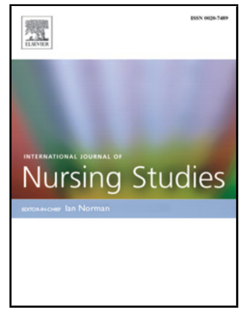
Accepted Manuscript



Title: Physiological vital sign ranges in newborns from 34 weeks gestation: A systematic review

Authors: Michelle Paliwoda, Karen New, Fiona Bogossian, Mark Davies

PII: S0020-7489(17)30230-4
DOI: https://doi.org/10.1016/j.ijnurstu.2017.10.004
Reference: NS 3033

To appear in:

Received date: 16-5-2017
Revised date: 7-9-2017
Accepted date: 8-10-2017

Title: Physiological vital sign ranges in newborns from 34 weeks gestation: A systematic review

Michelle Paliwoda[1,2*], RN RM NI BN, BN(Hons), GradDipMid, MMID, MHSlc(Clinprac), Karen New RN, RM, PhD[1], Fiona Bogossian[1], RN, RM, DipAppSci – NEd, BAppSci, MPH, PhD, FACM and Mark Davies MB BS DCH PhD FRACP [1,2]

Affiliations:
1: The University of Queensland, Australia
2: The Royal Brisbane and Women's Hospital, Queensland, Australia

***Address correspondence to:** Michelle Paliwoda, Level 3, Chamberlain Building, The University of Queensland QLD 4072
07 336 52068
[michelle.paliwoda@uq.net.au]

Short title Newborn physiological vital sign reference ranges

Funding Source: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
Financial Disclosure/Acknowledgements: Michelle Paliwoda is the recipient of an Australian Postgraduate Award funded by the Australian Government. The remaining authors have no financial relationships relevant to this article to disclose.

Conflict of Interest: Authors have no conflicts of interest to disclose.
Clinical Trial Registration: N/A

Abbreviations: Early Warning Tool/s (EWT/s); Gestational age (GA); Late Preterm (LPT); Early Term (ET); Term (T); Post Term (PT); Blood pressure (BP); peripheral capillary oxygen saturation (SpO_2);

Table of Contents Summary: This review highlights the paucity and inconsistency in current normal vital sign ranges for newborns greater than 34 weeks gestation.

ABSTRACT

Context: The birth process and the moments thereafter are a crucial time for newborns as they adapt to extra uterine life. The adaptive process begins immediately and can take a number of days to complete. The process involves initiating and maintaining respirations, thermoregulation, and the change from foetal circulation to newborn circulation. The majority of newborns successfully adapt to extra uterine life, some experience difficulty. Early warning tools may assist clinicians identify early signs of failure to adapt and/or deterioration but these are dependent on 'Normal' vital sign reference ranges for triggering an escalation of care. Age-matched early warning tools may improve the sensitivity of tools.

Objective: To identify physiological vital sign reference ranges for newborns ≥ 34 weeks gestation from two hours of age.

Design: Systematic Review

Data Sources: Between August 2016 and January 2017, PubMed, CINAHL, Embase, The Cochrane Library databases, and conference abstracts were searched for primary studies published between 1946-2017. Reference lists of retrieved articles were reviewed for potential studies.

Review methods: Primary studies published in English that reported physiological vital sign reference ranges pertaining to well newborns born from 34 weeks gestation were selected. Two authors independently assessed eligibility of studies for inclusion. Titles and abstracts were matched with the inclusion criteria: studies investigating heart or respiratory rate, temperature, blood pressure and oxygen saturations in well newborns greater than 34 weeks gestational age.

Assessment of quality and grading of level of evidence were assessed using National Health and Medical Research Council level of Evidence Hierarchy Table and the Quality Assessment Tool for Quantitative Studies. Any disagreements were resolved by consensus. Data were extracted by two reviewers

Results: A total of 1497 primary studies were retrieved. Following screening and removal of duplicates and screening, 10 primary studies investigating heart rate (n=1), respiratory rate (n=1), temperature (n=1), blood pressure (n=4) and oxygen saturations (n=3) were eligible for inclusion in this review. The populations studied included term (n=6) or both preterm and term newborns (n=4). No reference ranges for any vital sign measurements could be identified from the included literature. In addition, inconsistencies between vital sign parameters of newborns were identified between the studies.

Conclusion There is paucity of normal vital sign data in the late preterm >34 weeks and post term gestational age cohorts despite literature suggesting differences in physiological maturity between these cohorts.

Introduction

Following birth, the newborn undertakes a significant adaptive process called the transition to extra uterine life.[1] Transition is one of the greatest challenges a newborn must overcome and can take up to 2-4 weeks to complete.[2] The process involves initiating and maintaining respirations, thermoregulation, and the change from foetal (shunt dependent) circulation to newborn circulation.[1,3,] Factors such as gestational age at delivery, mode of delivery, a significant intrapartum event, a congenital defect or infection can delay this process.[4] Even though the majority of newborns successfully adapt to extra uterine life, some experience difficulty.[1,4-6] Therefore, if delay or compromise during this time is not recognised in a timely manner, the newborn can experience a serious adverse event.

Due to changes in health systems and care and management of postnatal mother/newborn dyads, there is an expectation that all well newborns will 'room in' with their mothers.[7] Therefore, it is not uncommon that newborns as young as 34 weeks gestation (late preterm) to be cared for in the postnatal ward of the maternity setting with their mother.[7] However, it is important to note that these newborns are still premature and are physiologically immature compared to their term counterparts.[8, 9] Thus, we have chosen newborns from the late preterm gestational age of ≥ 34 weeks for the focus of this review.

