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Incidence and Prevalence of Hospital Acquired Pressure Injuries (HAPI) in Pediatric Population - A Systematic Review and Meta-analysis

BY

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ABSTRACT

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Title: Incidence and Prevalence of Hospital Acquired Pressure Injuries (HAPI) in Pediatric population - A Systematic Review and Meta-Analysis

Supervisor of Thesis: Dr. Mohammed, Fasihul Alam.

Background: Hospital acquired pressure injury (HAPI) is a serious patient safety issue that adversely affects patient's well-being and increases healthcare costs dramatically. Prevalence and incidence studies estimate the burden of PI to allow decision-makers to set priorities and allocate financial resources. However, the evidence of prevalence and incidence in pediatric population is scarce. This study is expected to systematically quantify the burden and identify the most frequently occurring HAPI stage(s) and anatomical location(s).

Methods: Observational studies were searched on databases including PubMed, Medline (via Ovid), EMBASE, SCOPUS, Cochrane Library, CINAHL (via EBSCO), and ProQuest Nursing & Allied Health. The quality of the studies was appraised. The Random effect models, subgroup analysis and meta-regression were employed due to substantial heterogeneity.

Results: Seventeen studies were included. The pooled prevalence and incidence of HAPI was 11.1% (95% CI 7.8 to 14.5) and 14.2% (95%CI 7.3 to 21.1) respectively. Stage I accounted for 54.5%. The most affected body sites were head, face, ankle and foot.

Conclusion: Study findings revealed that HAPIs are serious adverse events.

The majority of these injuries are avoidable as they are superficial. Results recommended using appropriate assessment tools for different pediatric age groups and implementing effective preventive measures and treatment strategies.

DEDICATION

I dedicate this work to all healthcare workers in the world, especially for those who care for pediatric patients and those who dedicate their carrier to help children for better health

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To my mother; the most precious in the world, and to my wonderful wife and children, who supported me during the learning journey. I am grateful to my supervisors; Professor. Lukman Thalib and Dr. Mohammed Fasihul Alam for their continuous academic supervision and support of my thesis work, and to the Dean of the College of Health Sciences, Dr. Hanan Abdul Rahim

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ABBREVIATIONS

AAWC: Association for the Advancement of Wound Care

AWMA: Australian Wound Management Association

CAWC: Canadian Association of Wound Care

CI: Confidence Interval

HER/EMR: Electronic Health Records/ Electronic Medical Records

APWCA: American Professional Wound Care Association

EPUAP: European Pressure Ulcer Advisory Panel

HAPI: Hospital Acquired Pressure Injury

LOS: Length of Stay

MDRPI: Medical Device Related Pressure Injury

NAUAP: National Pressure Ulcer Advisory Panel

NAWC: National Alliance of Wound Care

NDNQI: National Database of Nursing Quality Indicators

NICU: Neonatal Intensive Care Unit

NZWCS: New Zealand Wound Care Society

PPPIA: Pan Pacific Pressure Injury Alliance

PI: Pressure Injury

PICU: Pediatric Intensive Care Unit

SD: Standard Deviation

WHO: World Health Organization

UK: United Kingdom

USA: United States of America

CHAPTER 1: INTRODUCTION

A pressure injury (PI) is defined as "localized injury to the skin and/or underlying tissue usually over a bony prominence as a result of pressure or pressure in combination with shear" (1, 2). Pressure injuries are classified according to the level and severity of the injury and the tissue layers involved. (1). The following classification system is widely used in the global community of PI.

Stage I: Non-blanchable erythema of a localized area of intact skin (1).

Stage II: Partial thickness loss of dermis appears as a shallow open injury (1).

Stage III: Full thickness tissue loss, subcutaneous fat may be visible (1).

Stage IV: Full thickness tissue loss with exposed bone, tendon or muscle(1).

Un-stageable: Depth unknown full thickness tissue loss, where the base of the injury is covered by slough in the wound bed (1).

Suspected Deep Tissue Injury: Depth unknown purple or maroon localized area of discolored intact skin or blood-filled blister due to damage of underlying soft tissue (1).

In addition to the above categories, PI is defined according to the presence of medical device(s) and if it involves the mucus membrane. The two definitions are used:

Medical Device Related Pressure Injury: Results from the use of medical devices like catheters and leads. This PI is classified according to the above categories (1).

Mucosal Membrane Pressure Injury: Occurs on the mucous membranes, especially when there is a history of a medical device use at the injury location. This PI is not staged due to the anatomy of the mucous tissue (1).

The development of PI is associated with a myriad of factors and lead to significant suffering, pain, infections, prolonged length of hospital stay for patients, and increased burden on the healthcare system due to costs related to treatment, management,

and prevention of further complication (3). The burden of pressure injuries represents a significant portion of the national health budget and public hospital expenditure (4). Hospital acquired pressure injury (HAPI) has therefore become a recognized measure of the quality of care in healthcare settings (1, 5).

Since most HAPIs are avoidable or preventable, it is vital to detect those patients who are vulnerable and implement preventive strategies (1). Recommended prevention measures include proper skin assessment performed within eight hours of hospital admission and thereafter in regular intervals based on the level of risk assessed at admission (6). The use of a reliable and validated risk assessment tool for early detection of patients at risk is vital in reducing the incidence of HAPI in pediatric population (3).

Prevalence and incidence are the most common measures used to evaluate the burden of PI and to identify the commonly associated risk factors in healthcare settings. Information about prevalence and incidence enables decision-makers to set priorities and allocate financial resources with a focus on the prevention of PI (7).

Data from a well-conducted cross-sectional study and a reliable review of clinical documentation can help in the differentiation of HAPI from community-acquired PI. This, in turn, would allow the assessment of PI associated with nursing and hospital care, which in most cases are preventable (8, 9). Such regular and periodic assessments using valid data collection tools can also capture changing trends in HAPI (8, 9).

Although incidence is difficult to capture using cross-sectional surveys, the prevalence of HAPI obtained using periodic audits or surveys may provide a proxy measure of the quality of healthcare in any given setting (10, 11).

Point Prevalence of HAPI indicates that the total number of persons in a given population with an injury, that developed during that hospitalization (10, 11). Incidence is the number of patients with a new HAPI during a specific period (12).

Comparison of incidence data with surveillance data is important since they differ significantly, with incidence usually is being less than prevalence (13). Incidence data measure the effectiveness of prevention interventions or protocols for PI, whereas prevalence data provide a more accurate view of the extent of HAPI and associated risk factors. This information guides resource allocation and policy making to prevent PI (14).

Determining worldwide prevalence and incidence rates of HAPI in the pediatric population using a meta-analysis will establish current global level that can be utilized for benchmarking purpose in healthcare settings (15). Such meta-analysis will introduce reliable, valid and effective prevalence programs and guides for the prevention in the pediatric vulnerable groups.

There is a scarcity of studies on pediatric pressure ulcer development, risk factors, and prevention strategies. Many of the existing studies were conducted on small samples in a single site and used different methodological and analysis approaches (16-18). Moreover, these studies did not add valuable information regarding the association between HAPI development and identified risk factors.

There is a lack of evidence on HAPI prevalence and incidence from systematic review and meta-analysis based on comprehensive clinical studies. One systematic review aimed to quantify the incidence and prevalence of PIs in pediatrics and to identify the most affected anatomic sites, but did not attempt a meta-analysis (15).

A recent systematic review and meta-analysis of prevalence and incidence of pediatric and adult HAPI was limited to medical device related pressure injuries (19). Both studies experienced a high level of heterogeneity (15, 19). Our study differs from both studies in that it investigates all types and stages of HAPI in all pediatric populations. Up-to-date and reliable knowledge on HAPI in the pediatric population can help in improving the care and identify intervention(s) for managing this condition in this

vulnerable population (17).

1.1 Aim of the Study

This study aims to systematically review and quantify the global prevalence and incidence of hospital acquired pressure injuries in pediatric patients using the meta-analysis design. The study also aims to identify the most associated factors, pressure injury stages, affected age groups, and anatomical locations. The results of this study will generate evidence to guide further researches and policies in the prevention and treatment of HAPI in the pediatric population.

CHAPTER 2: LITERATURE REVIEW

This chapter provides an overview of the evidence from the literature on the development of pressure injury, the prevalence and incidence measuring the burden of pressure injury, and particularly the hospital acquired pressure injuries (HAPI) in pediatrics. It also presents a review of evidence on the common risk factors associated with HAPI development and the economic burden and costs associated with HAPI. The literature review helps to identify relevant information from published studies and identify gaps in the literature.

2.1 Importance of Pressure Injury and Hospital Acquired Pressure Injury

PI is considered to be one of the unpleasant complications in the healthcare setting (3). In particular, the incidence of stage III and IV of HAPI has been recognized as a measure for assessing the quality of services in a healthcare system (3). As such, monitoring the prevalence of HAPI as a core set of key performance indicators used to determine hospital performance, and in some countries, hospitals are financially penalized for not reporting or are not reimbursed by the government or health insurance companies for the treatment of such unwanted complication (13, 20).

In 2009, a group of international experts produced a document detailing the definition and classification of PI, and how to use and interpret prevalence and incidence studies of PI (21). This document is updated regularly according to emerging evidence on PI development, prevention and treatment practices (1).

2.2 Pressure Injury and Healthcare Quality

Pressure injury has been recognized as one of the core quality indicators in

healthcare settings; for nursing care, in particular, that includes adult and pediatric settings (1, 5). Many organizations adopted monitoring of PI as a key performance indicator of nursing care, which allows the organization to measure and report on the three dimensions of quality; structure (manpower and skills), process (guidelines, bundles, and practice) and outcome (5).

A study comparing the higher HAPI prevalence rate in Sweden with that in the USA in acute healthcare facilities identified the need to link the care process and outcome, and suggested using point prevalence of HAPI as an indicator to measure and benchmark it to a well-recognized international body (22).

A systematic review in 2009 revealed that there is a significant impact of pressure injury on the patient's health-related quality of life (physical, social, psychological, etc.), and suggested the development of quality outcome measures to study this impact (23).

The National Pressure Ulcer Advisory Panel (NPUAP) conference in 2010 declared that most PIs are avoidable, however, some are unavoidable in hemodynamically unstable or terminally ill patients. However, preventive measures should be provided to all patients at risk (24).

2.3 Incidence and Prevalence of Pressure Injury

Validation and comparing the incidence data with surveillance data is highly important as many studies demonstrated that they differ significantly. The incidence of HAPI is two to six times less than the point-prevalence, and in some instances, prevalence is 10 times the incidence of HAPI (13). Incidence data measure the effectiveness of prevention interventions or protocol of PI, whereas prevalence data provide a more accurate view of the extent of HAPI and the associated risk factors. This information guides resource allocation and policy making to prevent PIs (14).

Many prevalence studies have been done around the world on HAPI. A descriptive study in Canada between 1994 and 2008 showed that the use of clinical practice guidelines has improved patient care and has decreased HAPI, despite an increase in the risks over time (7). However, in this meta-analysis, we review prevalence and incidence studies concerning HAPI in pediatric population aiming to increase the focus on the extent of the problem and contribute to standardize healthcare practice in terms of the prevention and treatment of HAPIs.

2.4 HAPI in the Pediatric Population

The pediatric population is considered a vulnerable group, and pediatric patients are at high risk for many unpleasant events including pressure injury, particularly when they are admitted to acute care hospitals. Usually, PI is caused by pressure, shear or both, which decreases the blood flow to the affected area, resulting in poor oxygenation and nourishment, then hypoxia, cell death and tissue damage, which result in PI (25).

There are limited studies on the rates of HAPI among the pediatric population in acute and critical care settings, and a lack of evidence on the HAPI risk factors in different pediatric age groups. However, there has been ample research focusing on best practices and prevention and treatment of HAPI among the adult population (25, 26).

Neonates and infants are vulnerable populations and at higher risk to develop PI, especially in a critical care environment. The epidermal layer at these younger ages is thinner and immature, which makes their skin prone to water loss and permeable to chemicals. This affects the main skin function of protecting the underlying tissues from the outside environment and is the cause of PI resulting from pressure and shear (27).

2.5 Incidence and Prevalence of HAPI in Children

Many prevalence and incidence studies have included adult and pediatric populations, however, the main focus has been on reporting adult population results(16). Previous studies on HAPI vary in age groups, unit type, healthcare settings, sample sizes, countries, HAPI identification and staging, and risk assessment scales (28, 29).

