interrogative or literature review or an expert opinion that was based on experiential evidence (see Dang & Dearholt, 2017).

After determining the level of evidence, I assigned the quality of the evidence as: (a) high quality, (b) good quality, or (c) low quality. A high level of quality was assigned to evidence if consistent generalizable results were found (see Dang & Dearholt, 2017). Evidence of good quality had the characteristic of forming a fairly definitive conclusion, and a low-quality rating was assigned if no conclusion was made from the results of the evidence (see Dang & Dearholt, 2017). Mefford's theory, the JBI approach, and the Johns Hopkins EBP model and hierarchy of evidence guided me in this doctoral project towards achieving a thorough conclusion that was based on what evidence has shown.

Relevance to Nursing Practice

The History of Incubator Humidity

Blackfan and Yaglou (1933) were the pioneer researchers of this topic, suggesting the importance of humidity in the care of preterm infants. Twenty years later, Silverman and Blanc (1957) concluded that 80%–90% environmental humidity had a tremendous effect on preterm infant survival when compared to 30%–60% humidity. Their research began the evidence of TEWL.

Harpin and Rutter (1985) conducted a study on the effects of 60% incubator humidity on evaporative losses in infants born less than 30 weeks gestation. They concluded that 60% incubator humidity compared to 30% led to less evaporative losses and better temperature control, but pseudomonas aeruginosa was collected on occasion from the humidity chamber (Harpin & Rutter, 1985). Given the technology available, these scholars recommended that infants less than 30 weeks gestation receive 4 to 7 days of incubator humidity (Harpin & Rutter, 1985).

Existing Scholarship

To further investigate incubator humidity infection risk, Lynam and Biagotti (2002) tested microbe contamination in the incubator, Giraffe Omnibed, when 65% humidity was delivered. They determined that the Giraffe Omnibed humidification process to boil water prior to dispersing humidification did sterilize the water when contaminated with pseudomonas aeruginosa, serratia marcesens, escherichia coli, or candida albicans (Lynam & Biagotti, 2002). No microbes were ever found in the patient areas of the incubators when the humidity chambers were contaminated (Lynam & Biagotti, 2002). Pseudomonas aeruginosa was found at 24 hours and candida albicans was found in the humidity chambers up to 48 hours after contamination, suggesting thermal death occurred within the humidification system between 48 and 72 hours after contamination (Lynam & Biagotti, 2002). These researchers recognized that many NICUs use higher incubator humidity and suggested that future studies be conducted on the microbe growth at higher humidity levels (Lynam & Biagotti, 2002).

Sinclair and Sinn (2008) conducted a systematic review on incubator humidity. Although it was not published, they presented their investigation of four studies at the Australia and New Zealand Perinatal Society Conference, suggesting that prolonged moderate levels of humidity might delay epidermal barrier formation and increase TEWL

(Sinclair & Sinn, 2008). They discussed that there was not clear evidence that humidity "reduces fluid requirements, weight loss, the incidence of patent ductus arteriosus, or increases the risk of intracranial hemorrhage, sepsis, or mortality" (Sinclair & Sinn, 2008, p. s1). These scholars also remarked that there was paucity in strong research surrounding incubator humidity amount and duration (Sinclair & Sinn, 2008).

Thereafter, Sinclair, Crisp, and Sinn (2009) published a survey that identified variation in incubator humidity practices among 26 NICUs in the Australian and New Zealand Neonatal Network. All NICUs in their study provided incubator humidity to preterm infants. The amount ranged from not being measured to 100% and the duration ranged from 3 to 77 days (Sinclair et al., 2009). Variation also existed in the incubator humidity weaning process (Sinclair et al., 2009). Sinclair et al. concluded that future trials would direct clinical guidance in determining the optimal levels and duration of incubator humidity.

Knobel (2014) detailed the thermoregulation process in the care of preterm infants. The author found that there are not any standard guidelines for the amount and duration of incubator humidity and that additional research is needed in this subject (Knobel, 2014). Knobel concluded that according to the evidence available, high incubator humidity is beneficial in thermal stability, skin integrity, TEWL, and fluid and electrolyte balance in the extremely preterm infant population and suggested lowering humidity to 60% as soon as the infant tolerates this change to minimize risks.

Current State of Nursing Practice

National organizations, such as the American Academy of Pediatrics (AAP), National Association of Neonatal Nurses, Academy of Neonatal Nursing, and the Neonatal Network, did not have accessible guidelines or policies for incubator humidity at the time of this DNP project. In this doctoral project, I assessed evidence related to incubator humidity and identified where lack of knowledge in this topic exists. The specific areas for future research are suggested in a later section of this document. It was my hope that this project brings about the beginning of consistency in incubator humidity practices, providing the preterm infant population best care and optimal outcomes.

Current use of incubator humidity is inconstant as documented by Sinclair et al. (2009) and Knobel (2014) as well as evidenced by my clinical experience in several northeastern U.S. hospitals. In the Australian and New Zealand survey conducted by Sinclair et al., 77% of hospitals responded that they had an incubator humidity policy in place, but there was a wide range of variation among those policies. Incubator humidity practice policy surveys in the United States have not been published to date. Through a search of extant literature for this project, I found a few American hospital incubator humidity policies. A wide range of variation existed among the policies reviewed. Incubator humidification variation exists in the large hospital system in which I am employed, with multiple NICUs at different facilities.

The addition of incubator humidity for the care of preterm infants has been shown to improve survival (Silverman & Blanc, 1957) but has also been linked to an increased risk for infection (Etienne et al., 2011). The gap in knowledge of the optimal amount and duration of incubator humidity leaves the practice of neonatology with the uncertainty of what level and treatment length of humidity is most beneficial for preterm infant outcomes. I created this doctoral project to close the gap in knowledge by synthesizing the evidence of preterm outcomes related to incubator humidity.

Advancing Nursing Practice

The inconsistent use of incubator humidity in the care of preterm infants has been a concern of many scholars; yet, strong evidence is lacking for specific recommendations or national guidelines to be generated. Therefore, I conducted a detailed analysis of what is known in different areas related to incubator humidity use in the care of preterm infants in this project. The goal of this doctoral project was to answer the clinical question of what affect the level and duration of incubator humidity has on preterm infants. This was accomplished by evaluating the evidence in the areas of preterm infant skin maturation and barrier formation, TEWL, fluid and electrolyte balance, infection, family-centered care, and incubator humidity effect on phototherapy treatment. Through the evaluation of these categories, I achieved an approach to comprehensive nursing care as Mefford's (2004) theory suggested.

Standardization in nursing practice leads to safer practice, improved quality of care, and better outcomes (Upshaw-Owens, 2019). This DNP project had the goal to advance nursing practice by presenting a synthesis of the evidence. With the conclusions and dissemination of this project, it is my hope that optimal level and duration of incubator humidity can be achieved for every preterm infant.

Local Background and Context

The lack of standardized incubator humidity in the care of neonates has led to inconsistent use in many NICUs and ignited my interest to select this topic for my doctoral project. Optimal incubator humidity is a gap in neonatal practice. NICU patients are receiving varying amounts of incubator humidity. NICUs that do not have written incubator policies have significantly different levels and duration of humidity use within their unit (Sinclair et al., 2009). There also is a marked difference in the specifics of the policies between the hospitals that have developed NICU incubator humidity policies (Sinclair et al., 2009). Because of previous research showing improved survival, the use of humidity is considered standard treatment for extremely preterm infants, yet there are not any nationally recognized recommendations. Humid incubator conditions have shown to affect the preterm infant's TEWL, electrolyte balance, skin maturation, and temperature stability (Delanaud et al., 2017; Naka et al., 2016; Shlivko et al., 2014; Tengattini et al., 2015; Turnball & Petty, 2013). However, it is concerning that there is a lack of large randomized controlled trials comparing different levels and duration of incubator humidity in the NICU. With this synthesis of the existing evidence, the gap in knowledge was filled with a concise collection of patient outcomes affected by incubator humidity level and duration.