Recent patient safety mandates have prompted improvements in the care of newborns in health care settings in Australia and overseas.[8-10] Early Warning Tools have been implemented in healthcare settings for the identification of early signs of deterioration in all 'patients' including newborns cared for postnatally in the maternity setting. It has been proposed that the use of an early warning tool might assist clinicians to identify and respond to clinical deterioration by providing a systematic process to document physiological observations using pre-defined vital sign parameters.[8]

Early Warning Tools are designed to indicate when physiological observations deviate from predefined 'normal' reference ranges. Potential clinical deterioration is often indicated by a colour coded zone or aggregate numerical score[8] and alerts the clinician to 'escalate care'. However, the authors of a previous study reviewing early warning tools in newborns ≥ 34 weeks gestation who were deemed well and cared for in the maternity setting, reported that the ineffectiveness of three neonatal early warning tools was attributed in part to differences in reference ranges of identified 'normal' physiological parameters.[9] That is, each tool had different cut-off points for vital signs with the exception of respiratory rate. The researchers concluded that this influenced whether an escalation of care was required and resulted in inconsistencies in care escalation. In addition, differences were noted for gestational age indicating that a single universal tool may not be appropriate for the newborn population given that physiological maturity is inversely related to gestational age.[9,10]

In view of the identified limitations with the early warning tools previously tested, we hypothesise that their effectiveness may be improved with age-specific vital sign parameters. Therefore, this review sets out to identify the normal physiological reference ranges for five vital signs (heart rate, respiratory rate, temperature, blood pressure, and oxygen saturation) following the initial stabilisation period for well newborns cared for in the maternity setting: late preterm (34^{+0}- 36^{+6}), early term (37^{+0}- 38^{+6}), term (39^{+0}- 41^{+6}) and post term (≥42^{+0}).[11]

Objective

To examine the literature to identify vital sign reference ranges for newborns ≥ 34 weeks gestation from two hours of age.

Methods

We conducted a systematic review, which we report according to the PRISMA guidelines.[12] Between August 2016 and January 2017, PubMed, CINAHL, Embase, The Cochrane Library databases, and conference abstracts were searched for primary studies published between 1946-2017. All primary studies published in English that reported physiological vital sign reference ranges of well newborns born from 34 weeks gestation were selected. Search terms used were: “Neonate/Infant” AND “vital sign*” OR “heart rate” OR “respiratory rate” OR “temperature” OR “blood pressure” OR “oxygen saturation*”. Medical Subject Headings (MeSH) included: Infant, newborn.

Primary studies

Primary studies of all study designs pertaining to well newborns following birth ≥34 weeks gestational age during the first week of life and included either: heart or respiratory rates, temperature, blood pressure, and oxygen saturations were retrieved. Literature was limited to the English language and human subjects. Reference lists in retrieved articles were reviewed for potential studies.

Study selection and extraction

Two reviewers (MP, KN) independently screened the titles and abstracts. Full text articles from databases and additional sources were assessed for inclusion by two reviewers (MP, KN) and discrepancies were resolved by discussion or by involving a third person (FB). A data extraction spreadsheet was designed and data extraction, quality and grading of level of evidence was completed independently by two reviewers (MP, KN) for each of the included studies. Due to the heterogeneity of the included studies meta-analysis could not be performed. Sample size, outcome measures and study design were synthesised narratively and are presented in Table 1.

Results

The initial search identified 1497 references. Following removal of duplicates and review of titles and abstracts, 1335 were excluded. The remaining 162 full text articles were reviewed for eligibility and, of these, 154 were subsequently excluded (see Figure 1). Two additional primary studies were identified from the reference lists of reviewed articles and were eligible for inclusion resulting in a total of 10 primary studies included in this review

The Ten studies were assessed for Level of evidence and risk of bias using the National Health and Medical Research Council level of Evidence Hierarchy Table[13] and the Quality Assessment Tool for Quantitative Studies[14]. The studies included in this review were either an interrupted time series without a parallel control group (n=8)[15,16,18-21, 23, 24], cohort study (n=1)[22] or case series (n=1)[17] and received evidence levels of III-3 (N=10).[15-24] The quality of the quantitative studies varied with seven of the ten indicating 'weak' [15,16,18-20,22,24] quality; two of moderate[17,21] quality and the remaining study of strong[23] quality.

The five vital signs have been investigated by researchers in ten primary studies: heart rate (n=1),[15] respiratory rate (n=1),[16] temperature (n=1),[17] blood pressure (n=4)[18-21] and oxygen saturation (n=3).[22-24] These are presented in Table 1.

Of particular importance, the results reported by many of the researchers, did not quantify gestational age, but reported the newborn population as term and/or preterm. The populations studied included term (n=6) [15-17,19,20] or both preterm and term newborns (n=4).[18, 22-24] In addition, the researchers reported results as means or percentiles.[15-22, 24] Only one study in which the researchers investigated peripheral capillary oxygen saturations at varying altitudes, indicated a reference range.[23]

Heart rate

Sadoh and Sadoh[15] investigated heart rate for the first day following birth. The researchers conducted a study that used the average of three heart rate measurements taken over a three-minute period (right arm) from 473 term African newborns. The median heart rate overall was 133 beats per minute when asleep, awake or calm. No range was identified. There were no differences noted for sex (133 beats per minute male; 133 beats per minute female).

Respiratory rate

Tveiten, Diep, Halvorsen and Markestad[16] investigated respiratory rate up to 24 hours of age. The researchers conducted a prospective study which investigated the respiratory rates of 953 term newborns, measured via stethoscope for a 60 second period at two hourly intervals, for 24 hours following birth. The mean respiratory rates were: two hours: 47.3 breaths per minute, four hours: 43.1 breaths per minute, eight hours: 43.2 breaths per minute, 16 hours: 44.7 breaths per minute, and 24 hours: 44.8 breaths per minute, although standard deviations were not reported. The authors report no significant associations between respiratory rate and mode of delivery. However, differences were reported between sex, with term male newborns having higher respiratory rates than their female term counterparts, although, the actual difference was not stated. Respiration rate differed by as much as five breaths per minute between wake and sleep.

Temperature

Takayama, Teng, Uyemoto, Newman and Pantell[17] investigated temperature beyond two hours of age in term newborns. Retrospective axillary temperature data obtained from medical charts of 203 newborns were taken at 30, 60, 90 minutes, and at two, four, six, and eight hours following birth. The authors reported mean temperature at birth was 36.5°C and by two to three hours the mean was 0.2°C higher than at birth. By 15-20 hours, axillary temperatures in the newborns were 0.3°C higher than the mean. Although the researchers proposed hypothermic and hyperthermic ranges, no normal temperature ranges for term or preterm newborns were reported.