The HAPI rate in the pediatric population varies widely, that is reflected on studies results on pediatric HAPI in different hospital settings. The prevalence of HAPI in general pediatric floor ranges from 0% to 13%, while the prevalence in neonatal intensive care units (NICU) and pediatric intensive care units (PICU) reached 27% in some studies (30, 31). Chronically ill children are more vulnerable and at a higher risk of developing PI, which is usually associated with medical devices. The incidence range of HAPI in NICU and PICU was 1% to 7% (30, 32). One large multisite study reported an overall HAPI incidence in PICU ranging from 0.8% to 17.5% (32).

In terms of the type of hospital, where the studies were conducted, the prevalence of HAPI in the pediatric population in tertiary hospitals ranged from 7.1% to 13.4% (31, 33), and incidence ranged from 11.7% to 21.8% (33, 34). In public hospitals, prevalence ranged from 6.6% to 34.5% (35, 36), and incidence range from 7.3% to 12.7% (35, 37)

In terms of region, in North America, the prevalence of HAPI in pediatrics ranged from 1.1% to 23.1% (25, 38), and incidence ranged from 3.8% to 26.7% (28, 39). In Europe, the prevalence ranged from 6.6% to 34.5% (35, 36), and incidence ranged from 7.3% to 12.7% (35, 37)

A clear association is noted between HAPI and many other interactive factors, including hospital type and settings, country, level of understanding of the healthcare team, use of valid and reliable pressure ulcer risk assessment tool, child age, severity of the child's illness, length of hospital stay, use of medical devices, use of preventive measures, and other factors (17, 28, 29). Despite the recognition of these factors,

prevalence and incidence vary widely within similar settings, regions, and hospital types (26, 38, 40, 41).

2.6 HAPI Associated Risk Factors in the Pediatric Population

A variation in HAPI rates has been identified between different countries, healthcare facilities, and even between units within the same settings. Such variation is due to the difference in associated risk factors, including age, the severity of patient's health status, hospitalization period, and presence of medical devices, and implementation of proper assessment, prevention practices and effective treatment (3, 42-44).

A systematic review of 54 studies all over the world concluded that the development of PI in the adult population is explained by complex associated factors under three major domains: mobility/activity, perfusion and skin/pressure injury status (45). Tissue tolerance is influenced by extrinsic factors (pressure, shear, friction and moisture), and intrinsic factors (age, skin integrity, nutrition, perfusion, infection and hemodynamic alteration). HAPI is also influenced by the hospital structure and unit process(46).

Critically ill children are hemodynamically compromised and are at a higher risk of developing HAPI, even if they are exposed to low pressure, especially if this is accompanied by loss or decreased sensory perception and decreased mobility and activity (21). Infant and small children usually are incontinent, and their skin becomes more compromised in chronic illness and in the presence of pressure on the skin (26, 46). Infants cannot move independently away from pressure and shearing sources such as the weight of medical devices place children at higher risk of HAPI (26). Older children with chronic disability conditions such as Spina Bifida are more prone to develop PI (47).

Premature and full-term neonate skin lacks subcutaneous fat (26, 40), and infants born prematurely have a lower level of collagen tissue (26, 46). All neonates with lower fat mass are at higher risk of developing PI, especially when bony prominence areas face pressure or shearing(26). However, the literature on PI in premature infants is scarce (26).

2.7 Cost of HAPI

In 2011, a study in Australia estimated that 17.3% of the total treatment cost for hospitalized patients was spent treating hospital-acquired complications, including HAPI. As a result, the study authors recommended considering this financial impact when priorities are set and implementing appropriate programs to prevent PI and other complications (48). Although the burden of PI on the Australian health system is lower than most other high-income countries, this is still considered an avoidable wastage, and efforts should be made to prevent HAPI and associated costs (4). This could be achieved by training and education programs for the healthcare workers on HAPI assessment, preventive measures and treatment (49).

A cohort study over 12 months on the cost of the PI in the UK reported that the mean cost ranged from £1400 for PI category I to > £8500 for the other categories of PIs, and the cost of treatment of an unhealed PI is estimated around £12 300 per ulcer (50).

In 2016, a study measured the total cost of HAPI based on epidemiological reports. The cost was measured at the patient level in acute care settings across the entire United States. The study reported that HAPI cost exceeded $26.8 billion, particularly the incremental cost of stage I HAPI is 8%, and for stage II is 31%. The small incidental rate stage III and stage IV cost about 59% of the whole cost (51). The care of a HAPI costs on average $10708. The major driver of this cost was the length of stay (LOS), which was estimated to be about 2.2 days longer for HAPI patients (51).

2.8 Prevention of HAPI

Many organizations and researchers have studied prevention and treatment tools, but these have focused mainly on the adult population. The “Prevention and Treatment of Pressure Ulcers: Quick Reference Guide” was developed based on scientific evidence and regularly updated by the National Pressure Ulcer Advisory Panel (NPUAP), European Pressure Ulcer Advisory Panel (EPUAP) and Pan Pacific Pressure Injury Alliance (PPPIA). This guide is being used by most of the international bodies and is recognized worldwide as the guide for reference in the healthcare setting. It includes patient-centered care recommendations on proper assessment, prevention, and treatment (1).

The guide enforces all prevention strategies that can be implemented when a high-risk patient is identified. These include proper repositioning techniques, tolerable mobilization, skin cleaning and drying using the appropriate massage technique and a balanced skin cleanser, an individualized continence management plan to protect the skin from excessive moisture and ensure hydration to reduce risk of skin damage, and use of prophylactic dressings to protect the skin, especially in the presence of medical devices (1).

2.9 Risk Assessment Tools for HAPI

The Braden Scale is used worldwide as an assessment rating scale to predict patients at risk for developing PI (52). The Braden Scale includes six subscales, sensory perception, moisture, activity, mobility, nutrition, and friction and shear (52). The Braden Scale classifies patients according to the risk score. Scores range from 6 to 23, with lower scores indicating higher risk. Patients are classified into five levels: very high risk (6–9), high risk (9–11), moderate risk (12–14), at risk (15–18) and minimal risk (19–23).

However, these classification cut-off points vary among different health systems (52).

Many studies have evaluated the ability of the Braden Scales in terms of prediction of PI development. A meta-analysis that included 38 studies shown that the predictive validity of the Braden Scale is at a moderate level, however high heterogeneity among the included studies was identified as a limitation to the interpretation of the meta-analysis findings (53).

There are numerous other risk assessment scales used for PI. The Braden Q Scale is one of the most widely used. Braden Q Scale was adapted from the Braden Scale for the pediatric population by Quigley and Curley in 1996 (54). In addition to the six original Braden subscales (mobility, activity, sensory perception, friction, shear, and nutrition); tissue perfusion/oxygenation was included as the seventh subscale. A score from 1 to 4 is assigned to each subscale (54). As with the original Braden Scale, the lower the total score, the higher the PI risk. Recently in 2018, Yaoji Liao and others conducted a meta-analysis on the predictive ability of the Braden Q Scale and reported that it has moderate predictive validity, with medium sensitivity and low specificity (55). Another meta-analysis on the predictive efficacy of the Braden Q Scale in Pediatric Intensive Care Unit (PICU) concluded that it has moderate accuracy (56).

An inter-rater reliability study on the Braden Q Scale by Riccioni N and colleagues in 2019, demonstrated fair to good agreement with an intra-class correlation coefficient (ICC) of 0.726 (57).

2.10 National Database for Nursing Quality Indicators

The National Database for Nursing Quality Indicators (NDNQI) was developed in 1988 and is owned by the American Nurse Association (ANA) (5). NDNQI was managed by the University of Kansas School of Nursing, and NDNQI has been expanded

and further developed throughout the years based on updated knowledge from research studies. Data collection on adult PI began in 1998 and on pediatric PI in 2009.

The unit-level NDNQI database includes data on adult and pediatric units (26). There are standardized procedures for collection, identification and staging, data entry and reporting (5). Healthcare professionals must be well trained and educated to participate in these activities (5).

A review was conducted on the NDNQI for PI training programs concluded that it is an effective program that enables healthcare workers to accurately identify PI with proper staging, and differentiate community-acquired pressure injury from the hospital and/or unit acquired PI(5). An inter-rater reliability agreement study using prevalence-adjusted kappa (PAK) has demonstrated that the NDNQI survey is a reliable measurement tool for conducting a PI survey (11).

2.11 Researches on Hospital-Acquired Pressure Ulcers in Children

Although there are many studies on adult HAPI development, risk factors, and prevention strategies, studies on HAPI in children are scarce. Of those that have been conducted, studies were conducted, had small sample sizes were conducted in a single site (16-18) and used different methodological and analytical approaches. Moreover, these studies did not add valuable information regarding the association between HAPI development and identified risk factors (17). Our study is different as it aims to provide up-to-date overall pooled prevalence and incidence of HAPI among children, and identify the common occurring HAPI stages and commonly affect body sites

Research Questions:

1. What are the overall incidence and prevalence of HAPI among pediatric population?

2. What are the most common associated risk factors of HAPI in pediatric patients?

Study Objectives:

Primary Objective: Systematically quantify the overall incidence and prevalence of HAPI among pediatric population (up to 18 years) in inpatient settings.

Secondary Objective: Identify the most common associated risk factor(s), stages nd anatomical locations of HAPI in pediatric population in inpatient settings.

CHAPTER 3: METHODS- SYSTEMATIC REVIEW AND META-ANALYSIS

3.1 PRISMA

The systematic review has been conducted following the recommendations from the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) for reporting this systematic review and meta-analysis (58). The PRISMA checklist has been included as an Appendix 1

3.2 Inclusion Criteria

Eligible studies for this systematic review included studies that reported all stages of PI in the hospitalized pediatric and neonate population that included patients aged from one day up to 18 years, admitted to any of the pediatric and neonatal regular or intensive care units with no restriction on diagnosis or severity. Studies included were observational, cross-sectional or longitudinal design and peer-reviewed, with a full-text published in English, and have to have a large sample (of more than 20 participants). Studies with outcomes of incidence, point prevalence and the rate of HAPI reported as percentages or as rates were included.

3.3 Exclusion Criteria

Excluded studies were randomized control trials (RCTs), experimental studies and case-control studies. A study was excluded if it focused on specific subgroups (e.g. congenital heart disease patients or severely compromised patients who are at risk). Also, studies were excluded if they only focused on a specific PI stage or a specific type of PI such as medical device related pressure injury. Studies in non-hospital settings were excluded. Case-control studies and experimental studies were excluded due to the specific

inclusion and exclusion criteria, where generalizability was not supported.

3.4 Search Strategy

The databases were explored using Medical Subject Heading (MeSH) or Emtree terms of the following individual keywords and combinations using Boolean operators 'AND' and 'OR'. The keywords included "pressure injury", "pressure ulcer", "pressure sore", "decubitus ulcer", "bed ulcer", "bedsore", "bedsore", "prevalence", "incidence", "epidemiology", "rate", "frequency", "occurrence", and "density", "paediatric", "pediatric", "child", "infant", and "neonate".

3.5 Databases

The commonly used databases were searched, including PubMed, Medline (via Ovid), EMBASE, SCOPUS, Cochrane Library, CINAHL (via EBSCO), and ProQuest Nursing & Allied Health. A search for relevant studies reported in the reference lists of the included papers was also conducted. These publications' titles and abstracts were reviewed and duplicate entries were eliminated. Although the methodology for identification and classification of pressure injury was published in 2007, studies earlier to that date were included if the methods and designs were well-constructed. The search ranged from January 1^{st,} 2000 to March 1^{st,} 2020. The database search was performed between March 20 and March 30, 2020.

3.6 Study Records

The extracted records were reviewed by the author according to the inclusion and exclusion criteria. Duplicate records were eliminated and a PRISMA flow chart was created (Figure 1) (58).

3.7 Data Extraction

Data from the eligible studies were extracted by the author and were collected in a table that includes the name of the author(s), year of publication, location (country & region), country income classification, study design, type of point prevalence study, number and type of hospital(s), setting(s), age range, sample size, number and quality of skin examiner(s), female proportion, year of data collection and risk of bias. Appendix 2. provides the specifications of all studies included in the review

3.8 Risk of Bias Assessment

The quality assessment of the included studies was reviewed by two reviewers independently using Hoy's Risk of Bias Tool (Table 1), which was designed mainly for prevalence studies (59). The two reviewers resolved any discrepancies in assessment through discussion to reach an agreement (59). Hoy's Risk of Bias Tool consists of 10 items, items (1 to 4) assess the external validity (selection and non-response bias), while items (5 to 10) assess the internal validity (measurement and analysis bias).