Institutional Context and Strategic Vision

The information provided in this document is relevant to all hospitals with delivery capabilities, with a focus on hospitals that care for infants in Levels III A, B, and C NICUs nationally and internationally. The AAP (2019) stated that Level II NICUs should be limited to infants who are born greater than 32 weeks gestation. Incubator humidity has been reserved for infants born prior to 32 0/7 weeks due to the skin maturation of infants above this gestation (Allwood, 2011). It is generally accepted to use incubator humidity in the care of preterm infants. Yet, national organizations are hesitant to define policies without multiple randomized controlled trials that clearly direct specific care. Although more research is needed, there is evidence available in different areas of the preterm infant's care such as TEWL and skin development that can assist the neonatal provider in determining the optimal use of incubator humidity. The strategic vision for this DNP project was to identify and synthesize all the purposeful knowledge in the area of incubator humidity so that neonatal providers have a collection of evidence to base clinical decisions on in the care of preterm infants until further incubator humidity research is available for national guidelines and policies to be developed.

Relevant Terms

I used the following terms in this project.

Extremely preterm infant is an infant is born < 28 0/7 weeks of gestation (WHO, 2019).

Humidity is defined as the percentage of water vapor in the air when compared with the total water vapor that is possible at the same temperature (National Weather Service, n. d.). The incubator humidity discussed throughout this doctoral project is relative humidity.

Level I NICU is a hospital nursery that is equipped and staffed to resuscitate newborns, stabilize and prepare for the transfer of preterm or ill newborns, and care for stable infants > 35 weeks gestation (see AAP, 2019).

Level II A NICU is a special care hospital nursery that is equipped and staffed to resuscitate newborns, stabilize and prepare for the transfer of preterm or ill newborns, and care for infants > 32 weeks gestation weighing > 1,500 g without the capability to provide continuous positive airway pressure or mechanical ventilation (see AAP, 2019).

Level II B NICU is a special care hospital nursery that is equipped and staffed to resuscitate newborns, stabilize and prepare for the transfer of preterm or ill newborns, and care for infants > 32 weeks of gestation weighing > 1,500 g with the capability to provide continuous positive airway pressure or mechanical ventilation for less than 24 hours (see AAP, 2019).

Level III A NICU is a hospital unit that is staffed and equipped to provide continuous life support limited to conventional mechanical ventilation for infants > 1,000 g and > 28 weeks of gestation (see AAP, 2019).

Level III B NICU is a hospital unit that is staffed and equipped to provide continuous life support to infants with extreme prematurity, < 1,000 g and < 28 weeks of gestation, offering high-frequency ventilation, inhaled nitric oxide, pediatric medical subspecialists, and advanced imaging (see AAP, 2019). Level III B NICUs also have a pediatric surgeon and pediatric anesthesiologist either on site or at a nearby related institute (see AAP, 2019).

Level III C NICU is a hospital unit that has the capabilities of a Level III B NICU with the addition of cardiac surgical repair and extracorporeal membrane oxygenation (see AAP, 2019).

Neonatal Intensive Care is "a facility or unit staffed and equipped to provide continuous mechanical ventilatory support for a newborn" (CDC, 2016, p. 40).

Preterm infant is an infant who is born < 37 0/7 weeks of gestation (WHO, 2019).

Role of the DNP Student

Professional Relationship to the Doctoral Project

Practicing as a neonatal nurse practitioner for the past 10 years, I have had the opportunity to care for many preterm infants. Along with examining infants, initiating the plan of care, prescribing privileges, and attending high-risk deliveries, I have the responsibility to perform procedures such as endotracheal intubation, lumbar puncture, umbilical line placement, and placing peripherally inserted central catheters. Working in a Level III B NICU, it is also my responsibility as a neonatal nurse practitioner to travel to rural hospitals to stabilize and transport ill neonates. My experience has allowed me to view other hospital's use of incubator humidity which led to the recognition of local inconsistent practices as Sinclair et al. (2009) discovered in Austria and New Zealand.

The professional experience I gained as a neonatal nurse practitioner engaged my interest in optimizing the care of preterm infants in the NICU through EBP. Incubator humidity largely affects multiple body functions and by providing optimal incubator humidity, I believe stabilization of these systems can occur. In the large multi-centered organization where I am employed, there are not any system-wide standards for the amount and duration of incubator humidity. In 2015, I developed an incubator humidity policy for use in my local NICU. Since that time, our unit has experienced improved patient outcomes with only one episode of treatment required for preterm infant hypernatremia. This DNP project has led to revisions to my facility's incubator humidity policy. It remains a possibility that this project will lead to my unit's revised incubator humidity policy being approved for system-wide use throughout the organization.

My role in this doctoral project was to develop scholarly work that presents a document including all the neonatal clinical outcomes that are known to be affected by incubator humidity identified through quality evidence. Doctoral education is built on scholarship and research (AACN, 2006). By preparing this systematic review, I have met the DNP Essentials I-VIII as described by AACN (2006).

This DNP project used the JBI (2019) criteria to produce quality work that generated clear acknowledgment of what is known in this subject matter. Systematic reviews by definition do not create new knowledge, but instead summarize and synthesize the existing knowledge (Aromataris & Pearson, 2014). My employment responsibilities and my practicum experience were not incorporated in developing this systematic review.

Motivations and Potential Bias

As a nursing professional, I am motivated to establish well-being wholeness in the care of patients with an emphasis on evidence-based nursing practice. Nursing care is changing at a rapid pace (Aromataris & Pearson, 2014). Being an advanced practice nurse, enhancing care falls into the realm of my responsibilities as listed in the AACN (2006) DNP Essentials.

The goal of this DNP project was to seek the evidence surrounding outcomes related to incubator humidity. Biases can compromise results (Knoll et al., 2018). As the author of the incubator humidity policy at my facility, potential bias regarding the active incubator humidity policy in use at one hospital existed. To address this potential bias, the current policy at my facility was revised. This was accomplished after the completion of this DNP project, once full analysis of all the evidence on this topic was conducted.

Summary

In this section I discussed how incubator humidity has developed into current practice in the NICU. This project had the strong foundation of Mefford's theory, the Johns Hopkins EBP model, and the JBI approach to evidence-based healthcare. The level of evidence explained by Dang and Dearholt (2017) was used to identify the strength and quality of the evidence that was included in this project.

The DNP role of developing a systematic review was supported by the AACN (2006) DNP Essentials. My personal motivation and passion to improve preterm infant outcomes was the driving force that led to the creation of a high-quality scholarly synthesis of the evidence. The following Section 3 of this document details the methods that were used to analyze the evidence of what is known in the specific areas of preterm infant's care that relate to incubator humidity. The sources that were used for evidence retrieval and the evaluation tools of the evidence analysis are also explained.

Section 3: Collection and Analysis of Evidence

Introduction

Routine use of incubator humidity in the NICU is common; however, inconsistent incubator humidity usage, as supported by Sinclair et al.'s (2009) findings, is problematic for neonates because the optimal levels and duration of incubator humidity are unknown. The purpose of this doctoral project was to provide a systematic review of the evidence on preterm infant outcomes related to incubator humidity. Closing this gap in knowledge assists neonatal providers in determining the optimal amount and duration of incubator humidity. This synthesis of incubator humidity related outcomes might also assist the formation of incubator humidity policies so that standardized practices can be created. Standardization of care commences when EBP relays information for process improvement (Upshaw-Owens, 2019). Short- and long-term healthcare outcomes for the preterm infant population could be improved using the results of this synthesis of the evidence surrounding the practice issue of identifying the optimal incubator humidity amount and duration.

This section includes an in-depth description of the methodology of evidence collection that I used in this systematic review. Sources of evidence are explained, keyword search terms are stated, and inclusion and exclusion criteria are described. In addition, I explain Mefford's theory and the JBI approach to evidence-based healthcare. The Johns Hopkins hierarchy of evidence was another framework used in this project to determine the level of evidence and quality of the study (see Dang & Dearholt, 2017).