Blood pressure

The authors of four primary studies reported blood pressure for various periods between one and 14 days.[17-21] Samanta et al[18] conducted a study investigating non-invasive blood pressure of both term and preterm newborns up to 14 days of life. The researchers calculated the average of three blood pressure measurements taken at two-minute intervals and found that term newborns have higher systolic, diastolic and mean blood pressure than those born preterm. No differences were reported between sex, however, the researchers reported that birth weights correlated with mean arterial pressure rather than gestational age and increased with postnatal age. These findings are similar to Tan[21] who conducted a study on term newborns (n=46) and concluded that blood pressure increased with postnatal age and peaked on day five.

Similar findings were observed in studies conducted by Kent et al[20] and Sadoh and Ibhanesebhor,[19] who investigated normal blood pressure in term newborns using the average of three non-invasive blood pressure readings of varying study lengths from one day to up to six days respectively.[20, 19] The researchers reported no statistical differences between sex or gestational age groups. However, the researchers reported that blood pressure increased with advancing postnatal age. Normal ranges for systolic, diastolic, or mean arterial pressure blood pressures were not presented in any of the studies.

Oxygen saturation/s

The researchers of three primary studies investigated peripheral capillary oxygen saturations of newborns between 48 and 72 hours following birth.[22, 24] Shah et al[22] conducted a study on late preterm (n=20) and term newborns (n=40) to identify the newborn peripheral capillary oxygen saturation profile during the first 48 hours of life. Continuous readings of up to six hours were measured via pulse oximeter placed on the newborn's hand or foot if <3kgs or thumb or big toe if >3kgs. The researchers did not state whether readings were pre or post ductal. In addition, normal peripheral capillary oxygen saturation ranges for both late preterm and term newborns were not presented, however, mean peripheral capillary oxygen saturations for all newborns was 96.5%. No differences in peripheral capillary oxygen saturation were identified between sex (males, 95%; females 95%). The researchers reported data in 'time spent' in peripheral capillary oxygen saturation range and found that late preterm newborns spent 93% of the study time in saturations greater than 90% compared to term newborns that spent 96% of the time in saturations greater than 90%.

Ravert et al[23] conducted a multicentre study on late preterm (n=46) and term (n=764) newborns to identify normal peripheral capillary oxygen saturations between 4498 to 8150 feet elevation. Two to three readings of up to six seconds in duration were taken via a pulse oximeter on the newborns' right arm between 12-24, 36-48 and 60-72 hours. The authors reported significant differences between peripheral capillary oxygen saturation and altitude, with higher altitude normal peripheral capillary oxygen saturation range being 91-96%. Data for other gestational age groups such as the post term newborn were not reported in the study findings.

Rosvik[24] conducted a larger study in 6805 well newborns from late preterm to term (≥34 weeks gestational age). Post ductal peripheral capillary oxygen saturation readings of up to two minutes in duration, during the initial 24 hours of life were taken via the foot at four to five hours post birth.[24] No recommended normal peripheral capillary oxygen saturation range was reported for late preterm to term newborn population. However, the mean peripheral capillary oxygen saturation reading for all newborns was 98%. Differences were reported between sex with male newborn mean peripheral capillary oxygen saturation lower (97.9%) than female (98.1%) and via mode of delivery, with caesarean section readings higher (98.5%) than vaginal delivery (98%).

Discussion

The purpose of this review was to examine primary studies to identify vital sign reference ranges for five vital signs (heart rate, respiratory rate, temperature, blood pressure, and oxygen saturation). The population consisted of newborns ≥ 34 weeks gestation which comprised of late preterm (34^{+0}- 36^{+6}), early term (37^{+0}- 38^{+6}), term (39^{+0}- 41^{+6}) and post term (≥42^{+0}) following the initial stabilisation period.[11] To the best of our knowledge this is the first systematic review that attempts to collectively identify physiological vital sign ranges in the newborn population ≥ 34 weeks gestation, who are premature but are cared for in the maternity setting.

Newborn vital signs during the immediate stabilisation period (up to two hours following birth) have been explored in a number of studies.[25-29] It has been reported that peripheral capillary oxygen saturations take up to 15 minutes to stabilise,[25] heart rate up to one hour[6] and, up to three days for functional closure of the four circulatory ducts.[1,3] However, there is paucity in data for the remaining transition period, which takes approximately 12-72 hours.[1,3] This is surprising considering the important changes that occur during this time and the potential for failure to adapt. It is the newborn's potential for deterioration that has been the impetus for the development and implementation of neonatal early warning tools. [8-10]

The researchers of the included studies investigated a range of vital signs, using intermittent data sampling measurements or averages of several readings to determine normal values. The data capture period in the majority of these studies occurred between one and six days following birth.[15-24] Rather than presenting normal ranges which would be useful in the clinical setting, the studies presented results as means, which makes their interpretation into clinical practice or for the purpose of early warning tools difficult. Interestingly, textbooks present definitive vital sign parameter ranges,[6, 35, 47] although the evidence or sources for these ranges is difficult to ascertain in many of these publications.

While the data sampling methods varied between the studies, the majority sampled data at intermittent points in time. For example, in one study[15] the average of three heart rate measurements taken over three minute intervals were conducted. However, these brief data sampling sessions may not be sufficient to capture variability during the transition period or the effect of normal newborn behaviour such as crying, quiet state, unsettled, or sleep on vital sign parameters[6, 29]. This is important in the context of defining normal ranges which are applied to early warning tools. It may be that some early warning tools may trigger an escalation of care for a normal baseline heart rate, for example, in a sleeping post term newborn.

The triggering of an escalation of care has implications for families and the hospital. For example, a false positive trigger would result in unnecessary separation of the newborn from the mother and increase staff workload due to unnecessary investigations for the newborn. Conversely, the outcome for a false negative newborn may be notably different had deterioration been identified earlier or at all. Therefore, it is important to identify ranges appropriate for gestational ages in order to improve the sensitivity of neonatal early warning tools.