Each item of the 10 is assigned a score of 1 for yes or 0 for no (59). The overall quality score ranged from 1 to 10, which determines the quality of the study and the level of risk for bias at one of three levels; low(1-3), moderate (4-6), or high (7-10) (59).

Table 1. The 10 criteriaof Hoy's Risk of Bias Tool

No.	Risk of bias items	Risk of bias levels	Points Scored
1	Was the study's target population a close representation of the national population in relation to relevant variables, e.g. age, sex, occupation?	**Yes (LOW RISK)**: The study's target population was a close representation of the national population	**0**
		No (HIGH RISK): The study's target population was clearly NOT representative of the national population	**1**
2	Was the sampling frame a true or close representation of the target population?	**Yes (LOW RISK)**: The sampling frame was a true or close representation of the target population	**0**
		No (HIGH RISK): The sampling frame was NOT a true or close representation of the target population	**1**
3	Was some form of random selection used to select the sample, OR was a census undertaken?	**Yes (LOW RISK)**: A census was undertaken, OR some form of random selection was used to select the sample (e.g. simple random sampling, stratified random sampling, cluster sampling, systematic sampling).	**0**
		No (HIGH RISK): A census was NOT undertaken AND some form of random selection was NOT used to select the sample	**1**
4	Was the likelihood of non-response bias minimal?	**Yes (LOW RISK)**: The response rate for the study was ≥ 75%, OR, an analysis was performed that showed no significant difference in relevant demographic characteristics between responders and non-responders	**0**
		No (HIGH RISK): The response rate for the study was < 75%, and if any analysis comparing responders and non-responders was done, it showed a significant difference in relevant demographic characteristics between responders and non-responders	**1**
5	Were data collected directly from the subjects (as opposed to proxy)?	**Yes (LOW RISK)**: All data were collected directly from the subjects	**0**
		No (HIGH RISK): In some instances, data were collected from a proxy	**1**
6	Was an acceptable case definition used in the study?	**Yes (LOW RISK)**: An acceptable case definition was used	**0**
		No (HIGH RISK): An acceptable case definition was NOT used	**1**
7	Was the study instrument that measured the parameter of interest shown to have reliability and validity?	**Yes (LOW RISK)**: The study instrument had been shown to have reliability and validity	**0**
		No (HIGH RISK): The study instrument had NOT been shown to have reliability and validity	**1**
8	Was the same mode of data collection used for all subjects	**Yes (LOW RISK)**: The same mode of data collection was used for all subjects	**0**
		No (HIGH RISK): The same mode of data collection was NOT used for all subjects	**1**
9	Was the length of the shortest prevalence period for the parameter of interest appropriate?	**Yes (LOW RISK)**: The paper presented appropriate numerator(s) AND denominator(s) for the parameter of interest	9
		No (HIGH RISK): The paper did present appropriate numerator(s) AND denominator(s) for the parameter of interest but one or more of these were inappropriate	
10	Were the numerator(s) and denominator(s) for the parameter of interest appropriate	**Yes (LOW RISK)**: The paper presented appropriate numerator(s) AND denominator(s) for the parameter of interest	**0**
		No (HIGH RISK): The paper did present appropriate numerator(s) AND denominator(s) for the parameter of interest but one or more of these were inappropriate	**1**
11	Summary on the overall risk of study bias	**LOW RISK**	**0 – 3**
		MODERATE RISK	**4 – 6**
		HIGH RISK	**7 – 10**

3.9 Data Synthesis

The extracted quantitative data and findings from the included studies were collated in one table (Appendix 3). Meta-analyses were conducted on the prevalence and incidence of HAPI. The patient was the unit of analysis for prevalence and incidence, but the number of PI was used for the analysis of stages and anatomical location. The pooled estimate along with 95% confidence interval (95% CI) was calculated separately for incidence and prevalence. Heterogeneity was assessed using the I-squared statistic (I^2), which quantifies the percentage of variation between studies that is not due to chance. I^2 also indicates the appropriate meta-analysis model to employ (60). An I^2 value of less than 25% indicates low heterogeneity, 25-75% is moderate, and more than 75% indicates or substantial heterogeneity (60, 61). When heterogeneity among studies is substantial, the random effect model (REM) is employed as per Cochrane guidelines (60, 61).

Sensitivity analysis was employed to test the robustness of the meta-analysis findings, which was conducted by excluding the largest prevalence study, and by removing studies with moderate and/or at high risk of bias.

Subgroup analyses and meta-regression were used to explore the variation among the included studies. Bubble plots were produced after simple meta-regression. These are useful graphs that represent the relationship between continuous predictors and the effect size. They allow a visual assessment of the fitness of the regression model and identification of outlying studies that lie outside of the confidence interval bands. The size of the bubble is determined by the inverse of the effect size variance and refers to the precision of the study, whereby a larger bubble size indicates higher precision (62, 63).

A funnel plot was developed to test the publication bias. A funnel plot is a simple scatter plot that displays the individual study effect size (e.g. prevalence or incidence rate) against some measures of each study's size or precision. Often the standard error of the

individual study's estimated effect is considered as the measure of study size and presented on a vertical axis. This method was also followed in this study. Usually, the effect estimate precision increases as the study size increases, therefore, small studies are expected to scatter widely away from the true estimate, and large studies cluster narrowly (61). Egger's linear regression method was used to assess the funnel plot asymmetry. STATA-16 was used for all data he analyses (63).

CHAPTER 4: RESULTS

4.1 Search Findings Flowchart

The systematic search of databases and additional sources identified 865 studies, with 680 remaining after duplicates were removed. Out of 680 studies, 91 were identified to be potentially relevant after title and abstract screening. Of this, only 16 studies fulfilled the eligibility criteria of the review after full-text examination. One more eligible study was identified from the reference of the 16 studies. Thus, in total 17 studies were included in the systematic review and meta-analysis. (Figure 1)

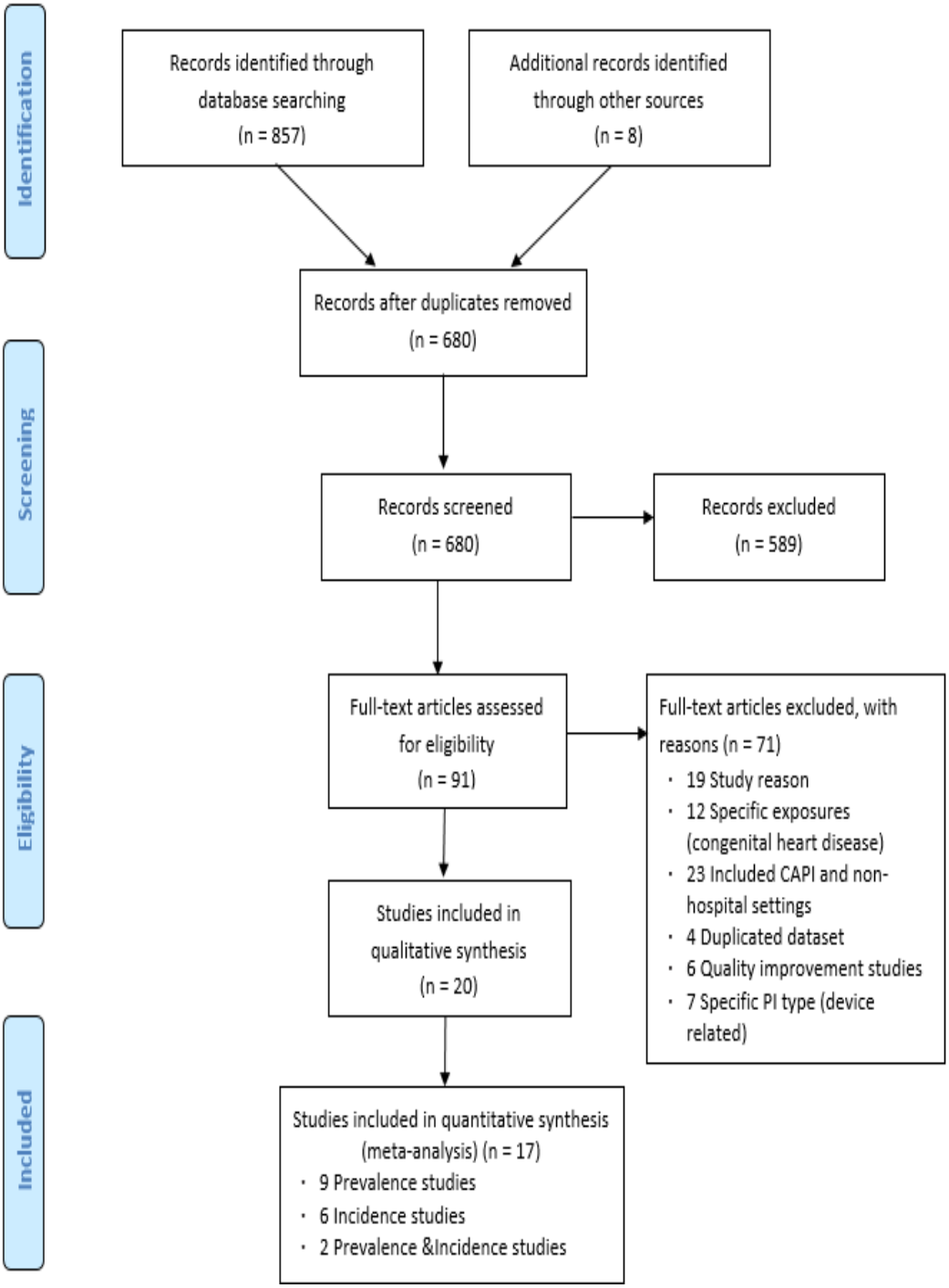


Figure 1. Flowchart of study selection

4.2 Study Characteristics

Appendix 2 presents the detailed data on characteristics extracted from the 17 studies for the meta-analysis. A total of 45,567 patients from the 17 studies were included. Studies were conducted in10 countries, predominantly in North America (n=7, 41%) and Europe (n=5, 29%). The remainder of the studies were from South America (n=2, 12%), Middle East (n=2, 12%) and Asia (n=1, 6%). Thirteen studies (76%) were conducted in high-income countries from North America, Europe and Japan, and the other four studies (24%) were conducted in two upper middle-income countries, Jordan and Brazil.

In six studies (35%), out of seventeen studies, patients were recruited from one hospital, and in 11 studies (65%), patients were recruited from more than one hospital. One study used secondary data analysis of NDNQI point prevalence from 271 hospitals (34).

Studies were conducted in different types of hospitals, governmental, public, tertiary, specialized, and/or university teaching hospitals. Type of hospital does not appear to be associated with the prevalence or incidence level detected.

Sample size varied widely among the included studies, the largest study had 39984 participants and the smallest had 77. Sample size is dependent on the inclusion criteria of the individual studies and related to the number and/or the size of hospital(s), where a study was conducted.

Skin inspection and physical examination were used in all studies to detect and/or confirm PI. More than half of the studies (n=10, 59%) used more than one examiner, who was either a trained nurse or an expert in wound care and pressure injury.

Two studies (12%) reported both prevalence and incidence of HAPI (58, 59), six studies (35%) reported only incidence (28, 34, 37, 39, 64, 65), and nine studies (53%)

reported only prevalence (17, 25, 31, 34, 65-69). Most of the studies were carried out exclusively in the pediatric population. One study was conducted with adult and pediatric populations (31), from which we extracted data relevant to children

A cross-sectional approach was implemented in all prevalence studies. The majority of the point prevalence studies (73%) were conducted on a single day, with the remainder being conducted on multiple dates over a period of time. Incidence studies were all cohort (prospective) studies conducted over a period that varies from 4 months to 24 months.

Eight of the eleven prevalence studies included patients aged from one day to 18 years (31, 35, 38, 66-69), and three studies did not include the neonatal age group (17, 25, 33). The mean age was not reported in most studies; however, the age range used as their inclusion criteria was reported, which varied according to the setting and the country, where the study was conducted. None of the studies included children older than 18 years of age (Appendix 2).