Practice-Focused Question

The practice-focused question for this doctoral project was: In premature infants < 32 0/7 weeks gestation cared for in the NICU, what impact does incubator humidity level and duration have on patient outcomes? My experience as a neonatal nurse practitioner allowed me to identify the uncertainty concerning optimal incubator humidity as a gap in knowledge. To address this practice problem, I analyzed all aspects of neonatal care related to incubator humidity, including preterm infant skin development, skin maturation, skin barrier formation, skin integrity, TEWL, preterm infant infections, incubator contamination, phototherapy, and skin-to-skin care. Synthesizing the evidence relating to all aspects of neonatal care aligned with Mefford's (2004) theory of health promotion for the preterm infant by identifying improvements to the patient's wholeness of health. The results of this project present neonatal intensive care providers with a synthesis of evidence that closes the gap in knowledge of best incubator humidity practice until further clinical trials arise and are appraised.

Sources of Evidence

To address this practice-focused question, I conducted a systematic review of patient outcomes related to incubator humidity. JBI's (2019) mission is to promote and support evidence-based healthcare. The JBI approach to evidence-based healthcare was developed to assist those who are critically appraising the evidence to produce quality documents that ultimately aide in healthcare clinical decision-making. I followed JBI's process to develop a systematic review to complete this project. The structure of the JBI approach created a strong foundation for this doctoral project. AACN (2006) described the role of the DNP as an expanded role that is responsible for demonstrating expertise, specialized knowledge, and the management of care for individuals and families. Through the development of this doctoral project, I produced a quality document that fulfills this DNP role expectation.

Published Outcomes and Research

I collected evidence for this project by conducting a thorough search using CINAHL, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, Ovid, Science Direct, UpToDate, and ProQuest databases. Citation searching was conducted on all appropriate articles as well as on current incubator humidity policies in use in the United States. Citation searching informs the researcher of relevant parallel topics and is a powerful complimentary search method to keyword searching (Hinde & Spackman, 2015). Along with computerized database searches, I used Google Scholar to search for published as well as grey literature. Hospital incubator humidity policies that were available online were accessed. Major children hospitals were phoned to inquire about incubator humidity policies use, as suggested by McArthur et al. (2017).

The foundation for evidence synthesis is an extensive literary search (Knoll et al., 2018). The search terms that I used were *incubator humidity* in conjunction with *neonate, newborn, neonatal intensive care, preterm, premature,* and *infant skin*. Additionally, the terms *humidification, humid, TEWL, skin maturity, skin barrier formation,* and *skin* *integrity* were searched. The Boolean operators *and* and *or* were used to combine these terms to focus the search of the literature.

JBI (2019) provided a rigorous process that scholars can use during critical appraisal and synthesis of diverse forms of evidence. By using the JBI approach, I aligned the diversity of evidence collected for this project. I accessed and reviewed high-quality published journal articles, textbook information, incubator manufacturing manuals, and institutional protocols for this project. Due to the narrow subject matter, my search was expanded to sources published within the last 15 years. The sources, terms, and methods of the search of the literature facilitated the exhaustive and comprehensive nature of this project by accessing all significant data pertaining to incubator humidity in the NICU.

Analysis and Synthesis

After the completion of the comprehensive literary search, I evaluated the articles and sources using JBI's (2019) inclusion and exclusion criteria. Articles that related to the practice-focused question that had been published in the last 15 years were included. Articles that were not related to preterm infant incubators were excluded as well as studies that were greater than 15 years old. A flow diagram displays my process of selecting evidence suitable for analysis (see Appendix A). These data were evaluated and synthesized to clearly relay all that is currently known on the topic of incubator humidity in the NICU. The JBI steps to developing a systematic review are to identify a practice problem, determine the eligibility of which studies will be included, conduct a thorough search, appraise the quality of the study, analyze the data, synthesize the findings, and explain the methodologies used (Aromataris & Pearson, 2014).

I used an evidence table for recording and organizing the literature collected (see Appendix B). The integrity of the evidence was interrogated by using the JBI critical appraisal checklist for systematic reviews and research syntheses (McArthur et al., 2017).The included evidence was then rated using the Johns Hopkins levels and quality of evidence framework to assign a specific level and quality code to each article (see Dang & Dearholt, 2017). Lack of data and missing data related to key incubator humidity patient outcomes is discussed in the limitation subsection of Section 4.

The nature of this project aligned the practice-focused problem of unknown optimal incubator humidity with a synthesis of the evidence. The results are presented in a systematic review of the evidence accessible to healthcare professionals. The recognized gap in knowledge is closed, allowing providers to make clinical decisions based on what evidence currently exists.

Summary

Incubator humidity is a common practice among NICUs; however, optimal use of incubator humidity has not yet been described in the field of neonatology. Upshaw-Owens (2019) explained that standardization that is not based on evidence might not be best for patient care. The purpose of this doctoral project was to close this gap in knowledge by determining what levels and duration of incubator humidity the evidence suggests leads to improved patient outcomes. Preterm infants are surviving at younger gestational ages with the support from advancements in technology (Boyd et al., 2017). These infants who are born on the threshold of viability require incubator humidity (Kim, Lee, Chen, & Ringer, 2010). The optimal length and duration of incubator humidity was a gap in knowledge that required attention.

Assessing the quality of research gives strength to the results (Whiting, Rutjes, Reitsma, Bossuyt, & Kleijnen, 2003). Identifying a standardized approach to quality assessment in a systematic review is important (Whiting et al., 2003). In the following section, I critically appraise the evidence related to preterm infant incubator humidity using the structured guidelines of JBI (2019). An evidence table provides the level and quality of each article determined according to criteria set forth by the Johns Hopkins Nursing EBP model (see Appendix B).

Section 4: Findings and Recommendations

Introduction

Incubator humidity is an inconsistent practice in the NICU and has been identified as such by Sinclair et al. (2009) in Australia and Deguines et al. (2012) in France. I, too, have validated inconsistent incubator humidity use in the United States by reviewing several U.S. Level III NICU incubator humidity policies. Locally, in the organization in which I am employed, varying use of incubator humidity is demonstrated throughout the several Level III NICUs in the system. Inconsistent incubator humidity in the NICU was the identified gap in practice which I sought to address with this project and the practice question of: In premature infants < 32 0/7 weeks gestation cared for in the NICU, what impact does incubator humidity level and duration have on patient outcomes? The purpose of this DNP project was to synthesize the existing evidence of incubator humidity levels and duration for preterm infants < 32 0/7 weeks gestation. My principal goal with this systematic review was to compile the research findings and recommend what additional research on preterm infant incubator humidity levels and duration in the NICU is warranted.

Sources of Evidence

To locate evidence for this project, I adhered to the systematic steps outlined by JBI (2019) and the *Walden University DNP Systematic Review Manual*. The practice question was formulated after thoroughly investigating the topic of incubator humidity levels in the NICU. The evidence was collected by completing a comprehensive and exhaustive search of the literature using the following eight databases: CINAHL, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, MEDLINE, Ovid, Science Direct, UpToDate, and ProQuest. The search terms used for the database search were *incubator and humidity, humidification*, or *humid* in conjunction with *neonate, newborn, neonatal intensive care, preterm, premature,* and *infant*. The Boolean operators *and* and *or* were used to combine these terms to focus the search of the literature. I narrowed the evidence to only include articles published in the last 15 years with dates of January 1, 2004 through August 1, 2019. Available in-use hospital NICU incubator humidity policies were obtained, and major children hospitals were phoned to inquire about the resources they used to guide incubator humidity policies, as suggested by McArthur et al. (2017). The obtained policies were used for citation searching to assure my evidence search was comprehensive and exhaustive. I accessed and reviewed high-quality published quantitative journal articles, textbook information, incubator manufacturing manuals, and institutional protocols for this project. The JBI (2019) approach provided a rigorous process that ensured that the critical appraisal and synthesis of the literature included diverse forms of evidence.