Improvements in the standards of care have allowed well newborns to 'room in' with their mothers[31] resulting in well newborns as young as 34 weeks to be cared for by their mothers in the postnatal ward within the maternity setting.[9] However, there is growing evidence that suggests late preterm infants are not just small term infants and that there are significant physiological differences between the newborn populations.[30] Thus generalising the data provided from term newborns, which has been the focus population in nine of the studies included in this review, to all gestation age groups, particularly on early warning tools could potentially effect the sensitivity and specificity of early warning tools. Incidentally, this has been the case as identified in a recent study examining a number of neonatal early warning tools.[9]

The authors of the included primary study that explored temperature recommended a mean normal temperature of 36.5°C[17]. This value was compared to other reference literature such as textbooks, and still, inconsistencies in what is considered normal were identified. For example, knowing that newborns have difficulty maintaining a normo-thermic state,[32] and that hypothermia is an independent risk factor for mortality[32], two textbooks presented normal temperature ranges for preterm newborns as 36.2-37.2°C[34] and 36.3-36.9°C.[6] Yet, both ranges overlap with the World Health Organization classification of mild hypothermia (36.0-36.4°C).[35] This highlights inconsistencies in recommended normal vital sign reference ranges between primary studies, textbooks and key health organisations. In addition, the primary study was a retrospective study of term newborns.[17] Retrospective chart reviews have inherent methodological shortcomings that, if not addressed, can influence the generalisability of findings and quality of research produced.[36] Similarly, the quality of a prospective trial depends on the type and amount of data collected.[37]

Most of the studies included in this review used intermittent data sampling as part of the study methodology. However, this method may not provide an accurate representation of normal vital sign ranges. For example, vital signs, such as the heart and respiratory rates of newborns have been reported to be higher in the three days prior to deterioration secondary to late onset sepsis[38] yet can be physiologically acceptable during periods of being unsettled, awake or in a quite state.[16, 29] In addition, newborn physiological vital signs vary during activities such as feeding and sleeping.[16, 29] Newborn behaviour is worth taking into consideration when designing an early warning tool.[9] A recent study testing the effectiveness of early warning tools in the postnatal ward reported clinicians escalated care based on judgement of abnormal neonatal behavioural signs such as vomiting, lethargy, and poor feeding – which were unable to be escalated on two of the three early warning tools tested because they were not included in the design of the early warning tools.[9]

Whilst the researchers of three primary studies that examined normal mean blood pressure values of newborns,[18-21] non-invasive blood pressure is not routinely conducted as part of daily newborn assessment in the health care setting. [19,39] In addition, the accuracy of non-invasive blood pressure monitoring has been questioned due to errors in measurement performance.[40,41] Yet, measuring blood pressure in the newborn is clinically important to identify a congenital disorder, a patent cardiac duct, or complications resulting from maternal recreational drug use.[42] These conditions manifest with either high or low blood pressure. Therefore, it is important to identify the normal postnatal-age blood pressure ranges in order to easily identify these potential problems.

In recent years, there has been a focus on the immediate stabilisation of oxygen saturations following birth until approximately two hours of age. This has resulted in the introduction of a random peripheral capillary oxygen saturation reading prior to transfer or discharge to detect congenital heart defect.[43] Similarly, recent studies have reported differences in peripheral capillary oxygen saturation readings between night and day[44] and between wake and sleep states[45]. In addition, other inconsistencies were identified between the primary studies as to what was considered normal peripheral capillary oxygen saturation with the authors of one study conducted at >4400 Feet elevation[22] reporting normal as 91%. Other reference literature present varying 'normal' peripheral capillary oxygen saturation values for term and preterm newborns.[46-49] These findings question current peripheral capillary oxygen saturation values and it seems that a universal value for normal peripheral capillary oxygen saturation range is problematic when trying to determine cut-off points for peripheral capillary oxygen saturation on an early warning tool.

It is important to note that literature revealed differences in normal vital sign reference ranges for term newborns and highlighted paucity in empirical data supporting current values for the well preterm newborns. That is, the authors of only two studies examined late preterm population and only one examined newborns >30 weeks gestation. It has been documented that there are several variables which contribute to physiological variation in vital signs such as gestation age, [30, 45,50] sex,[16,18] vital signs,[15-24] and activity.[16,29,51] This suggests that a universal reference range for newborns is problematic, as it does not reflect the complex interplay of variables that impact on clinical wellbeing. For example, a low heart rate in a late preterm newborn may be associated with compromise such as bradycardia secondary to infection; while this may be a normal physiological finding in the post term newborn.[9, 10] The differences in physiological maturity[30, 45,46] should be reflected in vital sign parameter ranges.

Limitations

Publications unable to be retrieved electronically were not included.

Conclusion

We could not identify reference ranges for any vital sign measurements from the literature included in this review. In addition, inconsistences between primary studies were identified regarding vital sign parameters of newborns. There is paucity of normal vital sign data in the late preterm >34 weeks and post term gestational age groups despite literature suggesting differences between physiological maturity between these groups. In the absence of robust data, generalising vital sign parameters to other gestational age groups, especially on early warning tools, will not be appropriate and will not capture subtle changes in wellness, but result in delayed identification and response to deterioration.

Considering this, there are likely differences in vital sign parameters within the newborn population and these changes extend throughout the transition period. Therefore, additional research such as an observation study incorporating longer duration of data capture that is prospectively collected is needed to determine whether there are differences during the first seven days of life amongst well newborns ≥34 weeks gestational age.

Recommendations for research

This review has highlighted the importance of and the need for further robust studies into the normal physiological parameters of newborns from 34 weeks gestational age throughout the newborn transition period.

Recommendations for practice

Midwives and neonatal nurses should continue to assess newborns as per hospital-based policies. No recommendations on standard normal physiological parameters can be made at this stage until a prospective observation study incorporating a longer duration of data capture or an expert consensus group validating normal neonatal physiological parameters based on primary evidence has been undertaken.

Contribution of the Paper

What is already known?