Three of the eight incidence studies were conducted on neonatal population only (37, 39, 65). Two studies were conducted in PICU settings (29, 34), and three studies were conducted in different pediatric settings, including the wards and the intensive care units that care for patients aged from one day to 18 years (33, 35, 64).

Only two incidence studies reported the incidence rate, both of which were conducted in NICU settings only. The rate reported in these two studies varied widely from 1.5 to 11.6 HAPI per 1000 patient days. Such variation was due to variation in the quality of methodology of the two studies.

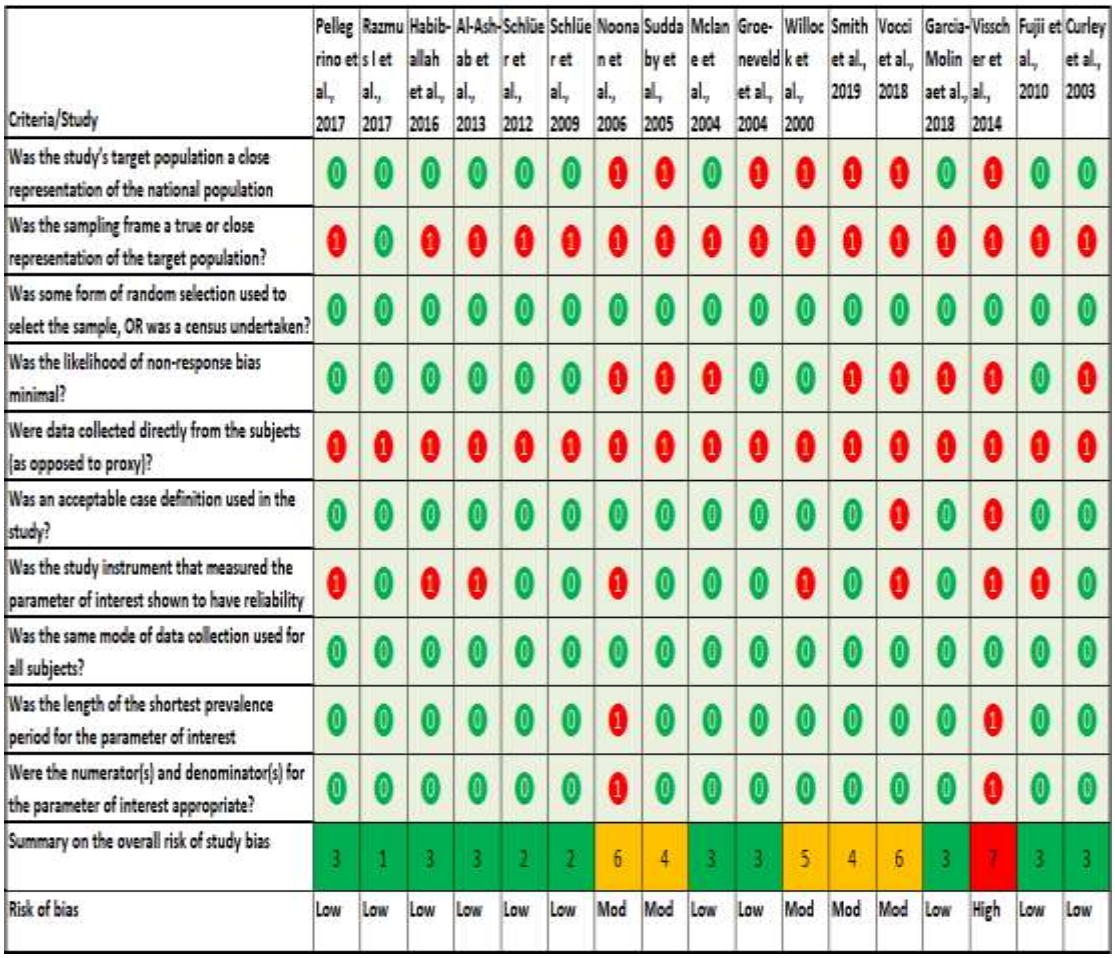
The median length of stay (LOS) in hospital was not reported in all studies. Of those studies that reported LOS, it was 2.3 times longer for patients with HAPI than those without HAPI. In prevalence studies that reported LOS, the average LOS for patients

with HAPI was 14 days (95% CI 2.3 to 25.7 days), compared to six days (95% CI 3.7 to 8.3 days) for patients without HAPI. In incidence studies, the average LOS for patients with HAPI was 36.6 days (95% CI 0.0 to 157 days), compared to 16.3 days (95% CI 0.0 to 43.8 days) for patients without HAPI. Ten studies (59%) reported on HAPI associated with the use of medical devices; among these studies, medical devices represented 54% of the total HAPIs.

4.3 Quality Assessment of Included Studies

Using Hoy's criteria for the risk of bias assessment in all included studies, the risk of bias was low in 11 (65%) studies, moderate in five (29%) studies and high in one (6%) study (Figure 2).

Selection bias and the external validity aspects of the studies were relatively low. Studies did not clarify the sampling frame, except for one study. The studies that were conducted in single hospitals were more likely to have selection bias as the samples were not representative of the population.



Criteria/Study	Pellegrino et al., 2017	Razmus l et al., 2017	Habib-allah et al., 2016	Al-Ash-ab et al., 2013	Schlüer et al., 2012	Schlüer et al., 2009	Noonan et al., 2006	Suddaby et al., 2005	Mclane et al., 2004	Groe-neveld et al., 2004	Willock et al., 2000	Smith et al., 2019	Vocci et al., 2018	Garcia-Molin aet al., 2018	Visscher et al., 2014	Fujii et al., 2010	Curley et al., 2003
Was the study's target population a close representation of the national population	0	0	0	0	0	0	1	1	0	1	1	1	1	0	1	0	0
Was the sampling frame a true or close representation of the target population?	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Was some form of random selection used to select the sample, OR was a census undertaken?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Was the likelihood of non-response bias minimal?	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	0	1
Were data collected directly from the subjects (as opposed to proxy)?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Was an acceptable case definition used in the study?	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Was the study instrument that measured the parameter of interest shown to have reliability	1	0	1	1	0	0	1	0	0	0	1	0	1	0	1	1	0
Was the same mode of data collection used for all subjects?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Was the length of the shortest prevalence period for the parameter of interest	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Were the numerator(s) and denominator(s) for the parameter of interest appropriate?	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Summary on the overall risk of study bias	3	1	3	3	2	2	6	4	3	3	5	4	6	3	7	3	3
Risk of bias	Low	Low	Low	Low	Low	Low	Mod	Mod	Low	Low	Mod	Mod	Mod	Low	High	Low	Low

Figure 2. The risk of bias plot shows the methodological quality assessment

4.4 Publication Bias

Assessment of publication bias was conducted using the Funnel plot, it showed asymmetry in studies dispersion about the line. Most of the prevalence studies fell outside the funnel, which indicated a high publication bias (Figure 3). Four out of eight incidence studies fell under the funnel but were not symmetrical (Figure 4).

Egger's test was conducted to assess and confirm the funnel plot asymmetry. The statistically significant p-value of the Egger's test for the prevalence studies confirmed the asymmetry of the funnel plot (slope=6.97, t=5.91, p=0.0001).

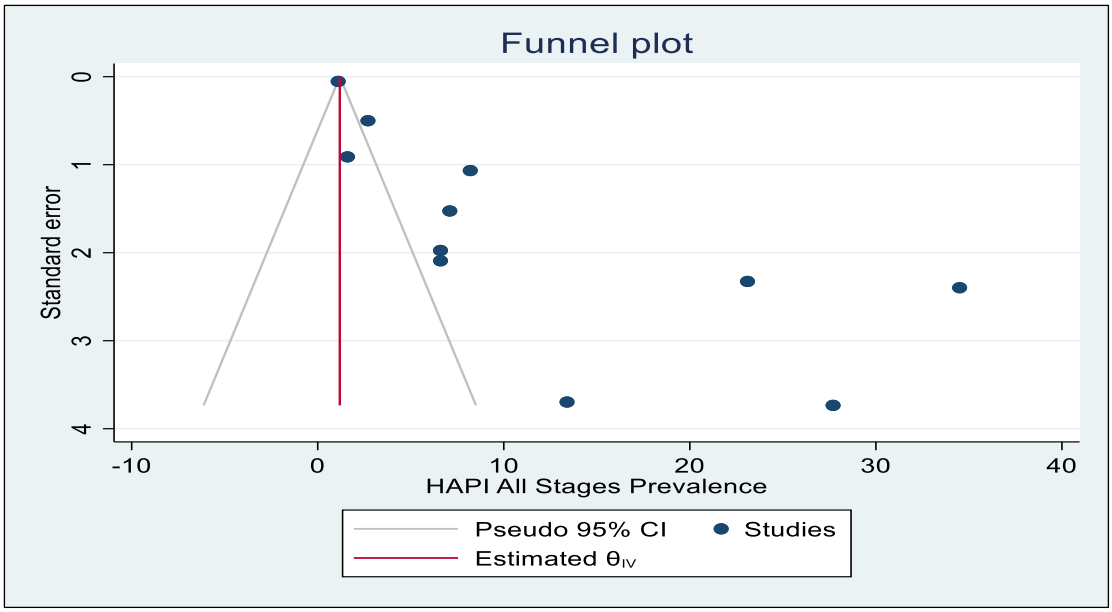


Figure 3. Funnel plot for Prevalence studies

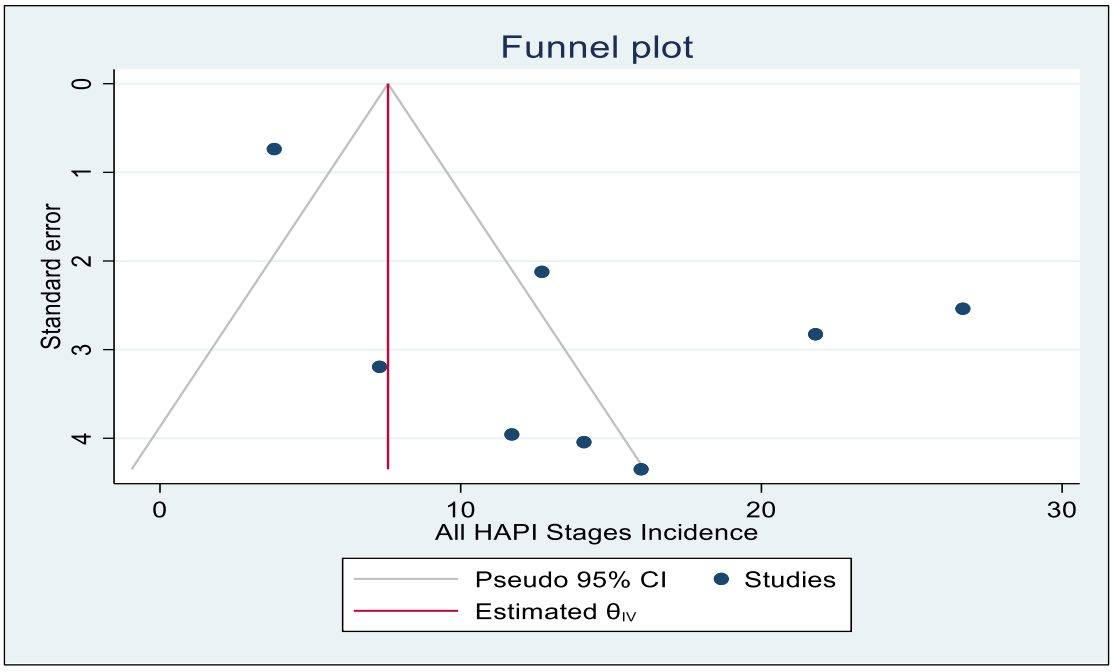


Figure 4. Funnel plot for Incidence studies

4.5 Meta-analysis of the Prevalence and Incidence

The overall pooled HAPI prevalence in 43,682 patients from 11 studies was 11.1% (95% CI 7.8 to 14.5) (Figure 5). When HAPI Stage I was excluded, the pooled prevalence was 2.3% (95% CI 1.4 to 3.1). The overall pooled HAPI incidence in 1,885 patients from 8 studies was 14.2% (95%CI 7.3 to 21.1) (Figure 6). Excluding HAPI Stage I, the pooled incidence was 5.2% (95% CI 3.2 to 7.2).

