Positioning of Preterm Infants for Optimal Physiological Development: a systematic review

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Executive Summary

Positioning of preterm infants is a basic task of neonatal nursing care. A variety of outcomes are affected by different body positioning of preterm infants. This review evaluates the clinical evidence of the effects of positioning of preterm infants with regard to physiological outcomes and sleep states.

Objectives To conduct a systematic review to determine the best available evidence related to the positioning of preterm infants. The specific review questions addressed were: the physiological outcomes affected by different positioning, and the best position for promoting sleep.

Criteria for considering studies for this review This review considered all studies that included infants born before 37 weeks of gestational age in any hospital setting. Outcomes included measures for physiologic effects and sleep state. The review primarily considered any randomized clinical trails (RCTs) that explored different positions in preterm infant but also included quasi-experimental designs.

Search strategy for identification of studies The search sought to find published and unpublished studies. The database search included: Pubmed, CINAHL, ProQuest, EMBASE, Science Direct, and Dissertation Abstracts International. Studies were additionally identified from reference lists of all studies retrieved.

Assessment and data extraction All studies were checked for methodological quality by two reviewers and data was extracted using tools developed by the Joanna Briggs Institute.

Data analysis The study results were pooled in statistical meta-analysis using Review Manager Software and summarized in narrative form where statistical pooling was not appropriate or possible.

Results Thirty two studies were included in the review. The results of this review support the prone position in preterm infants for improvement of arterial oxygen saturation, improved lung and chest wall synchrony of respiratory improvements, decreased incidence of apnea in infants with a clinical history of apnea, promoted sleep, and decreased gastroesophageal reflux. However, the prone position increased postural abnormalities, orthopaedic abnormalities of the feet, and delayed developmental musculature. The combined use of a postural support roll and a postural nappy while very preterm infants are nursed, improved hip and shoulder posture up to term postmenstrual age. The change in body position from horizontal to head-up tilt in very immature and unstable infants may affect the cerebral homodynamic. The management of position per se may not be sufficient for assisting preterm neonates to cope with the painful procedure. Furthermore, preterm infants are susceptible to oxygen desaturation in car seats and carrying slings.

Conclusion Prone positioning was shown to have many advantages for prematurely born infants. But the longer, deep sleep period and fewer awakenings associated with a prone position would support higher vulnerability for preterm infants to sudden infant death syndrome (SIDS). Therefore, all preterm infants placed in the prone position should have continuous cardio-respiratory and oxygen saturation monitoring. Preterm infants should be placed in a properly supported position to ensure functional support of all parts of the body as well as ensuring physical safety. In addition, preterm infants should not be left unattended in car safety seats and carrying slings.

Key words: Preterm infant, Position, Sleep, Physiological development.

Background

The early transition to extra uterine life creates a challenge for preterm infants who struggle to maintain previously organized patterns of functioning in the face of overwhelming stimuli. Premature infants are at risk for developmental delays. Due to immaturity, they often lack adequate muscle tone and are at risk for developing abnormal movement patterns as well as skeleton deformation [1]. Some delays are related to postural problems and improper body mechanics rather than to neurological impairment. Hypotonic or decreased muscle tone was normally observed in the infant born 28 to 30 weeks' gestational period. Most premature infants also demonstrate an excessive hypotonic state and are unable to combat the force of gravity; therefore, extension becomes the dominating force. Proper positioning of premature infants may promote normal motor development while minimizing the development of abnormal movement patterns.

Positioning of preterm infants is basic neonatal nursing care. It includes supine, prone, side-lying, and head up tilted position. Several studies demonstrated a variety of outcomes affected by different body positioning of preterm infants. In addition, several studies indicated a strong association between prone sleep position and Sudden Infant Death Syndrome (SIDS) [2]. Preterm infants, compared with those born at term, have a higher incidence of SIDS. Prematurely born infants account for between 10% and 20% of SIDS cases [3]. As a result of these findings, there is increasing pressure to avoid the prone sleep position in all infants, including preterm infants who do not have respiratory distress and are being readied for hospital discharge. The American Academy of Pediatrics has recommended since 1992 that infants be placed to sleep in a non-prone position to reduce the risk of sudden infant death syndrome (SIDS). Since that time, the frequency of prone sleeping has decreased from >70% to approximately 20% of US infants, and the SIDS rate has decreased by >40%. However, SIDS remains the major cause of death in infants from 1-12 months of age, and there are still several potentially modifiable risk factors [4,5.] The physiological mechanisms that underlie SIDS remain unknown and prospects for further reduction may be tied to a better understanding of the mechanisms linking prone sleep to SIDS.