- Well newborns as young as 34 weeks gestation are often cared for in the maternity setting alongside their mothers
- Late preterm newborns are still premature and are often viewed as small term newborns despite being physiologically immature compared to their term counterparts.
- Early warning tools are being used to identify signs of compromise in well newborns cared for in the maternity setting

What this paper adds

- There is paucity and inconsistency in vital sign reference ranges of newborns greater than 34 weeks gestation
- Current early warning tool reference ranges may not be sensitive or specific to identify compromise in newborns of all gestational age groups
- Further research is needed into the physiological vital sign ranges of the newborn population

Contributors' Statements:

Michelle Paliwoda: conceptualised, designed and conducted the literature review; drafted the manuscript

Karen New: contributed to the design of the review, reviewed and revised the manuscript
Mark Davies: contributed to the design of the review, reviewed and revised manuscript
Fiona Bogossian: contributed to the design of the review, reviewed and revised manuscript

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Reference list

(1) Graves B, Haley MM. Newborn Transition. Journal of Midwifery and Women's Health. 2013;58:662-670. doi:10.1111/jmwh.12097

(2) Hertz D. Care of the Newborn: A Handbook for Primary Care. USA: Lippincott Williams and Wilkins; 2005

(3) Murphy P. The fetal circulation. Contin Educ Anaesth Crit Care Pain. 2005; 5(4): 107-112. doi: 10.1093/bjaceaccp/mki030

(4) Juve-Udina M, Fabrellas-Padres N, Delgado-Hito P, Hurtado-Pardos B, Marti-Cavalle, M, Girones-Nogue M, Garcia-Berman R, Alonso-Fernandez S. Newborn Physiological Immaturity: A Concept Analysis. Advances in Neonatal Care. 2015; 15(2):86-93. doi: 10.1097/ANC.0000000000000162

(5) Altman, C. Identifying newborns with congenital heart disease. In: UpToDate, Fulton, & Weisman, L (eds), UpToDate, Waltham, MA. [accessed on March 17, 2017]

(6) Gardner S, Carter B, Enzman-Hines M, Hernandez J, editors, Merenstein and Gardner's Handbook of Neonatal Intensive Care. (113-133). USA: Elsevier; 2016

(7) Fleming P, Arora P, Mitting R, Aladangady N. A national survey of admission practices for late preterm infants in England. BMC Pediatrics.2014;14, 150. doi10.1186/1471-2431-14-150

(8) Australian Commission on Safety and Quality in Health Care., 2010. National Consensus Statement: Essential elements for recognising and responding to clinical deterioration. Sydney: ACSQHC. Retrieved from: http://www.safetyandquality.gov.au/wp-content/uploads/2012/01/NSQHS-Standards-Fact-Sheet-Standard-9.pdf [accessed 14.02.16]

(9) Paliwoda M, New K, Bogossian F. Neonatal Early Warning Tools for recognising and responding to clinical deterioration in neonates cared for in the maternity setting: A retrospective case–control study. International Journal of Nursing Studies. 2016; 61:125-135. doi:/10.1016/j.ijnurstu.2016.06.006

(10) Paliwoda M, New K. Neonatal early warning tools: A literature review. Neonatal, Paediatric and Child Health Nursing. 2015;18(1):19-23.

(11) American College of Obstetricians and Gynecologists. Definition of term pregnancy. Committee Opinion No. 579. *Obstetrics and Gynecology.* 2013. 122:1139-40.

(12) Moher D, Liberati A, Tetzlaff, J, Altman, DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed10000097

(13) National Health and Medical Research Council. Additional levels of evidence and grades for recommendations for developers of guidelines. Canberra; 2009. Retrieved from:

https://www.nhmrc.gov.au/_files_nhmrc/file/guidelines/developers/nhmrc_levels_grades_evidence_120423.pdf [accessed 4.8.16]

(14) Effective Public Health Practice Project. Quality Assessment Tool For Quantitative Studies.: Effective Public Health Practice Project. Hamilton, ON; 1998. Retrieved from: http://www.ephpp.ca/index.html [accessed 16.8.17]

(15) Sadoh WE, Sadoh AE. Normal oscillometric heart rate of term African infants in the early days of life. Paediatr Int Child Health. 2012; 32(2):107-110. doi:10.1179/2046905511y.0000000015

(16) Tveiten L, Diep L, M. Halvorsen T. Markestad T. Respiratory rate during the first 24 hours of life in healthy term infants. Pediatrics. 2016; 137(4). doi:10.1542/peds.2015-2326

(17) Takayama J, Teng W, Uyemoto J, Newman T, Pantell R. Body temperature of newborns: What is normal. Clinical Pediatrics. 2000; 39(9): 503-510

(18) Samanta M, Mondal R, Ray S, Sabui, T., Hazra, A., Kundu, et al. Normative blood pressure data for Indian neonates. Indian Pediatr. 2015; 52(8): 669-673. doi: 10.1007/s13312-015-0694-y

(19) Sadoh WE, Ibhanesebhor SE. Oscillometric blood pressure reference values of African full-term neonates in their first days postpartum. Cardiovasc J Afr. 2009; 20(6): 344-347.

(20) Kent AL, Kecskes Z, Shadbolt B, Falk MC. Normative blood pressure data in the early neonatal period. Pediatr Nephrol. 2007; 22(9):1335-1341. doi:10.1007/s00467-007-0480-8

(21) Tan K. Blood pressure in full-term healthy neonates. Clinical Pediatrics. 1987; 26(1): 21-24. doi: 10.1177/000992288702600103

(22) Shah PS, Hakak H, Mohamed A, Shah J, Young J, Kelly E. Oxygen saturation profile in late-preterm and term infants: a prospective cohort study. J Perinatol. 2014; 34(12): 917-920. doi:10.1038/jp.2014.107

(23) Ravert P, Detwiler TL, Dickinson JK. Mean oxygen saturation in well neonates at altitudes between 4498 and 8150 feet. Adv Neonatal Care. 2011;11(6): 412-417. doi:10.1097/ANC.0b013e3182389348