The next step in this systematic review was to identify the method of appraisal used. I followed the Johns Hopkins levels and quality of evidence, outlined by Dang and Dearholt (2017), for quantitative research. Level I evidence included randomized controlled trials or systematic reviews of randomized controlled trials, Level II evidence included quasi-experimental studies or systematic reviews that included quasi-experimental studies, Level III evidence included nonexperimental or mixed-method design systematic reviews or studies, Level IV evidence included the opinion of respected authorizes or nationally recognized committees, and lastly, Level V evidence was identified as an interrogative or literature review or an expert opinion that was based on experiential evidence (see Dang & Dearholt, 2017). After determining the level of evidence according to the guidance of the Johns Hopkins levels and quality of evidence, I assigned the quality of the evidence as (a) high, (b) good, (c) or low quality. A high level of quality was assigned to evidence if consistent generalizable results were found (see Dang & Dearholt, 2017). Evidence of good quality had the characteristic of forming a fairly definitive conclusion, and a low-quality rating was assigned if no conclusion was made from the results of the evidence (see Dang & Dearholt, 2017).

Inclusion criteria included peer-reviewed, full-text, journal articles available in the English language that addressed the practice question. I limited articles to the 15-year publication timeframe of January 1, 2004 through August 1, 2019. Exclusion criteria included articles that were not available in full text, those that were not available in English, and those that did not address the practice question. Low-quality evidence articles according to the Johns Hopkins levels quality of evidence that did not conclude significant results about incubator humidity level or duration in the NICU were not included in this systematic review.

After identifying the databases, terms, appraisal method, and inclusion and exclusion criteria, the next step in this project was to perform the evidence search. I organized the evidence by themes of skin-to-skin care, infection, dermatology, fluid and electrolyte balance, and other incubator humidity-related articles. An evidence table (see Appendix B) was created assuring the integrity of the evidence was explained through limitations that identified conflicting or missing information and highlighted the significance of the findings.

There were 347 articles identified by the search criteria that were published in the last 15 years. I discovered 72 articles through other sources, such as citation searching. After removing duplicate articles, 340 articles remained out of the 419 total articles identified. After abstract review, 291 articles were excluded. I examined 49 full-text articles, and of these, 37 were excluded. The majority of these articles were excluded due to incubator humidity levels not being discussed as leading to an effect on the outcomes of the study. Other articles were excluded because no significant findings or conclusions on incubator humidity levels or duration were drawn, leading to a low-quality rating according to the Johns Hopkins levels and quality of evidence (see Dang & Dearholt, 2017). I selected 12 quantitative research articles for evaluation and analysis for this systematic review that met the inclusion criteria. A flow diagram was created using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines to detail the evidence search and selection of included articles in the review (see Appendix A).

Findings and Implications

The articles selected for this DNP project met the inclusion criteria and were thoroughly appraised. In this section, along with Appendix B, I identify the authors; year of publication; study design and method; purpose of the study; sample characteristics, such as population, size, and setting; limitations; key findings; and level and quality of evidence. Each article was carefully analyzed for the strength of the findings and the implications for the practice of incubator humidity use in the NICU. The selected articles were all relevant to the level and duration of incubator humidity and its effects, risks, benefits, and conclusions that assisted the synthesis of evidence and necessity for future research.

Skin-to-Skin Care

In a prospective, interventional study, Maastrup and Greisen (2010) evaluated 22 preterm infants who were < 28 weeks gestation in a Denmark Level III NICU. The purpose of their study was to determine if preterm infants in skin-to-skin care could maintain their temperature outside of the humidified incubator. Limitations of their study included the small sample size, inconsistent humidity levels with the mean of 63% incubator humidity, and the inconsistency of the family member who provided the skin-to-skin care. In their study, 16 mothers, one father, and one female sibling were placed skin-to-skin with the preterm infant. Mean infant skin temperatures were increased by 0.1 C with the mother and decreased by 0.3 C when skin-to-skin with other family members ($p = 0.011$). Their study provided Level II B evidence that extremely preterm infants were able to maintain stable temperatures while outside of the humidified incubator during skin-to-skin care with their mother when proper transferring techniques were used. The identified area for future study was the evaluation of temperature control when preterm infants are skin-to-skin care with other family members (Maastrup & Greisen, 2010).

Karlsson, Heinemann, Sjors, Nykvist, and Agren (2012) prospectively studied 26 preterm infants born in Sweden who were < 27 weeks gestation within their first 9 days of life. The purpose of their study was to evaluate the thermal balance and the physical environment of extremely preterm infants during skin-to-skin care. Limitations of their study included a small sample size, differing skin-to-skin positions, and techniques to transfer the infant to the mother were not optimized. The mean incubator humidity level of 68% was significantly higher than outside the incubator in the skin-to-skin environment humidity of 42% ($p < 0.001$; Karlsson et al., 2012). The results of this Level II B study revealed that extremely preterm infants had increased insensible water loss of 1 g per kg during skin-to-skin care (Karlsson et al., 2012). Extremely preterm infants were able to maintain stable temperatures outside of the humidified incubator environment according to the nonsignificant differences between the infant's pre- and posttest temperatures ($p = 0.32$; Karlsson et al., 2012). The authors concluded that the amount of increased insensible water loss did not outweigh the recognized benefits of skin-to-skin care (Karlsson et al., 2012).

Incubator Humidity Effects on Infection

De Goffau et al. (2011) investigated whether microbe contamination level could be predicted from incubator temperature and humidity settings. Twenty-three previously occupied NICU incubators were divided into two groups of ≤ 60% incubator humidity and ≥ 60% incubator humidity, and the temperature distribution and microbe contamination were identified (de Goffau et al., 2011). The article lacked a strict systematic swab method for all of the incubators with the first 11 incubators being swabbed more often than the last 12 incubators (de Goffau et al., 2011). The results of their study showed that there was increased microbe growth in the cooler regions of the incubators when incubator humidity was ≥ 60% ($p = 0.002$), while incubator humidity of ≤ 60% did not meet statistical significance ($p = 0.275$) for increased microbe growth in the cooler regions of the incubator (de Goffau et al., 2011). I assigned this article as Level II B evidence. Future research of a larger correlation study that evaluates the relationship between microbial growth and humidity level was suggested (de Goffau et al., 2011).

Etienne et al. (2011) conducted a case study to investigate the cause of three primary diagnoses of cutaneous aspergillosis in extremely preterm infants with the gestational ages between 23 4/7 weeks and 24 3/7 weeks in a U.K. NICU. The limitations identified in their article were the case study design and the retrospective, environmental sampling, which led to the assignment of a Level V C evidence rating. The results of their case study revealed that aspergillus fumigatus was found in the humidity chambers of three infected neonates, one of whom died. The microsatellite typing concluded that a genotypical relationship existed between the humidity chambers and the infected infants (Etienne et al., 2011). The results of their study provided insight that future research is needed in the area of real-time strain typing during outbreaks or cluster infections in the NICU (Etienne et al., 2011).

Dermatologic Incubator Humidity Studies

Visscher and Narendran (2014) performed a literature review in the United States with the purpose of reviewing the skin ontogeny related to fetal development, preterm infant skin, and the effects after birth. Their review detailed the relationship of environmental factors after delivery on the skin barrier formation in preterm infant skin. Visscher and Narendran added valuable information towards answering the practice problem in this systematic review by explaining that even extremely premature infants have a rapid skin barrier formation within 5 days after birth with full stratum corneum maturation estimated to occur between 2 to 9 postnatal weeks. A significant increase in involucrin and albumin was noted in preterm infant ≤ 32 weeks gestation, suggestive of barrier disruption, inflammation, and TEWL (Visscher & Narendran, 2014). A limitation of their study was that the details of the literature search were not revealed, leading to the assignment of a Level V B evidence rating. Future areas of investigation included the relationship between gestational age and the maturation of the stratum corneum to provide evidence on microflora, susceptibility to injury, permeability, structure, and composition (Visscher & Narendran, 2014).