Both plots show the pooled prevalence and incidence and the individual studies' effect sizes along with their 95% confidence interval using the random effect model (REM) of meta-analysis. REM was used because the heterogeneity that existed among studies was considerable. The standard errors of individual effect sizes were adjusted and integrated to quantify the degree of heterogeneity, which is displayed as Tau-squared (τ^2) (Figures 5 and 6) (61).

The weight for each study is reported in the % Weight column in Figure 5 and 6. Ideally, the more precise the study is, the larger its weight percentage. However, REM grant more weight to smaller studies, and less weight to larger studies, therefore, the weight percentage of all studies are relatively close, In the prevalence model (Figure 5), the weight percentages range from 7% to 10%, and in the Incidence model (Figure 6), they vary from 11.4% to 13.8%.

There was a significant heterogeneity between studies for prevalence ($I^2 = 97.7$, $p < 0.01$) and incidence ($I^2 = 94.2$, $p < 0.01$). Therefore, the sources of heterogeneity were investigated by conducting subgroup analysis and meta-regression. The robustness of the meta-analyses findings was assessed by conducting sensitivity analysis. Tables 5 and 6 detailed the sensitivity and sub-group analysis results on both prevalence and incidence.

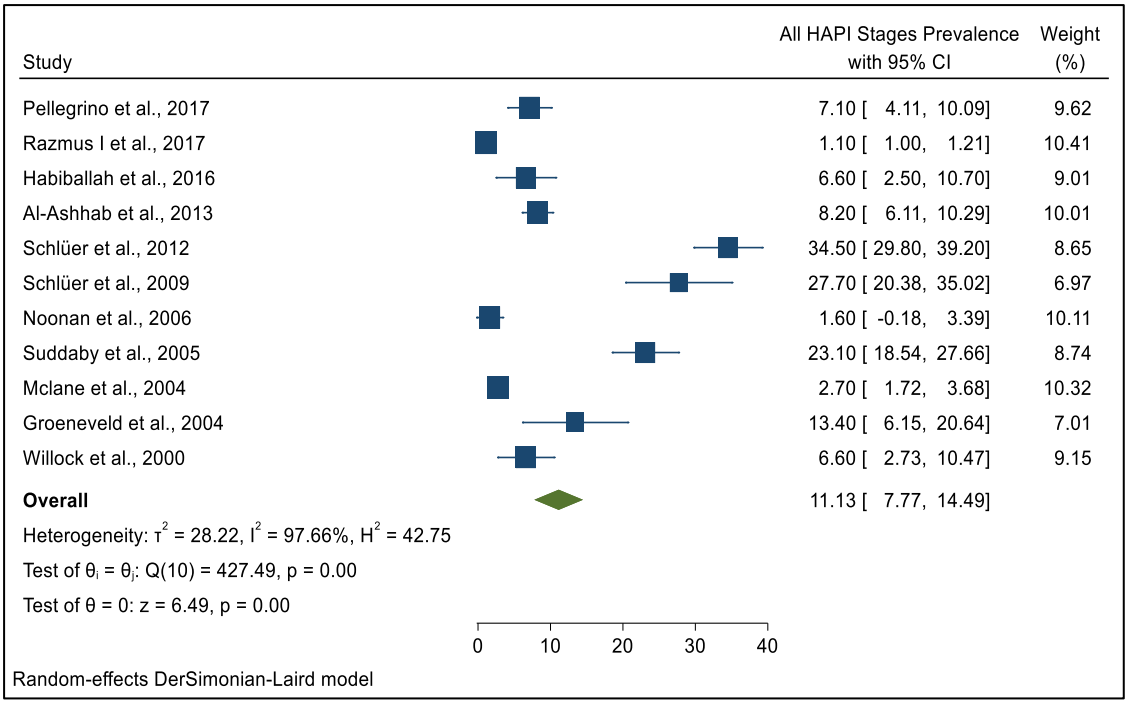


Figure 5. Forest plot- All HAPI Stages Prevalence in pediatric population

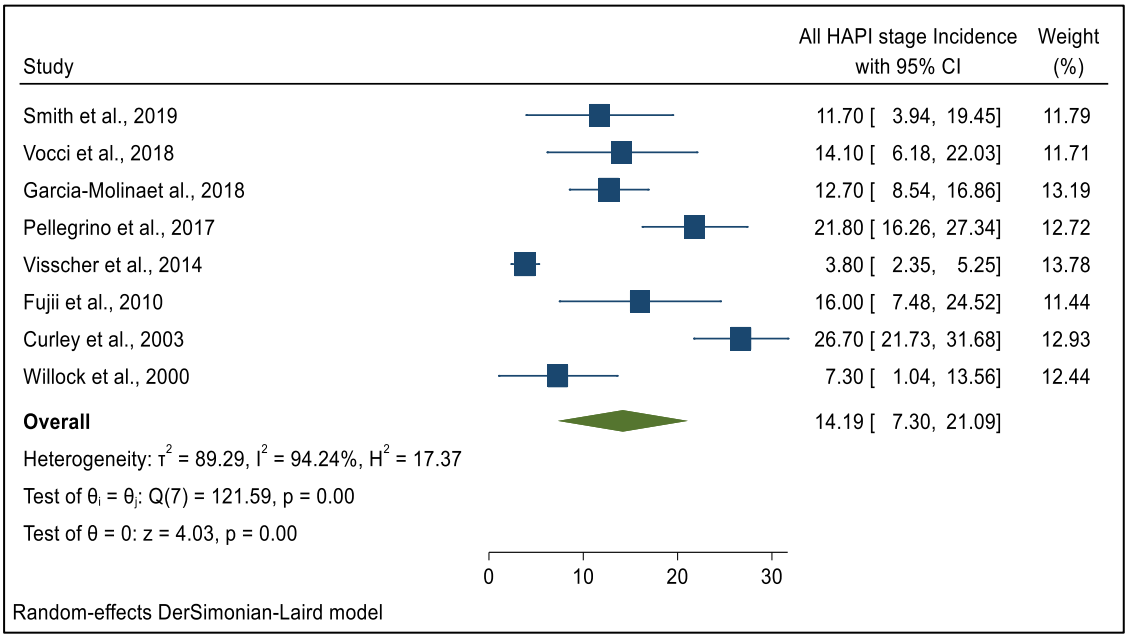


Figure 6. Forest plot- All HAPI Stages Incidence in pediatric population

4.6 Meta-analysis of Pressure Injury Stages and Anatomical Locations

The data for the pooled studies came from 336 hospitals with a total sample size of 45,567 children. A total of 1,093 children developed 1,594 HAPI. Stage I and Stage II accounted for 54.5% (95% CI 52.0 to 57.1) and 26.7% (95% CI 24.5 to 29.1) respectively, Stage I and Stage II are commonly associated with the use of medical devices. The other serious HAPI events occurred less frequently: Stage III accounted for 4.2% (95% CI 3.2 to 5.3), Stage IV for 0.9% (95% CI 0.47 to 1.5), Deep tissue injury (DTI) for 6.5% (95% CI 5.3 to 7.9), and Unstageable for 7.2% (95% CI 5.9 to 8.6). (Table 2).

Fourteen of the 17 studies provided data on the anatomical locations of HAPI. The face and head, including the nose, ear and mouth were the most affected anatomical locations; (34.7%; 95% CI 31.1 to 38.4), followed by foot and heel (19.7%; 95% CI 16.8 to 22.9), and sacrum (16.8; 95% CI 14.0 to 19.8). Other locations accounted for 28.9% of all events (95% CI 25.5 to 32.4) (Table 2)

These results indicate that the superficial HAPI (stage I and stage II) were the most common HAPI (81%), and head and foot are the commonly affected body sites (54%)

Table 2. Summary of the meta-analysis of HAPI stages and locations proportion

PI Stages	Number of HAPI	Estimate	SE	95% CI	I^2	P
Stage I	806	0.55	0.013	[0.52, 0.57]	99.60%	<0.001
Stage II	395	0.27	0.011	[0.24, 0.29]	99.60%	<0.001
Stage III	62	0.04	0.005	[0.03, 0.05]	99.60%	<0.001
Stage IV	13	0.01	0.002	[0.00, 0.02]	99.60%	<0.001
DTI	96	0.06	0.006	[0.05, 0.08]	99.60%	<0.001
Unstageable	106	0.07	0.006	[0.06, 0.09]	99.60%	<0.001
Total	**1478**					
Location	**Number of HAPI**	**Estimate**	**SE**	**95% CI**	**I^2**	**P**
Face & Head	238	0.34	0.018	[0.31, 0.38]	96.00%	<0.001
Foot & Ankle	135	0.20	0.015	[0.17, 0.23]	96.00%	<0.001
Sacrum	115	0.17	0.014	[0.14, 0.20]	96.00%	<0.001
Other	198	0.29	0.017	[0.25, 0.32]	96.00%	<0.001
Total	**686**					

4.7 Sensitivity Analysis, Subgroup Analysis and Meta-regression

The substantial heterogeneity across studies when pooling prevalence and incidence of the hospital-acquired pressure injury was explored by conducting sensitivity analysis, subgroup analysis and meta-regression. Sensitivity analysis included removing the studies with high and moderate risk of bias and removing the largest prevalence study, which accounted for 91.5% of the patients.

Figure 7 and Tables 3 and 4 show the result of the sensitivity analysis. Both the pooled HAPI prevalence and incidence in low risk of bias subgroup was slightly higher than the overall estimates, and associated with substantial heterogeneity 13% (95% CI 8.1 to 17.1%; I^2= 98.1, p<0.001) and 18.0% (95% CI 11.8 to 24.2%; I^2= 82.2, p<0.001) respectively (Tables 3 and 4). After excluding the prevalence study with the largest sample, the pooled estimate increased slightly from 11.1% (95% CI 7.8 to 14.5%) to 12.7% (95% CI 7.9 to 17.6%; I^2= 97.0, p<0.001) (Figure 7 and Table 3)

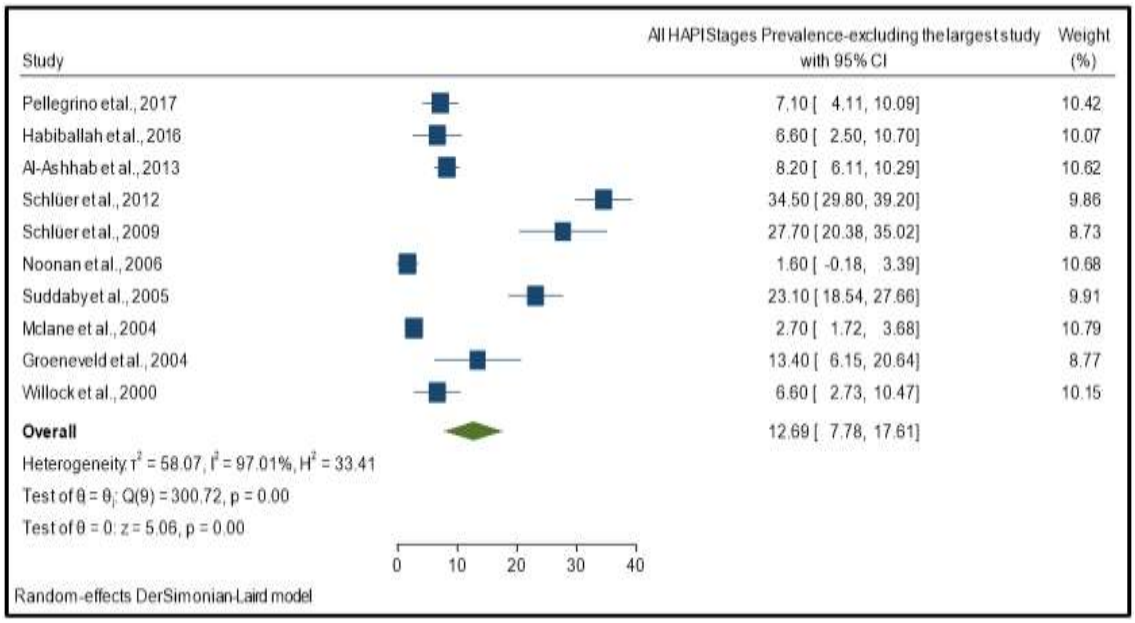


Figure 7. Forest plot- All HAPI Prevalence studies, excluding the largest study

Subgroup analyses based on geographic region, income level of the country and the number of skin examiners were conducted. When assessed by region, the pooled prevalence of HAPI in studies from Europe was 22.9% (95% CI 3.6 to 42.1%) with substantial heterogeneity, which was twice the overall pooled estimate. The prevalence of HAPI in studies from North America was 6.5% (95% CI 3.4 to 9.6%), also with substantial heterogeneity. The prevalence in studies from South America and the Middle East were 7.1% (95% CI 4.1 to 10.1%) and 7.8% (95% CI 6.0 to 9.7%), respectively (Table 3).