(24) Røsvik A, Øymar K, Kvaløy JT, Berget M. Oxygen saturation in healthy newborns; influence of birth weight and mode of delivery. J Perinat Med. 2009; 37: 403-406. doi:10.1515/JPM.2009.070

(25) Nuntnarumit P, Rojnueangnit K, & Tangnoo A. Oxygen saturation trends in preterm infants during the first 15min after birth. Journal of perinatology. 2010; 39:399-402

(26) Salihoglu O, Can E, Beskardes A, Koc B, Tan I, Can G et al. Delivery room blood pressure percentiles of healthy, singleton liveborn neonates. 2012; 54:182-189. doi: 10.1111/j.1442-200X.2011.03520.x

(27) Hulsoore R, Shrivastav J, Dwivedi R. Normal oxygen saturation trend in healthy term newborns within 30 minutes of birth. Indian J Pediatr. 2011; 78(7):817-820. doi 10.1007/s12098-011-0405-1

(28) Gautam S, Agrawal A. Oxygen saturation trends in newborn after birth. Journal of evolution of med and dent sci. 2015;4(63).

(29) Yiallourou S, Sands S, Walker A, Horne R. Maturation of Heart rate and blood pressure variability during sleep in term-born infants. Sleep. 2012; 35(2): 177-186. doi: 10.5665/sleep.1616

(30) Engle, W., Tomashek, K., & Wallman, K. "Late-Preterm" infants: A population at risk. Pediatrics. 2007; 120(6), 1390-1401. doi: 10.1542/peds.2007-2952

(31) Temkin E. Rooming-In: Redesigning hospitals and motherhood in cold war America. Bulletin of the History of Medicine. 2002;76(2): 271-298. Doi: 10.1353/bhm.2002.0101

(32) Soll RF. Heat loss prevention in neonates. Journal of Perinatology. 2008; 28(S1): S57-S59. doi: 10.1038/jp.2008.51

(33) Mullany LC, Zatz J, Khatry SK et al. Risk of mortality associated with neonatal hypothermia in southern Nepal. Arch Pediatr Adolesc Med. 2010;164(7), 650-656.

(34) The World Health Organisation. Pregnancy, Childbirth, Postpartum and Newborn Care: A guide for essential Practice. 3rd ed, The World Health Organization: Luxembourg; (2015) Retrieved from: http://www.who.int/maternal_child_adolescent/documents/imca-essential-practice-guide/en/ [accessed 2.2.17]

(35) Jardine L, Sinha S, Miall L. Essential Neonatal Medicine. 5th ed. USA: Wiley-Blackwell; 2012

(36) Joanna Briggs Organisation. New Joanna Briggs levels of Evidence. 2014. from: http://joannabriggs.org/assets/docs/approach/JBI-Levels-of-evidence_2014.pdf [accessed 1.3.17]

(37) Oxford Centre for Evidence-Based Medicine. Levels of Evidence. 2009. from http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/ [accessed 1.3.17]

(38) Yapicioglu H, Ozlu F, Sertdemir Y. Are vital signs indicative for bacteremia in newborns? J Matern Fetal Neonatal Med. 2015; 28(18): 2244-2249. doi:10.3109/14767058.2014.983896

(39) The Royal Hospital for Women. Neonatal Observations Guideline: Local Operating Procedures: Blood Pressure Measurement in Newborn Care Centre; 2008. Retrieved from: https://www.seslhd.health.nsw.gov.au/rhw/Newborn_Care/ Guidelines/Nursing/BloodPressureMeasurementinNewbornCareCentre.pdf [accessed 2.2.17]

(40) Dasnadi S, Aliaga S, Laughon M, Warner D, Price W. Factors influencing the accuracy of noninvasive blood pressure measurements in NICU infants. Journal of Perinatology. (2014); 32(7): 639-644. doi: 10.1055/s-0034-1390345

(41) Devinck A, Keukelier H, Savoye D, Desmet L, Smets K. Neonatal blood pressure monitoring: visual assessment is an unreliable method for selecting cuff sizes. ACTA Paediatrica. 2013; 101(10): 961-964. doi 10.1111/apa.12328

(42) LeFlore J, Engle, W. Clincial Factors influencing blood pressure in the neonate. NeoReviews. 2002; 3(8):e145-150 Retrieved from: http://www.ohsu.edu/xd/health/services/doernbecher/research-education/education/residency/upload/res_lounge_blood-pressure.pdf

(43) Scott PA, Predischarge oxygen saturation check for the well newborn. The Journal for Nurse Practitioners. 2014;10(3):209-210.

(44) Terrill P, Dakin C, Hughes I, Yuill M, Parsley C. Nocturnal oxygen saturation profiles of healthy term infants. Arch Dis Child. 2015; 100: 18-23. doi: 10.1136/archdischild-2013-305708

(45) Kugelman A, Colin A. Late preterm infants: near term but still in a critical developmental time period. Pediatrics. 2013; 132(4): 741-751. doi:10.1542/peds.2013-1131

(46) Ricci S, Kyle T. Maternity and Pediatric Nursing. China: Wolters Kluwer Health; 2008.

(47) Fleisher, G., Ludwig, S, editors. Textbook of Pediatric Emergency Medicine. 6th ed. United States of America: Lippincott Williams & Wilkins; 2010

(48) Lissauer, T., & Fanaroff, A. Neonatology at a Glance. 2nd ed. United States of America: Wiley-Blackwell; 2011

(49) Verklan M, Walden M. Core Curriculum for Neonatal Intensive Care Nursing. USA: Elsevier; 2015.