In a randomized controlled trial, Agren et al. (2006) tested how the level of incubator humidity influences the postnatal skin maturation. They included 22 preterm infants between 23 and 27 weeks gestation in their Swedish study. Limitations included a small sample size and the fact that not all the infants were evaluated for TEWL on Days 0, 3, and 7 due to instability of the patients. Their study provided evidence that extremely preterm infants who were nursed in 75% incubator humidity after the first week of life exhibited increased TEWL when compared to infants nursed in 50% incubator humidity after the first week of life ($p < 0.001$) and significant differences in temperature stability, weight gain, and serum sodium levels were not found. Their findings suggested that 75% incubator humidity beyond the first week of life may delay skin barrier formation without benefiting other body systems. I assigned this article an evidence rating of Level I B. Areas in need of future investigation are the level of humidity in skin barrier formation related to microbe and environmental toxins (Agren et al., 2006).

Allwood (2011) composed a literature review in Australia to develop evidence-based skincare guidelines for infants between 23 and 30 weeks gestation. Six articles from the previous 10 years were included with a total sample size of 4,145 patients. A limitation of the applicability of findings for the purpose of this review was that some of the included articles included infants > 30 weeks gestation. Allwood's document concluded that preterm infants are at increased risk for skin injury, that the majority of epidermal development is complete by 32 weeks gestation, and that skin barrier formation and increased strength of the dermis-epidermis connection occurs with increased gestational age. Incubator humidity recommendations were to begin humidity at 85% for the first week, and then wean to 50%, however the duration to extend humidity was not evident in the literature (Allwood, 2011). I assigned their literature review as a Level V A evidence rating. A future area of study that was identified was studying the application of adhesives to neonatal skin (Allwood, 2011).

Incubator Humidity Effect on Fluid and Electrolyte Balance

Sung et al. (2013) completed a retrospective exploratory study that investigated the fluid and electrolyte balance of 218 extremely low-birth-weight preterm infants during the first week of life while in high humidity incubators in Korea. Infants who were ≤ 24 weeks gestation in 95% incubator humidity levels were compared with ≥ 26 week gestation infants in 60% incubator humidity. A major limitation of the study was that infants in the 25-week gestational group were excluded due to varying humidity levels. Another limitation of the study was that the groups were not of equal gestational ages. The sample size gave this article strength in the findings that 22- and 23-week infants exhibited an increased insensible water loss, fluid intake, and electrolyte imbalance despite 95% incubator humidity. Infants who were 24 weeks gestation nursed in 95% humidity did not have a significant increase in insensible water loss compared to infants ≥ 26 weeks gestation in 60% incubator humidity. Infants ≥ 26 weeks gestation in 60% incubator humidity did not exhibit increased insensible water loss when compared with those in 80% humidity concluding that in this population, 60% incubator humidity was sufficient (Sung et al., 2013). The 3 days of 95% incubator humidity which was then gradually decreased may have sufficiently compensated for insensible water loss, fluid intake, and electrolyte balance in the 24-week gestational age group (Sung et al., 2013). This study was determined to be a Level III B evidence. The future direction of study included insensible water loss investigation of 22- and 23-week infants (Sung et al., 2013).

Kim et al. (2010) conducted a retrospective study on 182 extremely low-birth-weight infants who were < 1,000 g in a U.S. medical center. The purpose of the study was to compare extremely preterm infants in humidified and nonhumidified incubators to identify changes in temperature, fluid and electrolyte management, and growth. Secondary outcomes included mortality, bronchopulmonary dysplasia, necrotizing enterocolitis, patent ductus arteriosus, sepsis, and intraventricular hemorrhage. A limitation in this study was that the inclusion criteria did not include gestational age, a known determinant of skin maturation (Fanaroff & Fanaroff, 2012). Another limitation was that the study design may have allowed for unrecognized practice changes in the time differences (humidified group 2002-2005, nonhumidified group 2002-2003) of the study (Kim et al., 2010). Two groups of infants < 1,000 g at birth were studied comparing incubator humidity (70%-80% for Week 1, then 50%-60% Week 2 until corrected to 32 weeks) versus no incubator humidity. Significant findings in the humidified group were increased growth velocity ($p = 0.020$), a decreased incidence of severe bronchopulmonary dysplasia ($p = 0.003$), less fluid intake ($p < 0.0001$), less urine output ($p < 0.0001$), less insensible water loss ($p < 0.0001$), less weight loss ($p < 0.0001$), lower incidence of hypernatremia (*p* = 0.003), higher incidence of hyponatremia (*p* = 0.014), and less electrolyte sampling (*p* = 0.0248; Kim et al., 2010). No significant differences were found for mortality (*p* = 0.155) temperature instability, intraventricular hemorrhage (*p* = 0.897), patent ductus arteriosus (*p* = 0.882), necrotizing enterocolitis (*p* = 0.709), mild and moderate bronchopulmonary dysplasia (*p* = 0.904), or sepsis (*p* = 0.195) between the two groups (Kim et al., 2010). However, more infants in the humidified group were diagnosed with bacterial sepsis (adjusted odds ratio 1.6) and there was a positive correlation between hypernatremia and intraventricular hemorrhage (Kim et al., 2010) which warrants future study in these areas. The evidence rating of this study was Level III A.

Kong, Medhurst, Cheong, Kotsanas, and Jolley (2011) conducted a single-center randomized controlled trial in Austria that included 50 preterm infants ≤ 28 weeks gestation within the first 2 weeks of life. Limitations were that the nurses were unable to be blinded, it was performed at a single center, a larger sample size may have led to more statistically significant findings, and selection bias between groups was present for infants < 26 weeks with nine infants < 26 weeks in Group A versus four infants < 26 weeks in Group B. Infants ≤ 28 weeks gestation were randomized to 70% or 80% incubator humidity for the first 14 Days of life. No statistical significance was discovered between the two groups in skin integrity, body temperature (*p* = 0.8), fluid requirement, sodium levels, sepsis (*p* = 0.55), patent ductus arteriosus (*p* = 0.39), chronic lung disease (*p* = 0.09), or intraventricular hemorrhage (equal cases among the groups; Kong et al., 2011). Microbial growth was more prominent in the incubators with 80% humidity (Kong et al., 2011), suggesting not offering levels > 70% incubator humidity unless necessary. I rated this article as a Level I A evidence and the authors offered direction for future research in the area of comparing levels of humidity for differing durations. More research is needed comparing humidity levels in patients < 26 weeks.

Additional Incubator Humidity Studies

An experimental data collection study by de Carvalho, Torrao, and Moreira (2011) had the purpose of measuring the irradiance level of phototherapy in humidified incubators in Brazil. The three levels of 60%–70%, 80%, and ≥ 90% were studied in a double-walled neonatal incubator with three different phototherapy devices. The study had limitations of using one incubator and that the irradiance meter measured to 1μW/cm²/nm, which may not have been strong enough to make conclusions on the low irradiance of the fluorescent phototherapy device (de Carvalho et al., 2011). The key findings concluded that incubator humidity of 60%–70% did not alter phototherapy irradiance, while incubator humidity ≥ 80% decreased LED and halogen phototherapy by 10%-45% (de Carvalho et al., 2011). Fluorescent phototherapy irradiance was unaltered by humidity levels (de Carvalho et al., 2011). The rigor of verifying the irradiance level of the phototherapy devices and measuring meters used as well as executing the irradiance level tests for the incubator humidity levels led me to assign this article as a Level II A study.

Prazad et al. (2008) collected data in a U.S. observational descriptive study with the purpose to identify and quantify 45 volatile compounds in four differing incubator operational modes. Ten unoccupied NICU incubators were used to study what effect the different operational modes had on the airborne compounds. One limitation in this study was that the incubators were unoccupied, possibly increasing the compounds inside the incubator compared to occupied incubators that would have the portholes opened during the care of the neonate. There was also uncertainty of the clinical implications due to no reference points available from the occupational safety and health administration (OSHA) on safe exposure levels of the studied compounds in the fetal or newborn population, although the levels were below the exposure limits for adults and animals (Prazad et al., 2008). The results revealed that when 50% incubator humidity was added, airborne volatile organic compounds were increased ($p < 0.0001$ - $p < 0.0006$; Prazad et al., 2008). This study had a rigorous study design with air samples adhering to a systematic collection method and each collection sample was repeated at two different time periods that were 5 months apart leading to a Level III A evidence rating. The conclusions of this study revealed the need for future research in the area of neonatal exposure limits of airborne volatile organic compounds (Prazad et al., 2008).