Regional subgroup analysis could not explain the heterogeneity between studies. There was no significant statistical subgroup effect ($p = 0.380$) and there was substantial heterogeneity within subgroups (Europe and North America), which showed statistically significant differences ($p<0.001$), with wider confidence intervals across the European studies.

Sub-group analysis across geographical regions to explore the differences in HAPI incidence also failed to explain the variability between studies. Pooled incidence of HAPI in studies from Europe was 11.2% (95% CI 8.0 to 14.3%; $I^2=0.00$, p-value 0.37), and 15.1% (95% CI 0.0 to 37.6%; $I^2=98.7$, p-value <0.001) in studies from North America (Table 4). Incidence of HAPI in studies from South America was 18.5% (95% CI 11.0 to 26.0%) ($I^2=59.0$, p-value 0.12), and 16.0% (95% CI 7.7 to 24.5%) in the only study from Asia (Table 4). Although studies from Europe and South America show low and moderate heterogeneity respectively, the differences were not statistically significant. North American studies had the major contribution to the heterogeneity among all incidence studies included in the meta-analysis, however, the confidence interval indicated that the estimate was not statistically significant.

Subgroup analysis based on income levels of the countries showed the estimate of the pooled prevalence of HAPI among high income countries was 12.7% (95% CI 8.6 to 16.8%) (Table 3). The prevalence among the middle and upper income countries was 7.7% (95% CI 6.1 to 9.2%). There was substantial heterogeneity among studies from high-income countries (I^2=98.1, p-value <0.001) while the heterogeneity was lower among studies from middle-upper income countries (I^2=00.0, p-value 0.72) (Table 3).

Subgroup analysis among incidence studies based on country income level showed that the pooled incidence of HAPI among high income countries was 12.9% (95% CI 5.1 to 20.7%), and the incidence among upper middle income countries was 18.5% (95% CI 11.0 to 26%) (Table 4). There was substantial heterogeneity among studies from high income countries (I^2=94.6, p-value 0.0001), while the heterogeneity was moderate among studies from middle upper income countries (I^2=59.0, p-value 0.12), however, this difference was not statistically significant (Table 4). This indicated that the heterogeneity among incidence studies could not be explained by subgroup analysis based on country income.

Univariate and multivariate meta-regression analyses were conducted to further understand the source of variability in the meta-analysis. The analyses assessed the association between HAPI prevalence and study characteristics, which included sample size, the median length of stay (LOS), number of skin examiners, and year of data collection.

In univariate meta-regression, none of the study characteristics explained the variability for prevalence or incidence. However, in the multivariate meta-regression model, three characteristics were statistically significantly associated with prevalence (number of hospitals, estimate: 2.41 (95% CI 1.53 to 3.30, p<0.001); sample size, estimate: -.068 (95% CI -0.086 to -0.049, p<0.001); and median LOS, estimate: 4.27

(95% CI 1.25 to 7.30, p<0.001). These three characteristics explained 97.4% of the total variance between the included studies and yielded a statistically significant model (p<0.001).

Three bubble plots in Figure 8 display the relationship between the HAPI prevalence and these three continuous variables using the predicted regression line and the 95% confidence bands with the scatterplot. They demonstrate the fitness of the regression model. Bubble size represents the precision of the individual studies, whereby a larger bubble size means a more precise study estimate.

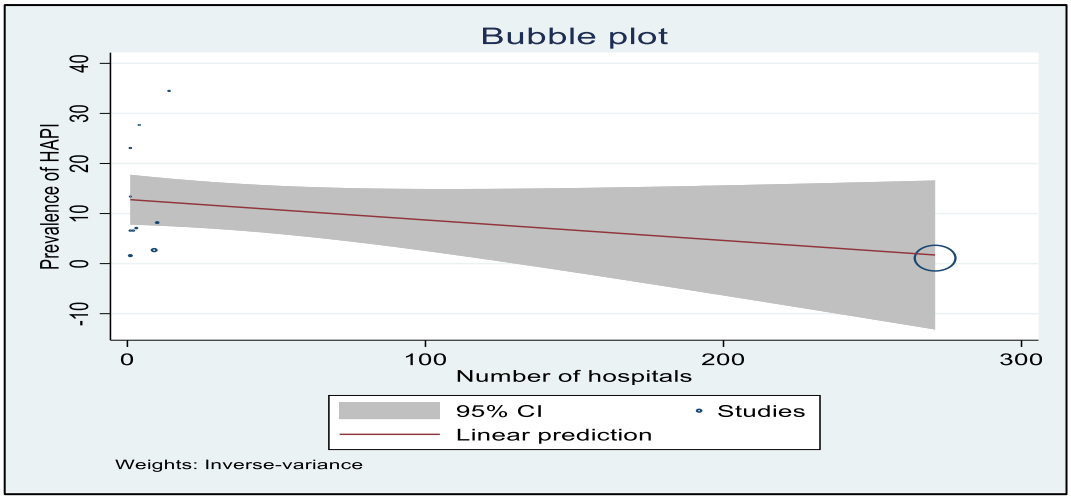
The median LOS graph shows a better fit of data than the other two variables, as the studies are close to the regression line. LOS was therefore the characteristic that best explaining predictor of HAPI, that can be explained clinically too. The other two graphs do not demonstrate the same level of fitness of data. Since we used the model of the random-effects weight, most of the bubble sizes look similar.

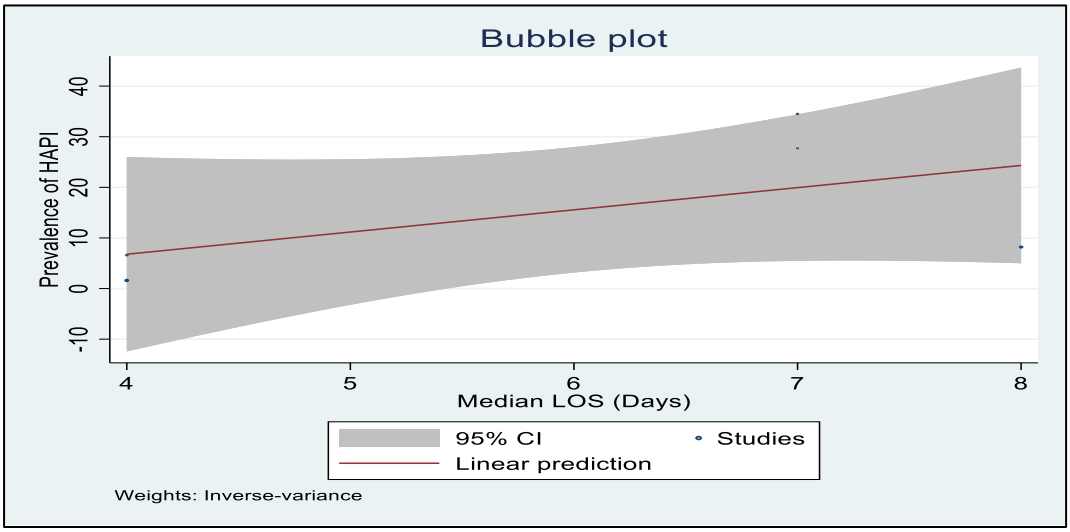
Table 3. Summary of Meta-analysis (Subgroup Analysis-Prevalence Model)

Item	*Studies (n)*	*Patients (n)*	*Pooled estimate*	*95% CI*	*I^2(%)*	*P-value*
HAPI Prevalence						
Overall	11	43682	11.1	[7.8, 14.5]	97.7	0.0001
Excluding Stage I	11	43682	2.3	[1.4, 3.1]	79.2	0.0001
Excluding the largest study	10	3698	12.7	[7.8, 17.6]	97.2	0.0001
Risk of bias(HAPI Prevalence)						
Low	9	43247	13.0	[8.9, 17.1]	98.1	0.0001
Moderate	2	435	3.8	[0.0, 8.7]	81.1	0.021
Region Subgroup (HAPI Prevalence)						
Europe	3	750	22.9	[3.6, 42.1]	97.7	0.0001
North America	5	41744	6.5	[3.4, 9.6]	96.4	0.0001
South America	1	314	7.1	[4.1, 10.1]		
Middle East	2	874	7.8	[6.0, 9.7]	0.0	0.496
Asia						
Income Subgroup (HAPI Prevalence)						
High	8	42494	12.7	[8.6, 16.8]	98.1	0.0001
Middle Upper	3	1188	7.7	[6.1, 9.2]	0.0	0.723

Table 4. Summary of Meta-analysis (Subgroups Analysis-Incidence Model)

Item	**Studies**	**Patients (n)**	**Pooled Estimate**	**95% CI**	**I^2(%)**	**P-value**
HAPI Incidence						
Overall	8	1885	14.2	[7.3, 21.1]	94.2	0.0001
Excluding Stage I	8	1885	5.2	[3.2, 7.2]	63.6	0.0001
Risk of bias(HAPI Incidence)						
Low	5	977	18.0	[11.8, 24.2]	82.2	0.0001
Moderate	2	167	10.2	[3.6, 16.9]	42.6	0.187
High	1	741	3.8	[2.4, 5.2]		
Region Subgroup (HAPI Incidence)						
Europe	3	427	11.2	[8.0, 14.3]	0.0	0.367
North America	2	1063	15.1	[0.0, 37.6]	98.7	0.0001
South America	2	314	18.5	[11.0, 26.0]	59.0	0.119
Asia	1	81	16.0	[7.7, 24.5]		
Income Subgroup (HAPI Incidence)						
High	6	1571	12.9	[5.1, 20.7]	94.6	0.0001
Middle Upper	2	314	18.5	[11.0, 26.0]	59.0	0.119





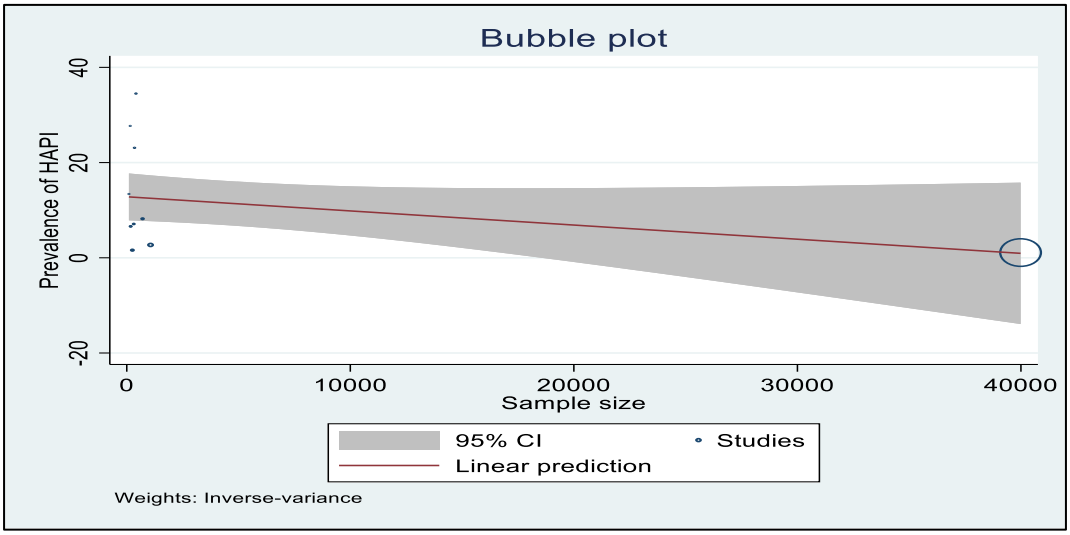


Figure 8. Bubble plots of the univariate meta-regression

CHAPTER 5: DISCUSSION

5.1 Principle Findings

This systematic review and meta-analysis were conducted to estimate hospital acquired pressure injury prevalence and incidence among pediatric population. The analysis included 45,567 children from 17 studies published between the years 2000 and 2020. The point prevalence of pressure injury was the main outcome calculated in 43,682 patients from 11 studies, and the incidence was the main outcome calculated in 1,885 patients from 8 studies.