(50) Longin E, Gerstner T, Schailble T, Lenz T, Konig S. Maturation of the autonomic nervous system: differences in heart rate variability in premature vs. term infants. J Perinat Med. 2006; 34(4): 303-8. doi: 10.1515/JPM.2006.058

(51) Pillitteri, A. Maternal and Child Health Nursing: Care of the Childbearing & Childrearing Family. 6th ed. United States of America: Lippincott Williams & Wilkins; 2010

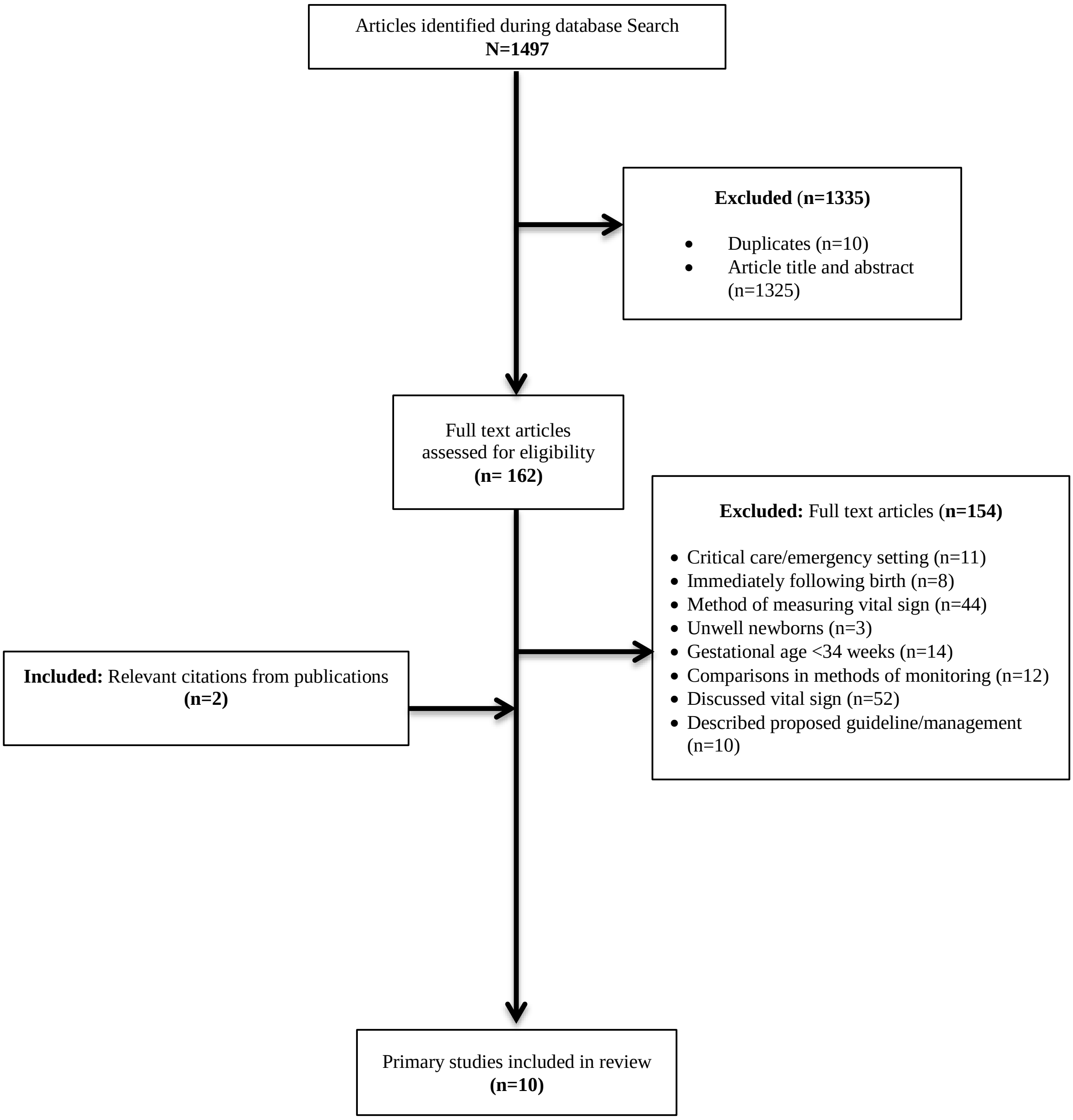


Figure 1
Literature search: screening, inclusion and exclusion

Peer reviewed articles									
N=10	**Author**	**Date**	**Population (Gestational Age/Group)**	**Sample**	**Duration**	**Vital Sign**	**Method**	**Results**	**Normal Range**
1	Sadoh & Sadoh[15] **Country:** Africa **Journal:** Paediatrics and International Child Health **Level of Evidence**: III-3 **Quality Assessment:** Weak	2012	Newborn (T)	473	1 day	Heart rate	**Device**: Dinamap 8100 Oscillometric Average of 3x HR measurements over 3 minute intervals (Right arm).	No significant difference between sex. Median HR (bpm): Male 133bpm; Female 133bpm	n/s
2	Tveiten, Diep, Halvorsen & Markestad[16] **Country:** Norway **Journal:** Pediatrics **Level of Evidence:** III-3 **Quality Assessment:** Weak	2016	Newborn (T)	953	24 hours	Respiratory rate	**Device:** Stethoscope RR readings taken at: 2, 4, 6, 8, 16, & 24 hrs post birth 1 minute duration via mouth/nose	Mean (bpm): 2 hrs: 47.3 4 hrs: 43.1 8 hrs: 43.2 16 hrs: 44.7 24 hrs: 44.8 Males respiration rate higher than girls – 1.6 (95% CI, 0.8 to 2.4; *P* <.001) breaths per minute. No differences observed in respiratory and mode of delivery.-0.1; 95% CI, -1.2 to 0.96 breaths per minute RR also higher when awake than asleep 5.2 (95% CI, 1.5 to 4.8; *P* <.001 breaths per minute.	n/s
3	Takayama, Teng, Uyemoto, Newman & Pantell[17] **Country:** United States of America **Journal:** Clinical Pediatrics **Level of Evidence:** III-3 **Quality Assessment:** Moderate	2000	Newborn (T)	203	Up to 6 days	Temperature	**Retrospective chart review using device:** Steritemp Digital thermometer Axillary temperature readings taken at 30, 60, 90 minutes, and 2, 4, 6, then 8th hourly post birth	Mean temperature in °C Birth: 36.5 2-3 hrs: 0.2 higher than birth 15-20 hrs: 0.3 higher than the mean	n/s
4	Samanta, Mondal, Ray, Sabui, Kundu, Chatterjee & Sarkar[18] **Country:** India **Journal:** Journal of Tropical Pediatrics **Level of Evidence:** III-3 **Quality Assessment:** Weak	2015	Newborn (T, >30k)	1617	Up to 14 days	Blood Pressure	**Device:** Multi Channel monitor (Star 55). Oscillometry Readings taken days: 4, 7 & 14 at approx. ½ hour post feed/intervention on right upper arm. 3x BP readings at 2 min intervals. Average used for analysis	BP increases with postnatal age: MAP 3.92 ± 0.071 mmHg day 4-7; 3.26 ± 0.068 mmHg day 7-14. Term newborns have higher SBP, DBP and MAP than preterm: MAP Day 4 - 60.92 ± 6.378 (T); 48.91 ± 5.545 (PT); MAP Day 7 – 64.49 ± 5.477 (T); 53.25 ± 5.395 (PT); MAP Day 14 – 67.61 ± 5.138 (T); 57.53 ± 5.658 (PT) Birth wt correlated with MAP than GA. No significant differences of BP between sex identified.	n/s