Unintended Limitations

The gestational age of study participants was a limitation that impeded the collection of evidence. Several articles were excluded because the gestational age of the participants was greater than 32 weeks. These studies were discarded for this document to strengthen the focus of the project on infants less than 32 weeks gestation. Within the articles evaluated, gestational age persisted to be problematic in compiling a conclusion on the level and duration of incubator humidity that included all infants less than 32 weeks gestation. This barrier impacted the project by complicating the findings of each study. The evidence suggested that infants < 26 weeks gestation need different incubator humidity levels than infants who are born at 26–32 weeks gestation.

Implications

The implications that were drawn from the evidence collected in this review can be applied to not only the individual preterm infant, but also to their family, neonatal nurses, the organization, the organization system, the field of neonatology, as well as the community and nation. By optimizing incubator humidity levels and duration, clinical outcomes of preterm infants will be improved. The evidence discussed suggests incubator humidity can lead to improved neonatal management in several areas of preterm infant health fulfilling the stipulation of Mefford's theory. The improved preterm infant outcomes might then lead to decreased usage of community resources, government funding, and healthcare spending, creating a tumbling effect of positive social change in society.

Recommendations

The gap-in-practice of unknown optimal incubator humidity levels and duration has been addressed in the findings of this project. The evidence does not close this gap, but rather narrows the gap by some degree according to gestational age and days of life.

Although some conclusion can be drawn, more research on incubator humidity levels and duration that is focused on infants < 26 weeks gestation is needed.

The evidence in this review suggests that the benefits of skin-to-skin care outweigh the additional insensible water loss that preterm infants exhibit when outside the humidified incubator (Karlsson et al., 2012). Extremely premature infants have been shown to maintain stable temperature regulation when skin-to-skin with their mother (Maastrup & Greisen, 2010), concluding that skin-to-skin care with the mother is a beneficial and safe practice for the population of infants less than 32 weeks gestation who are cared for in humidified incubators.

The evidence concludes that skin barrier formation and maturation of the stratum corneum is nearly complete by 32 weeks gestation (Allwood, 2011; & Visscher & Narendran, 2014), offering the implication to limit incubator humidification for infants born < 32 0/7 weeks gestation. Agren et al. (2006) demonstrated that preterm infants who remained in incubator humidity of 75% after the first week of life had delayed skin barrier maturation when compared to 50% incubator humidity after the first week of life. This evidence, along with the work by Visscher and Narendran (2014) suggests that preterm infants have a rapid skin barrier formation in the first 5 days of life and additional high levels of humidity might impede skin maturation after delivery leading to increased TEWL (Agren et al., 2006). Clear evidence has demonstrated that 60%–70% incubator humidity for the first week of life followed by 50%–60% incubator humidity until 32 weeks corrected age compared to no incubator humidity positively impacted preterm infant outcomes, such as decreasing severe bronchopulmonary dysplasia, electrolyte imbalance, weight loss, and insensible water loss, among other findings (Kim et al., 2010).

Sung et al. (2013) demonstrated that infants born < 24 0/7 weeks gestation had increased TEWL even when supported with 95% incubator humidity, compared to 24 week infants who demonstrated that 95% humidity for the first 3 days compensated the TEWL, while infants ≥ 26 weeks gestation did not exhibit increased insensible water loss when in 60% versus 80% incubator humidity. On the contrary, the evidence supported by Kong et al. (2011) suggested that that no patient benefits were found when incubator humidity was set to 80% versus 70%, while microbial growth was more prominent in the 80% group, although this was not statistically significant. Other studies provided evidence that microbe growth is higher in incubator humidity ≥ 60% (de Goffau et al., 2011), and humidity chambers were found to be contaminated during the investigation of neonatal infections leading to death (Etienne et al., 2011). In addition, Prazad et al. (2008) found a significant increase in volatile airborne compounds when 50% humidity was added to the neonatal incubator. Additional evidence revealed that phototherapy was found to be affected by incubator humidity, with levels ≥ 80% decreasing the irradiance by 10%–45% (de Carvalho et al., 2012).

In conclusion, the evidence suggests that careful consideration be given when providing preterm infants with incubator humidity > 70% who may have developed a skin barrier and do not require the humidity protection for TEWL as demonstrated in the first days of life. The evidence surrounding the benefits of continuing incubator humidity at 50% to 60% beyond 2 weeks after birth remains limited. However, several studies have demonstrated that microbes and toxins thrive in humid conditions (de Goffau et al., 2011; Etienne et al., 2011; Kong et al., 2011; Prazad et al., 2008).

Strengths and Limitations

Strengths

A major strength of this project was following the knowledge concepts of Mefford's theory of health promotion for the preterm infant to compile evidence that linked the preterm infant's wholeness of health to incubator humidity. All research should be guided by a theoretical framework to contribute scientific value to the findings of scholarly work (McEwen & Wills, 2014). Using Mefford's theory for the foundation of this doctoral project brought structure to defining the process of implementing incubator humidity evidence into practice.

Another strength of this systematic review is that the many scholars across the globe confirm that incubator humidity has varying practice among NICUs that requires attention. This confirms the need for a systematic review of the evidence. The inconsistent practice of incubator humidity solidifies the importance of the conclusions of this review and the need for future research relevant to the practice question. Findings from this systematic review were strengthened by using JBI systematic review guidelines, including an independent review and appraisal by a second doctoral-prepared researcher.

This second independent review ensured that the search for the evidence was exhaustive and minimizes bias in the appraisal and application of the evidence.

Limitations

The largest limitation to this DNP project was the lack of availability of large randomized trials comparing different incubator humidity levels and duration. Another limitation of this document was that neonatal expert opinion was not included in this report. Experts in the field of neonatology who have developed neonatal textbooks explain that incubator humidity should be provided to preterm infants (Fanaroff & Fanaroff, 2012), however detailed information was not found on the level or duration.

Future Opportunity

Investigating the practice issue of inconsistent incubator humidity in the NICU has led to the conclusion that future studies are needed comparing incubator humidity levels and duration correlated with gestational age. During the process of completing this DNP project, it has been determined that future studies are needed to evaluate the level of humidity in the NICU environment comparing that to the closed heated non-humidified incubator and what impact this may have on neonates. Future incubator humidity research of infants < 26 weeks gestation will be beneficial to the management of this unique population. Large randomized controlled trials that evaluate preterm infant skin barrier formation and how humidity affects this formation will significantly assist practice guideline formation in the level and duration of incubator humidity in the NICU. The research area of incubator humidity holds great opportunity for additional evidence to be collected that can further clarify the precise incubator humidity level and duration according to gestational age. Until this knowledge is generated, neonatal providers are responsible for evaluating the evidence that currently does exist on this subject to guide the use of incubator humidity in the NICU.

Section 5: Dissemination Plan

Introduction

In this final section of the DNP project, I provide a reflection using a self-analysis. The dissemination plan is outlined, and the challenges and solutions that accompanied completion of this project are discussed. My previous role as a neonatal nurse along with my current role as a neonatal nurse practitioner has prepared me for the next level of nursing professionalism. Completion of this doctoral degree and the findings in this document will bring positive change to the field of neonatology. I now possess the knowledge and skills to identify areas of need and to bring quality evidence into practice. Reflecting upon the work of this DNP project brings guidance to future work because this is expected from those who have this terminal nursing degree (AACN, 2006).