Both overall pooled HAPI prevalence (11.1%) and incidence (14.2%) represent a substantial burden of HAPI on the healthcare system. Ideally, incidence should detect HAPI at a lower rate than prevalence (13), but in this meta-analysis; the pooled incidence was higher than pooled prevalence,. This reflects the need to ensure enough resources are available to conduct more incidence and prevalence studies using a robust methodology and incident reporting mechanism.

Lower prevalence than incidence in our analysis may be due to different methodologies, different countries and different settings in the included studies. Prevalence studies are at risk of selection and information bias. Many prevalence studies from high-income countries faced non-response bias, and some eligible cases were not included due to illness severity or refusal to give consent for participation. Prevalence studies did not include some units, where very sick or terminally ill children are admitted, whereas incidence studies included all PI in all patients in all units. These factors were likely to have contributed to a higher incidence than prevalence.

Descriptive studies are subject to selection and information bias. Many of the prevalence studies in this analysis required consent for participation, and were conducted on a small sample from a single hospital, which influenced the number of participants

and led to selection bias and lower prevalence.

The majority (81%) of the reported HAPI in our analysis were stage I and II, that indicates that there is a need to focus on the implementation of a patient assessment protocol to detect patients at risk of HAPI at an early stage and apply preventive measures accordingly, especially for those patients on medical devices and/or critically ill with fragile skin (37).

More than 50% of the reported HAPI in this analysis were device related HAPI, such as monitoring devices, oxygen saturation and pulse oximetry probe, oxygenation apparatus, mechanical ventilators and intravenous catheters. The most common locations were the face, head and foot, which were associated with the use of medical devices (15). This result alerts for the importance of appropriate HAPI assessment policy and procedure and for effective prevention protocol to reduce the chance of developing HAPI (34).

Skin examination was performed in all studies by one, two or three trained examiners to detect and/or to confirm the hospital acquired pressure injuries. On many occasions, the researcher was the examiner. Such studies require a considerable amount of time, training, education and other resources to accurately identify and stage pressure injury. They also require complex analysis to obtain prevalence or incidence estimates and to determine the associated risk factors (16).

Incidence of HAPI indicates the effectiveness of the assessment and the preventive measures in hospitals, while the prevalence indicates the effectiveness of the preventive and treatment measures. The high overall pooled prevalence and incidence in this review indicate that there is a need to focus on the assessment, prevention and treatment of HAPI among the pediatric population (51).

From the sensitivity analysis, 76% of the studies with low risk of bias showed

higher prevalence and incidence of HAPI than the pooled estimates of all studies, which reflects the variation of the overall results and the existing heterogeneity. There was a clear variation among the studies in reporting results as there was no standard reporting protocol. Many studies did not report on length of stay, unit of admission, medical device related pressure injury, and the common body location of PIs. Also, there are methodological variations among the studies, such as the number of skin examiners, and the use of risk assessment tools. The methodological variation and incomplete result reporting made the comparability among the studies on the pediatric population difficult and affected the pooled incidence and prevalence.

5.2 Comparison with Other Studies

In term of comparison of our result to previous studies, one previous systematic review was conducted to measure the prevalence and incidence of pressure injury in pediatric population, however, it did not calculate a pooled estimate due to heterogeneity in studies quality, PI classification and clarity issues in inclusion and exclusion criteria (15). In the review, 19 studies from North America and Europe were included. The study recommended that epidemiological studies on PI in pediatric population require improvement in the quality of the conducting and reporting of PI incidence and prevalence studies, and suggested that future studies use the STROBE statement (15).

Despite the limitations, findings in the above review (15) were in line with results from our systematic review meta-analysis, particularly concerning the common HAPI locations, which were the occipital region, nose and chin. The above review also highlighted that the use of the device-related pressure injury is higher in children than in adults (15).

Another recent systematic review and meta-analysis study aimed to synthesize the

prevalence and incidence of medical device related pressure injury in adults and children (19). The review of 29 cross-sectional and cohort studies from 14 countries reported a 9% pooled incidence and 8% pooled prevalence among pediatric population (19). Common devices were respiratory, monitoring devices, cervical immobilization, casts and tubing and catheters (19).

Interpretation of results from this review has some limitations; assessment tools and stages from the included studies were not analyzed in the meta-analysis. Also, the results on device related PIs were not compared to other patient groups to determine if patients on devices were at higher risk (19). Finally, the pooled estimates were associated with high heterogeneity (19).

5.3 Exploration of Subgroup Analysis Findings and Meta-regression Findings

The prevalence and incidence of HAPI among the pediatric population from various parts of the world and different settings were pooled in this meta-analysis. Substantial heterogeneity was detected across included studies. Therefore, the variation was explored through subgroup analysis and meta-regression to assess the clinical and methodological characteristics of the included studies.

For geographic region subgroup analysis, prevalence and incidence vary across regions, but heterogeneity still existed. Low heterogeneity was only identified in some regions due to the low number of studies from that specific region, such as the two prevalence studies from the Middle East. I^2 usually quantifies the variability that results in a genuine heterogeneity rather than from chance (61). However, due to the small number of studies in some of the sub-groups, I^2 could be misleading (60). Therefore, the confidence interval is preferred to confirm how significant heterogeneity is (70).

Substantial heterogeneity across these studies was noticed at the data collection

phase. Studies varied across countries, healthcare settings and hospital size and type; patients from a tertiary specialized hospital would be expected to have multi-comorbidities, and stay for a longer hospitalization period with more devices and equipment used to support their care. All of these factors contribute to the development of pressure injury.

Other characteristics of the studies contributed to variation, such as the difference in methodological quality, the use of different assessment and data collection tools, and the use of a different level of skin examiners (number and expertise). These characteristics influenced the validity and reliability of the results, particularly, HAPI identification and classification.

In our study, European studies reported the highest HAPI prevalence (22.9%) (35, 36, 68). Two of the three studies were conducted by the same author using similar methodology and patients from 18 solely pediatric hospitals of two neighboring countries, Germany and Switzerland. Children included in these two studies were from all units, including highly specialized and long term units, such as neonatal and pediatric intensive care units, rehabilitation and burn units. These units have the most critically ill children, who are exposed to drugs, have decreased mobility and activity, and poor tissue perfusion and sensory perception. In these two studies, two trained skin examiners using a reliable tool and inter-rate reliability procedure were used. These factors contributed to the higher rate of HAPI prevalence in these studies.

Studies from the Middle East reported a lower prevalence (7.8%) than the pooled prevalence. Both studies were from Jordan and were conducted in a wider variety of healthcare settings (66, 67). Only one skin examiner performed the skin examination. Patients recruited in the prevalence studies were from medical, surgical, and critical care. Lower acuity patients may be admitted, where a short hospitalization is expected with

less device use, therefore. This may explain the lower HAPI prevalence than that in Europe.

Prevalence from the North American studies was the lowest among the regions (6.5%) (17, 25, 31, 38, 69). The low prevalence was mainly influenced by one study with a large sample (39,984 patients) that included data from 271 different hospitals types, where NDNQI methodology was used to assess and report HAPI, which implement a standard process of patient assessment during the quarterly point survey, and standard training provided to the skin assessors across several hospitals resulted in an extremely low HAPI prevalence (1.1%) (17, 25, 31, 38, 69).

HAPI in North America is one of the quality sensitive indicators that measure hospital performance. HAPI occurrence leads to longer hospitalization and may impact hospitals financially. Hospitals in North America have established reliable assessment tools and reporting systems and implemented preventive and treatment protocols for HAPIs across all age groups. Therefore, it is expected to have extra attention from nursing assessment and management of skin.

Incidence and prevalence studies on pediatric HAPI varied widely across the studies included for analysis. Studies reported different results and at different presentation models, especially with respect to the location, units of admission, length of stay, staging and device related. These variations could be due to the evolving conceptualization framework of PI over the last two decades, pressure injury and wound care associations adopting new assessment tools and classification concepts, such device related, mucous membrane PI and other, therefore, we noticed that the information and result presented vary, and consequently, reasonable comparability was not achieved. However, in this analysis, we attempted to present comparable results and highlight this issue to alert future researchers working on pediatric PI (15).

The Braden Q Scale has been used in the majority of the studies for PI risk assessment as it is a useful tool to compare patient groups that are at higher risk for PI development and to subsequently implement appropriate preventive measures. The Braden Q scale predictive validity of HAPI in children has been shown to be moderate (55). However, most of the studies included in this review did not report on either measure (55).

Heterogeneity was explored further using meta-regression by study characteristics, we found that number of hospitals, sample size, and median LOS were statistically significant and explained 97.4% of the variation in the prevalence model. It was found that the HAPI prevalence is expected to increase 4 times as the LOS increase of one day, and increase by 2.5 times by including one more hospital in a prevalence study, but HAPI prevalence is expected to decrease by 0.07 times with each patient increase of sample size.

High variation among the incidence studies was due to variation in terms of healthcare settings. Of the eight incidence studies, three were conducted in neonatal settings only, two in the PICU setting only, and three were in PICU and pediatric wards. The prospective cohort studies' periods varied in length from four to 24 months. The number of hospitals and sample sizes varied, four of the studies were conducted in one hospital with a small sample size of less than 100 patients. In terms of risk of bias, there was variation among incidence studies, with five studies having low risk of bias, 2 moderate risk and one with high risk of bias.

In the incidence model, meta-regression yielded two statically significant variables (use of medical device and median LOS) statistically significant. The coefficients (slopes) for use of medical device (-18.5) and medical LOS (-0.28) suggested negative correlations with HAPI occurrence. These correlations were not clinically

significant as it is well established that both factors contribute to HAPI incidence.

Many of the studies in this analysis reported on clinical units where HAPI developed. Patients in high critical units developed HAPI more frequently than in regular medical or surgical units. That would be explained by longer stay, use of medical devices and critically severely ill patients in such critical care units (15).

The findings of this study are consistent with previous studies, with respect to common risks and associated factors for HAPI in the pediatric population. The hospitalization period is one of the main risks for HAPI development, which usually accompanies a chronic diseased patient (71).

Patients admitted to critical care unit are at higher risk due to the poor health status of the patient, and the use of different medical devices, especially equipment used for respiratory support and vital signs monitoring (19). Other medical devices contribute to the HAPI formation in the younger pediatric population due to limited mobility and fragile skin (72).

Critically sick children usually experience nutritional issues, mobility limitation and tissue perfusion and compromised oxygenation, all of these also increase the risk of HAPI development in pediatric patients, especially if they are still at younger age “newborn or infant” (15, 73).

Many developed countries have got a well-established healthcare system that is being evaluated and rated according to patient sensitive indicators. HAPI is one of these indicators that measure the outcome, the structure as well as the process of healthcare services. To track HAPI occurrence, these countries established a national surveillance system for pressure injury (38, 69). However, the focus on pediatrics was different from that for adults, which might be due to inaccurate magnitude of the problem (30).

5.4 Policy, Clinical and Research Implications

The findings of this review indicate that more than one in ten children develop pressure injuries while they are admitted to hospital. This should alert the healthcare services to the burden of HAPI in the pediatric population and provides scientific evidence to guide decision-makers about resource allocation. These findings highlight the importance of implementing HAPI assessment and preventive policy and procedures and protocols (74). Many previous studies have reported that implementing PI prevention bundles or PI reduction programs were correlated with a substantial reduction of HAPI prevalence and treatment cost (27, 49, 75).

This study revealed that Stages I and II are the most common HAPI occurred among pediatric population, which are commonly associated with the use of medical devices. The finding provides evidence for the need to establish an appropriate assessment protocol using a reliable risk assessment tool to detect children at risk and implement effective measures to prevent HAPI development (15, 16). The likelihood of developing PI is reduced if proactive and effective preventive strategies are implemented, especially in high-risk settings (34). There are international bodies working on PI identification, prevention and treatment. Their evidence-based practice regulation and guidelines assist healthcare settings to adopt reliable and valid assessment and preventive tools (1).