5	Sadoh & Ibhanesebhor[19] **Country:** Africa **Journal:** Cardiovascular Journal of Africa **Level of Evidence:** III-3 **Quality Assessment:** Weak	2009	Newborn (T)	473	1 day	Blood Pressure	**Device:** Dinamap 8100 Oscillometry 1 hr post feed in asleep/quite/calm state, 3x successive BP readings taken via size 3-4 cuff for one day only. Average of 3x readings used for analysis	SBP, DBP, & MAP increased with postnatal age – being lower on day 1 than on subsequent days. No statistical difference in SBP, DBP & MAP between males and females or birth weight observed. Mean Day 1 SBP - 66.8 ± 7.7, DBP - 38.5 ± 6.3 and MAP 47.9 ± 6.3 mm Hg.	n/s
6	Kent, Kesckes, Shadbolt & Falk[20] **Country:** Australia **Journal:** Pediatric Nephrology **Level of Evidence:** III-3 **Quality Assessment:** Weak	2007	Newborn (T)	406	Up to 6 days	Blood Pressure	**Device:** Propaq Encore 202 EL monitor - smart cuff 3x readings per day until discharge. Average of 3x readings used for analysis.	Differences in BP values on days 1 and 2 with males being lower on day 2. No differences observed between BP and GA. Results indicate rise in BP with postnatal age. Median Day 1 SBP - 65, DBP - 45 and MAP 48 mm Hg. Median Day 4 SBP - 70, DBP - 46 and MAP 54 mm Hg.	n/s
7	Tan[21] **Country:** Singapore **Journal:** Clinical Pediatrics **Level of Evidence:** III-3 **Quality Assessment:** Moderate	1987	Newborn (T)	46	Up to 6 days	Blood pressure	**Device:** Dinamap[#] 3x consecutive readings – RUA, LUA, LL were taken. Mean values recorded. Readings were taken for the first six days.	Blood pressure peaked on day 5. BP diverges with postnatal age. No significant difference with awake/sleep state. Day 1: SBP - 70.54 ± 9.13 / 70.41 ± 9.59 (Awake/Asleep) DBP- 42.73 ± 9.81/42.28 ± 11.97 (Awake/Asleep) MAP – 55.32 ± 8.63/55.45 ± 11.35 (Awake/asleep).	n/s
8	Shah, Hakak, Mohamed, Young, & Kelly[22] **Country:** United States of America **Journal:** Journal of Perinatology **Level of Evidence:** III-3 **Quality Assessment:** Weak	2014	Newborn (T, LPT)	60	6 hours	Oxygen Saturation	**Device:** Nellcor Oximax N 600X pulse oximeter. **Probe/Site:** Oximax Max-N <3kgs (Hand/foot) Oximax Max N1 >=3kgs (thumb/big toe Continuous reading for 6 hours. Pre/post ductal readings not specified in article.	Mean SpO2: T: Majority >95% LPT: significant time <=90% No significant difference between sex.	n/s
9	Ravert, Detwiler & Dickinson[23] **Country:** United States of America **Journal:** Advances in Neonatal Care **Level of Evidence:** III-3 **Quality Assessment:** Strong	2011	Newborn (T, LPT)	812	Up to 72 hours	Oxygen Saturation (Pre/post ductal)	**Device:** Pulse oximeter (Make/model unknown) Right upper limb; left lower limb for 6 seconds of stable waveform. 2-3 readings between taken between: 12 and 24 hours, 36-48 hours; 60-72 hours (if still admitted).	Mean SpO2 of newborns born at higher altitudes are lower 91-96% than those born lower altitudes 97%. 4498 feet: 95-96.67%; 6800 feet: 93.91-95.36%; 7851 feet: 91.80-94.37%; 7890 feet: 93.44-96.10%; and 8150 feet: 93.69 – 96.25%.	91-96%
10	Rosvik, Oymar, Kvaloy & Berget[24] **Country:** Norway **Journal:** Journal of Perinatal Medicine **Level of Evidence:** III-3	2009	Newborn (>34K)	6805	Up to 24 hours	Oxygen Saturation	**Device: RAD-SV** pulse oximeter Post ductal readings via foot between 4-5 hrs post birth (2 and 24 hours permitted) for at least 2 minutes	Mean SpO2 All cohort: 98%; Mean levels lower in male (97.9%) than female (98.1%) neonates Mean levels higher in caesarean section (98.5%) than vaginal delivery (98.0%)	n/s

Quality Assessment: Weak	of stable waveform.

Table 1: Newborn physiological vital sign reference ranges by publication

Legend: T – Term; LPT – Late Preterm; 'n/s'- not stated; ^ - once stabilized; > - supplementary document for this policy; # model unknown; * applies to all healthy newborns; respiratory rate (bpm) – breaths per minute; heart rate (bpm) beats per minute; SBP – Systolic blood pressure; DBP – diastolic blood pressure; MAP – mean arterial pressure; GA – Gestational age; kg – kilogram; BWt – birth weight