Dissemination

My plan for the local dissemination of this work is to present a research poster to disseminate the findings, which will also be used to guide revisions to the current NICU incubator humidity policy in my hospital. Furthermore, the findings will be presented to the local organizational system in which a system-wide NICU incubator humidity policy is not currently in place. Because inconsistent incubator humidity has been identified not only locally, but also in several countries (Deguines et al., 2012; Sinclair et al., 2009), it is important to convey the findings and areas in need of future research to a broad neonatal nursing audience by publishing in a neonatal peer-reviewed journal. Through the dissemination of this work, neonatal providers will have the evidence synthesized to help guide humidity use in the NICU. Neonatal outcomes, such as improved fluid management, skin barrier formation, and electrolyte balance as well as decreased severe bronchopulmonary dysplasia and risk for infection will ultimately be achieved. Highlighting the areas that still require additional research will lead scholars to focus on generating more research surrounding the issue of incubator humidity in the NICU.

Analysis of Self

This doctoral journey has advanced my knowledge and skill set towards becoming a leader in the field of neonatal nursing. In particular, this DNP project has disciplined me as a scholar to pursue a practice issue that I believed in. I recognized there was a practice issue, confirmed other scholars agreed, and structured the project based on theory allowing me to evaluate how to enhance several neonatal body systems through synthesizing the evidence of humidity levels in the care of preterm infants in the NICU. I will continue to work toward improving patient outcomes in the NICU through EBP implementation, becoming a life-long learner.

Challenges were met with solutions as I worked diligently on producing a document valuable to the field of neonatal nursing. One barrier in the completion of this DNP project was the continual research of secondary citation sources. Although this expanded my knowledge base greatly, it led to reviewing many unnecessary articles that were not relevant to the practice question of this project. Throughout my doctoral journey, I have improved my management, leadership, and professional skills, conquering difficult barriers, such as project deadlines and interdisciplinary project management. This journey has taught me how to be an effective leader in healthcare by appraising the evidence around a practice issue, followed by interpreting the findings and developing a plan for dissemination.

Summary

In summary, incubator humidity is a common practice used worldwide in neonatal management; however, the field of neonatology suffers the consequences from the lack of standardized incubator humidity guidelines. The practice of incubator humidity is warranted (Kim et al., 2010) but does not come without risks (Allwood, 2011; de Carvalho et al., 2011; de Goffau et al., 2011; Etienne et al., 2011; Kim et al., 2010; Prazad et al., 2008). Removing the preterm infant from the humidified incubator environment for skin-to-skin care has been shown to be a safe practice during the first weeks of life (Karlsson et al., 2012; Maastrup & Greisen, 2010). The evidence suggests that infants born ≥ 32 0/7 weeks gestation have skin maturity that does not require incubator humidity (Allwood, 2011; Visserchere & Narendram, 2014). In infants born < 32 0/7 weeks, neonatal providers should strive to prevent unnecessary TEWL by lowering high levels of incubator humidity after the first week in an attempt to improve skin barrier formation. Studies have demonstrated that 60%–70% incubator humidity is effective in preventing TEWL in infants born ≥ 26 weeks gestation (Kong et al., 2011; Sung et al., 2013). For the population of infants born at 24 weeks, 95% incubator humidity offered for 3 days, followed by 70%, stabilized insensible water loss (Sung et al., 2013); however, this level of humidity was not recommended by Kong et al. (2011) unless necessary due to microbial growth.

No clear evidence exists comparing incubator humidity levels for infants < 26 weeks gestation. This should be the focus of future research, which will guide the optimal levels and duration for this population. More evidence is also needed to determine microbial growth in incubator humidity of > 80%. In this document, I presented a synthesis of the evidence in several aspects of care that can assist the neonatal provider in selecting incubator humidity levels and duration until further research is available.

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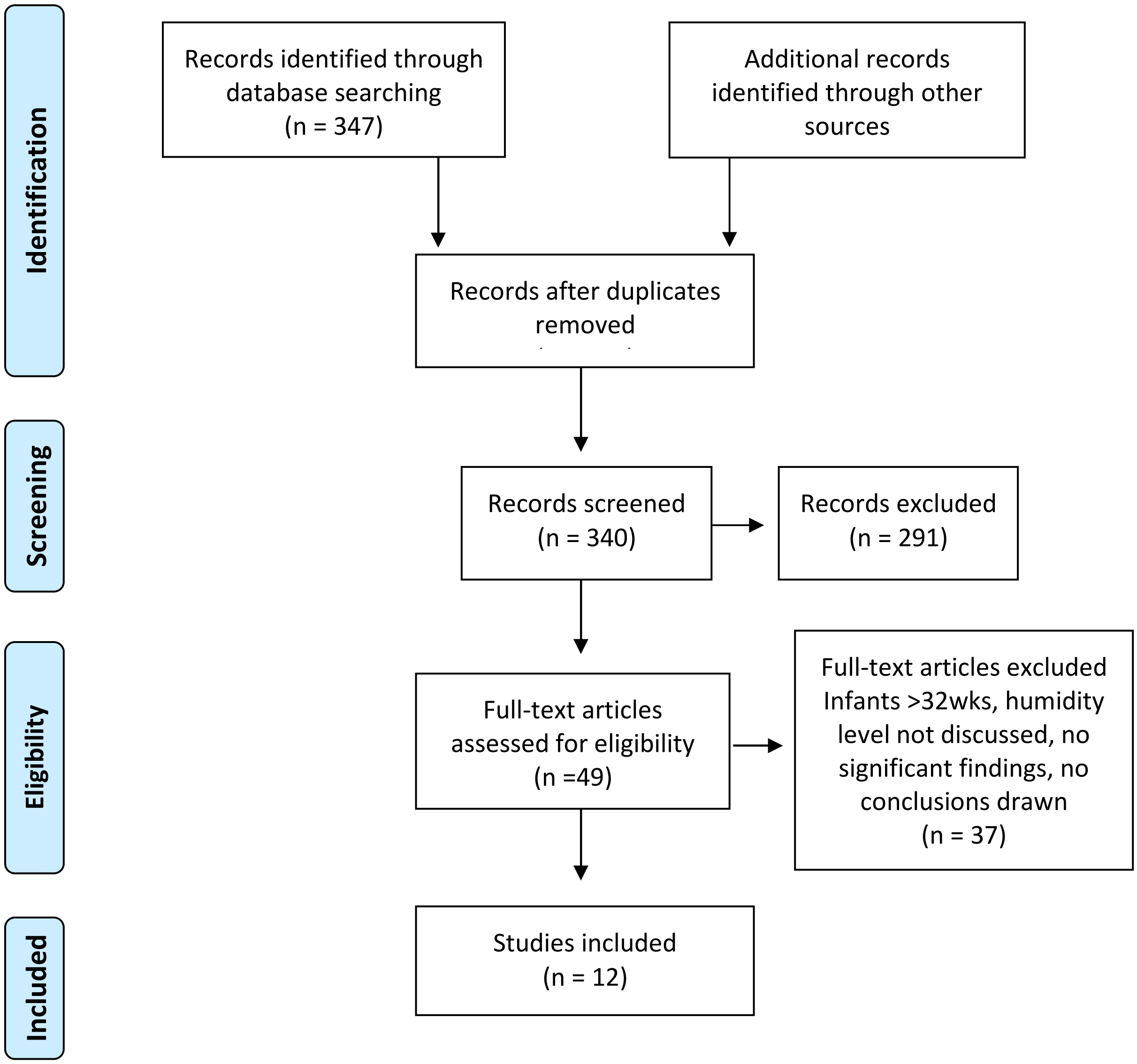
Appendix A: Flow Diagram