The results of this study highlight the importance of educational programs on PI assessment and prevention for the child-caring nursing staff (19). Policymakers need to understand that the different age groups among the pediatric population require different assessment tools and preventive measures (71). For example, the current NPUAP criteria for assessing Stage I pressure ulcers should be included in an education program for front-line staff (66).

Many of the studies in this review reported limitations related to the generalizability of their results due to limited sample size or a unique study site. The findings of this review show the variation across prevalence and incidence studies in data collection and risk assessment tools, the number of skin examiners and inter-rater reliability and age group. Future research should consider this and improve the quality of the study methodology by increasing the representativeness of samples and enhancing the external validity. Future research on HAPI prevalence and incidence should consider adopting standard guidelines for the methodology and result reporting criteria to improve the quality of studies, support comparability and decrease variation (21).

CHAPTER 6: STRENGTHS & LIMITATIONS, RECOMMENDATIONS AND CONCLUSIONS

6.1 Strengths and Limitations

This systematic review and meta-analysis is the first comprehensive review of the incidence and prevalence of all stages of HAPI in the pediatric population. An international protocol and guidelines were strictly followed to search, extract and appraise data from internationally recognized databases. Sensitivity analysis was conducted to ensure result robustness, and subgroup analysis and meta-regression were employed to explain variation. Publication bias was assessed to ensure the effect of different studies on the results.

English articles were only included in this review, which is considered a limitation, however, 47% of the studies were from countries that English is not the mother tongue. This review experienced substantial heterogeneity among the included studies, however, this was assessed using the appropriate methods. Studies used different methodologies and settings, which may impede valuable outcomes. The generalizability of the finding of many studies was limited due to the small sample from a single site.

6.2 Recommendations

This review provides a quantification of the HAPI worldwide. These results should be used to guide future planning of healthcare and allocation of appropriate resources to promote strategies for assessment, prevention and treatment of HAPI. Results of this review show that majority of pressure injuries are device related and are stage I and II, which are preventable through implementing a reliable and valid assessment procedure that considers the characteristics of different age groups and healthcare settings. It is recommended that prevalence and incidence studies on pediatric HAPI use a robust methodological procedure and reporting, and a standard protocol may be formed for this purpose.

6.3 Conclusions:

This study quantifies the extent of prevalence and incidence of hospital acquired pressure injuries in pediatric population. HAPIs lead to an increased healthcare burden on many healthcare systems globally. However, the majority of these HAPI events are avoidable since they are superficial injuries, and associated with extended LOS and use of medical devices. Healthcare systems can avoid increased utilization of services by adopting appropriate assessment tools for different age groups in the pediatric population, and implementing effective preventive measures and treatment strategies to manage HAPIs. The considerable heterogeneity across studies highlights the importance of standardized methodology for conducting prevalence and incidence studies on HAPI in the pediatric population

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Appendix 1. PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	i, 3
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	iii-iv
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	14
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	15
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	16-17
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	16-17
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	16-17 Figure 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	16-17
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	17-18
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	17-18
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	19-20
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I2 for each meta-analysis).	19-20

Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	19-20
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	19-20
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	21 Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	22-25 Appendix 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	26-27 Figure 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	28 Figure 5 & 6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	28-30 Table 2 Figures 5 and 6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	26-27 Figures 2, 3 and 4
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	32-37 Tables 3 and 4 Figures 5, 6, 7 and 8
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	38-47
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	48
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	49
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

APPENDIX 2. ALL STUDIES SPECIFICATIONS

Author & year	Country	Region	Income Country	Design	Type of Point prevalence	Number of hospitals	Type of hospital(s)	Study Duration	Setting	Number and Quality of Skin Examiners	Age Range	Sample size	Female proportion	Year of Data Collection	Risk of Bias
Pellegrino et al., 2017	Brazil	South America	Upper Middle Inco	Cross-sectional	Multiple	3	2 Tertiary & 1 Tertiary University	15 Months	Ward and PICU	One experienced nurse in wound and stoma care (primary researcher)	1 month to 18 years	314	0.50	2012	Low
Razmus I et al., 2017	USA	North America	High Income	Cross-sectional	Multiple	271	Mixed	12 Months	Ward, PICU and NICU	Two trained nurses in wound and stoma care	1 day to 18 years	39984	0.55	2012	Low
Habiballah et al., 2016	Jordan	Middle East	Upper Middle Income	Cross-sectional	Single	2	One puplic Pediatric Hospital & One Tertiary University Hospital	One Day	Ward, PICU and NICU	One experienced nurse in wound and stoma care (primary researcher)	1 Day to 18 years	166	0.35		Low
Al-Ashhab et al., 2013	Jordan	Middle East	Upper Middle Income	Cross-sectional	Single	10	6 governmental, 2 university (Tertiary) and 2 private	4 Months	Ward and PICU	One trained staff	1 Day to 18 years	708	0.47	2012	Low
Schlüer et al., 2012	Switzerland	Europe	High Income	Cross-sectional	Single	14	Public	One Day	Ward, PICU and NICU	Two trained nurses (internal & external)	1 Day to 18 years	412	0.44	2009	Low
Schlüer et al., 2009	Germany	Europe	High Income	Cross-sectional	Single	4	Public	One Day	Ward, PICU and NICU	Two trained nurses (internal & external)	1 Day to 18 years	155	0.46	2006	Low
Noonan et al., 2006	USA	North America	High Income	Cross-sectional	Single	1	University Tertiary Children's Hospital	One Day	Ward and PICU	Two expert nurses	1 month to 18 years	252	0.48	2005	Moderate
Suddaby et al., 2005	USA	North America	High Income	Cross-sectional	Multiple	1	Public	15 Months	Ward and PICU	One trained nurse	1 month to 18 years	347	0.41		Low
Mclane et al., 2004	USA	North America	High Income	Cross-sectional	Single	9	NA	12 Months	Ward, PICU and NICU	Two trained nurses led by an expert in wound care	1 Day to 17 years	1064	0.44	2003	Low
Groeneveld et al., 2004	Canada	North America	High Income	Cross-sectional	Single	1	Tertiary Teaching Hospital	One Day	Ward, PICU and NICU	Three trained nurses led by an expert in wound care	1 Day to 16 years	97	0.50	2002	Low
Willock et al., 2000	UK	Europe	High Income	Cross-sectional	Single	1	Public	One Day	Ward and PICU	Two experienced first level nurses	1 Day to 18 years	183		1996	Moderate

Author & year	Country	Region	Income Country	Design	Type of Point preva	Number of hospitals	Type of hospital(s)	Study Duration	Setting	Number and Quality of Skin Examiners	Age Range	Sample size	Female proportio	Year of Data Colle	Risk of Bias
Smith et al., 2019	Irland	Europe	High Income	Cohort (prospective)	NA	1	Tertiarly Children Hospital	4 Months	PICU	Two trained nurses	1 Day to 18 years	77	0.46	2017	Low
Vocci et al., 2018	Brazil	South America	Upper Middle Inco	Cohort (prospective)	NA	1	Public Teaching Hospital	12 Months	Ward and PICU	The researcher	1 month to 15 years	85	0.40	2016	Moderate
Garcia-Molinaet al., 2018	Spain	Europe	High Income	Cohort (prospective)	NA	6	Public Hospital	12 Months	NICU	Two (One reasercher nurse and one clinical nurse)	Day 1 to 30	268	0.43	2013	Low
Pellegrino et al., 2017	Brazil	South America	Upper Middle Inco	Cohort (prospective)	NA	3	2 Tertiary & One Tertiary University	14 Months	Ward and PICU	One experienced nurse in wound and stoma care (Primary Reasearcher)	1 month to 18 years	229	0.41	2012	Low
Visscher et al., 2014	USA	North America	High Income	Cohor (prospective)	NA	1	Teaching Hospital	24 Months	NICU	One trained nurse and one expert nurse in wound and stoma care	Day 1 to 30	741		2009	High
Fujii et al., 2010	Japan	Asia	High Income	Cohort (prospective)	NA	7	3 University and 4 Public Hospitals	11 Months	NICU	One nurseand one researcher	Day 1 to 30	81	0.52	2006	Low
Curley et al., 2003	UAS	North America	High Income	Cohort (prospective)	NA	3	Free standing Children Hospital	21 Months	PICU	One nurse examin the neonate	21 days to 8 yrs	322	0.40	2000	Low
Willock et al., 2000	UK	Europe	High Income	Cohort (prospective)	NA	1	Public	One Day	Ward and PICU	One nurse	1 Day to 18 years	82		1996	Moderate

APPENDIX 3. QUANTITATIVE DATA FROM INCLUDED STUDIES

Author & year	Number of skin examiners	Age Range	Prevalence Numerator/denominator	L 95% CI	U 95% CI	PI Stage I proportion	Stage II and Above Prevalence Numerator/denominator	L 95% CI	U 95% CI	Median LOS (Days)	LOS for patients with PI (Days)	Medical Device
Pellegrino et al., 2017	1	1 month to 18 years	7.1% (22/314)	4.44	10.42	0.49	3.5% (11/314)	1.76	6.18			0.25
Razmus I et al., 2017	2	1 day to 18 years	1.1% (441/39984)	1.00	1.21	0.36	0.67% (268/39984)	0.59	0.76			
Habiballah et al., 2016	1	1 Day to 18 years	6.6% (11/166)	3.35	11.55	0.64	2.4% (4/166)	0.66	6.05	4	11	0.56
Al-Ashhab et al., 2013	1	1 Day to 18 years	8.2% (58/708)	6.28	10.46	0.78	1.8% (13/708)	0.98	3.10	8		0.78
Schlüer et al., 2012	2	1 Day to 18 years	34.5% (142/412)	29.88	39.28	0.85	5.1% (21/412)	3.18	7.68	7	10	0.92
Schlüer et al., 2009	2	1 Day to 18 years	27.7% (43/155)	20.86	35.50	0.84	4.5% (7/155)	1.83	9.08	7	25	0.8
Noonan et al., 2006	1	1 month to 18 years	1.6% (4/252)	0.43	4.00	0.25	1.2% (3/252)	0.25	3.44	4		
Suddaby et al., 2005	1	1 month to 18 years	23.1% 80/347	18.73	27.85	0.78	5.2% (18/347)	3.10	8.07			0.42
Mclane et al., 2004	2	1 Day to 17 years	4.0% (43/1064)	1.74	3.70	0.61	1.05% (11/1064)	0.52	1.84		10	
Groeneveld et al., 2004	3	1 Day to 16 years	13.4% (13/97)	7.33	21.82	0.76	3.2% (3/97)	0.64	8.77			
Willock et al., 2000	2	1 Day to 18 years	6.6% (12/183)	3.43	11.17	0.68	2.1% (4/183)	0.59	5.50			
Author & year	**Number of skin examiners**	**Age Range**	**Incidence Numerator/denominator**	**L 95% CI**	**U 95% CI**	**PI Stage I proportion**	**Stage II and Above Incidence Numerator/denominator**	**L 95% CI**	**U 95% CI**	**Median LOS (Days)**	**LOS for patients with PI (Days)**	**Medical Device**
Smith et al., 2019	2	1 Day to 18 years	11.7% (9/77)	5.49	21.00	0.89	1.3% (1/77)	0.03	7.00	6	7	0.78
Vocci et al., 2018	1	1 month to 15 years	14.1% (12/85)	7.51	23.36	0.54	4.05% (3/85)	0.73	9.96		7.7	
Garcia-Molinaet al., 2018	2	Day 1 to 30	12.7% (34/268)	8.95	17.27	0.57	5.5% (15/268)	3.16	9.00	11		0.84
Pellegrino et al., 2017	1	1 month to 18 years	21.8% (50/229)	16.67	27.75	0.64	7.9% (18/229)	4.70	12.10			0.25
Visscher et al., 2014	2	Day 1 to 30	3.8% (28/741)	2.53	5.42	0.12	3.3% (24/741)	2.08	4.78	42	92	0.8
Fujii et al., 2010	1	Day 1 to 30	16% (13/81)	8.83	25.88	0.21	12.7% (10/81)	6.08	21.50			
Curley et al., 2003	1	21 days to 8 years	26.7% (86/322)	21.95	31.90	0.70	8% (26/322)	5.34	11.60	6		0.12
Willock et al., 2000	1	1 Day to 18 years	7.3% (6/82)	2.73	15.25	0.50	3.65% (3/82)	0.76	10.00			