Appendix B: Incubator Humidity Evidence Table

Authors and Year	Study Design, Method	Purpose	Sample Characteristics and Setting	Limitations	Key Findings	Level and Quality
Allwood, M. 2011	Literature review	To develop evidence-based skin care guidelines for infants aged 23-30 weeks	23-30 week preterm infants, 6 articles included with total sample size of 4,145 patients, composed in Australia	Studies included well baby nurseries and infant > 30 weeks gestation in selected articles	Preterm infants are at increased risk for skin injury. The majority of epidermal development is complete by 32 weeks gestation. Skin barrier formation and increased strength of dermis-epidermis connection occurs with increased gestational age. Incubator humidity recommendations were to begin humidity at 85% for the first week, and then weaned to 50%, however the duration to extend humidity was not evident in the literature appraised	V A
Agren,J., Sjors, G., & Sedin,G. 2006	Randomized controlled trial	To test how the of level of incubator humidity influences the postnatal skin maturation	22 infants 23-27 weeks gestation were included, conducted in Sweden	Small sample size and not all the infants were assessed at days 0, 3, and 7 for TEWL due to patient instability	Extremely preterm infants who were nursed in 75% incubator humidity after the first week of life exhibited increased TEWL when compared to infants nursed in 50% incubator humidity ($p < 0.001$) and no difference in temperature stability, weight gain, or serum sodium levels were found. These findings suggest that increased incubator humidity may delay skin barrier formation.	I B
de Carvalho, M., Torrao, C., & Moreira, M.	Experimental data collection study	The purpose was to measure the irradiance level of	3 levels of humidity (60%-70%,	It was unknown if the results were influenced	Incubator humidity of 60%-70% did not alter phototherapy irradiance. Incubator humidity of ≥ 80% decreased LED	II A

2011		phototherapy in humidified incubators.	80%, and ≥ 90%) were studied in one incubator with 3 phototherapy devices in Brazil	by the distance between the light source and the irradiance meter. The irradiance meter measured only to 1µW/cm²/nm. Only one incubator was studied.	and halogen phototherapy by 10%-45%. Fluorescent phototherapy irradiance was unaltered by humidity.	
de Goffau, M., Bergman, K., Vries, H., Meesen, N., Degener, J., van Dijl, J., & Harmsen, H. 2011	Observational data collection study	To investigate whether microbial contamination level could be predicted from temperature and humidity settings	23 previously occupied NICU incubator in two humidity groups (≤ 60% and ≥ 60%) were studied to identify temperature distribution, 4-5 swab samples each incubator were analyzed for contamination	all 23 incubators were not swabbed the same amount of times	Increased bacteria growth was observed in cooler areas of the incubator when humidity was ≥ 60% (p = 0.002).	II B
Etienne et al., 2011	Case study	To investigate the cause of three primary diagnoses of cutaneous aspergillosis in neonate	3 extremely preterm infants (23 4/7 to 24 3/7 weeks gestation) in a U.K. NICU	Study design, retrospective environmental sampling	Aspergillus fumigatus was found in humidity chambers of three infected neonates.	V C
Karlsson, V., Heinemann, A., Sjors, G., Nykvist, K., & Agren, J. 2012	Prospective data collection, study	To evaluate thermal balance and the physical environment during skin-to-skin care in extremely preterm infants outside of the	26 preterm infants 22-26 weeks gestation during postnatal days 2-9	Small sample size, infants were in two positions during the study (side-lying and kangaroo position), generalized	Extremely preterm infants had increased insensible water loss outside the humidified incubator (mean 68% incubator humidity vs. 42% mean humidity during skin-to-skin care) equaling 1gram/kg. Infant skin temperatures remained	II B

		humidified incubator		term of parent was used, and transferring techniques were not optimized	stable with no significant difference between pre and post test (*p* = 0.32). Skin-to-skin care did not amount to a significant impact on fluid balance. The benefits of skin-to-skin care outweigh the minimal insensible water loss results.	
Kim, S., Lee, E., Chen, J., & Ringer, S. 2010	Retrospective data collection study	To compare extremely preterm infants in humidified and non-humidified incubators to identify changes in temperature, fluid and electrolyte management, and growth. Secondary outcomes included mortality, bronchopulmonary dysplasia, necrotizing enterocolitis, patent ductus arteriosus, sepsis, and intraventricular hemorrhage.	182 extremely low birth weight infants <1,000 g in a U.S. medical center	The study design may have allowed for unrecognized practice changes in the time differences of the study (humidified group 2002-2005, non-humidified group 2002-2003), inclusion criteria did not include gestational age	Two groups of infants <1,000 g were studied comparing incubator humidity (70%-80% week one, then 50%-60% weeks 2 until corrected to 32 weeks) versus no incubator humidity. Significant findings in the humidified group were increased growth velocity, a decreased incidence of severe bronchopulmonary dysplasia, less fluid intake, less urine output, less insensible water loss, less weight loss, lower incidence of hypernatremia, higher incidence of hyponatremia, less electrolyte sampling. No significant differences were found for temperature instability, intraventricular hemorrhage, patent ductus arteriosus, necrotizing enterocolitis, mild and moderate bronchopulmonary dysplasia, or sepsis between the two groups. However, more infants in the humidified group were diagnosed with bacterial sepsis (adjusted odds ratio 1.6) and there was a positive correlation between hypernatremia and	III A

					intraventricular hemorrhage.	
Kong, Y., Medhurst, A.,Cheong, J., Kotsanas, D., & Jolley, D. 2011	Randomized controlled trial, single center	To compare the effect of 80% and 70% incubator humidity on the body temperature with secondary outcomes of significant medical conditions, microbial contamination, skin integrity, daily serum sodium levels, daily fluid requirement, and weight gain	50 preterm infants ≤ 28 weeks gestation in the first 2 weeks of life in Australia.	Nurses were not blinded, single center, and sample size, selection bias between groups was present for infants < 26 weeks (9 in Group A vs 4 in Group B)	Infants ≤ 28 weeks gestation were randomized to 70% or 80% incubator humidity for the first 14 days of life. No statistical significance was discovered in skin integrity, body temperature, fluid requirement, sodium levels, sepsis, patent ductus arteriosus, chronic lung disease, or intraventricular hemorrhage. Microbial growth was more prominent in the incubators with 80% humidity, 85%-100% humidity was not recommended	I A
Maastrup, R. & Greisen, G. 2010	Data collection, prospective intervention study	To determine if preterm infants in skin-to-skin care can maintain their temperature outside of the humidified incubator	22 preterm infants < 28 weeks gestation in a Denmark level III NICU	Small sample size, differing humidity levels, inconsistent family member (1 sister and 5 fathers were skin-to-skin with infant being studied)	Extremely preterm infants were able to maintain stable temperature while outside the humidified incubator during skin-to-skin care with their mother if proper transferring techniques were used. Other family members who provide skin-to-skin resulted in a decrease in temperature ($p = 0.011$).	II B
Prazad, P., Cortes, D., Puppala, B., Donovan, R., Kumar, S., & Gulati, A., 2008	Observational descriptive data collection study	To identify and quantify 45 volatile compounds during various NICU incubator operation modes	10 unoccupied NICU incubators in the U.S. were used to study 45 compounds in 4 different operational settings	Concentrations were below OSHA exposure limits for adults and animals however, no data exists for neonates	Airborne volatile organic compound concentrations were increased when 50% incubator humidity was added.	III A

				therefore, unknown clinical implications. Incubators were unoccupied		
Sung, S., Ahn, S., Seo, H., Yoo, H., Han, Y., Lee, M., Chang, Y., & Park, W. 2013	Retrospective exploratory data collection study	To investigate fluid and electrolyte balance during the first week of life under high humidification in infants ≤ 24 weeks gestation	218 extremely low birth weight preterm infants ages 22 to > 26 weeks gestation in Korea	Infants in the 25 week gestational group were excluded due to varying humidity levels, comparing groups were not the same gestational age	22 and 23 week infants exhibited increased insensible water loss, fluid intake, and electrolyte imbalance despite 95% incubator humidity. 24 week infants nursed in 95% humidity for the first 3 days did not have a significant increase in insensible water compared to infants ≥ 26 weeks gestation in 60% incubator humidity. Infants ≥ 26 weeks gestation in 60% incubator humidity did not exhibit increased insensible water loss when compared with infants in 80%. humidity.	III B
Visscher & Narendran, 2014	Literature review	To review the skin ontogeny related to fetal development and effects after delivery	Term and preterm infants, conducted in the U.S.	Details of the literature search were not revealed.	Extremely premature infants have a rapid skin barrier formation within 5 days after birth. Full stratum corneum maturation is estimated to occur between 2-9 postnatal weeks.	V B