However, prone positioning was shown to have many advantages for prematurely born infants. Preterm infants in the prone position spend less time awake and more time quiet and asleep [6], cry less and move less [7,8]. Furthermore, previous studies found that preterm infants who lie in a prone position compared to those in a supine position have earlier motor milestones [9], decreased energy expenditure, more rapid gastric emptying and less gastric reflux [10,11], greater chest wall synchrony and improved respiration [12,13], decreased respiratory rate [7,12], greater tidal volume, minute volume, elastic work, inspiratory and tidal viscous work, total work of breathing, and work of ventilating [14], improved oxygenation in both spontaneous breathing preterm infants [13,15-17] and intubated preterm infants [7,18-20]. Despite the physiologic benefits of the prone position, the very low birth weight infant is at risk for postural abnormalities such as flattened posture that is known to affect developmental milestones up to age six [21]. Three studies indicated that the supine positioning in healthy preterm infants was associated with higher respiratory rate than the prone position [12,21,22], but the other study demonstrated that there were no significant differences in the incidence of clinically significant apnea, bradycardia, or desaturation between supine and prone positions [23]. In addition, some studies found that the head elevated tilt position reduces hypoxemic and bradycardic events in preterm infants [24,25], and increases transcutaneous PO_2 [26]. However, a comprehensive literature review during 1966-2000 by Monterosso [27] found that the prone position is preferred for very low birth weight infants because it promotes development of pulmonary, cardiovascular, sleep state organizational, and gastrointestinal functions and facilitates the preterm infants recovering from the respiratory complications associated with immaturity. In addition, the results of a systematic review suggested that prone position slightly improved the oxygenation in neonates undergoing mechanical ventilation [18]. However, there was no evidence concerning whether particular body positions during mechanical ventilation of the neonate were effective in producing sustained and clinical relevant improvements.

Although research shows advantages and disadvantages for both the supine and prone position among preterm infants to their physiological outcomes, there is a trend remaining toward keeping preterm infants in a supine position; mainly for ease of observation and handling. Also, there is the increased risk of sudden infant death syndrome in infants placed in a prone position. Also, premature infants are now widely recognized to be at risk of oxygen desaturation and secondary central apnea while restrained in infant car seat [28,29]. Therefore, clarification of the benefits and potential risks associated with body positioning in preterm infants is required to provide evidence-based clinical practice. This review evaluates the clinical evidence that investigates the effects of positioning of preterm infants on physiological outcomes including pain, electrocortical activity, respiratory function, hemodynamic, neuromotor development, gastric function and sleep states.

Objectives

The objective of this review was to compare the effects of different body positions on physiological outcomes and sleep on hospitalized preterm infants. The following questions were addressed in this review:

1. What are the physiological outcomes affected by different positioning of preterm infants?
2. What is the best position for promoting sleep among preterm infants?

Criteria for considering studies for this review

Types of participants

This review considered all studies that included healthy infants born before 37 weeks of gestational age in any hospital setting, including those admitted to newborn nurseries, neonatal intensive care units, and medical clinics.

Types of Intervention

Interventions of interest were those related to positioning of preterm infants including prone, supine, side-lying, head elevated tilt, car seats, and horizontally or vertically in a sling.

Types of outcome measures

The outcomes of interest were as follow:

1. Physiologic effects including respiratory function (oxygen saturation, tidal volume, functional residual capacity, respiratory rate), hemodynamic (heart rate, blood pressure), neuromotor development (muscle tone, posture, motor activity), and gastric function (gastroesophageal reflux, gastric residual).

2. Sleep state classified as awake, active sleep, quiet sleep or indeterminate sleep.

Types of studies

This review considered any randomized clinical trails (RCTs) that explore different positions in preterm infants. In the absence of RCTs, Quasi-experimental design was reviewed for a possible conclusion in a narrative summary to enable the identification of current best evidence regarding position in preterm infants. Studies included infants who had medical problems or were on medication at the time of study were excluded from this review.

Exclusion criteria

This review excluded articles that were of expert opinion, literature reviews, or included no detailed results of the study.

Search strategy

The search strategy was designed to identify both published and unpublished studies and comprised three stages:

1. An initial limited search included journal indexes from MEDLINE. An analysis of the text words contained in the title, abstracts, and subject descriptors / MeSH terms of relevant articles considered to identify additional key words.
2. Terms identified in this way and the synonyms used by respective databases, were adapted for an extensive search of the literature.
3. Reference lists and bibliographies of the articles collected from all included literature were also searched for additional relevant source journals.

All studies retrieved of a combination of keywords were reviewed regarding their title, abstract, and descriptive terms for meeting the inclusion criteria. Keywords included: position, positioning, sleep, prone, supine, side-lying, head elevated tilt, premie, preterm, premature and infants.

The time period of the search covered articles published from 1996 to 2006 in English and Thai language. Assessment for inclusion of foreign language publication was based on the English language abstracted, when available. The databases searched included: CINAHL, EMBASE, Cochrane Library, PubMed, ProQuest, and Science Direct, Currents @ OVID, EBSCO Host Research Databases, and Blackwell synergy. Individual search strategies were developed for each database, adopting the different terminology of index thesauri if available. A full report was retrieved for all studies that appeared to meet the inclusion criteria (Appendix 1).

Hand searching of the most recent issues of the following journals was done for additional references: Journal of Pediatric Nursing, Pediatrics, and Archives of Disease in Childhood, Neonatal Network. A search was conducted to locate relevant unpublished materials, such as conference papers, research reports, and dissertations. The sources that were searched to locate unpublished studies included: Dissertation Abstracts, Index to Theses, and direct communication with neonatal nurse researchers. Content experts were contacted in order to provide other alternatives for securing relevant literature.

All studies identified during the databases search were assessed for relevance to the review and full reports were retrieved for all studies that met the inclusion criteria as assessed independently by two reviewers. Discrepancies in reviewer selections were resolved at a meeting between reviewers prior to selected articles being retrieved. Those studies meeting the inclusion criteria were submitted to critical appraisal.

Methods of the review

Critical appraisal

All studies that met the inclusion criteria were assessed for methodological quality using an evaluation tool which was developed on an existing tool used by the Joanna Briggs Institute (JBI) (Appendices 2 and 3). Two reviewers independently critically appraised each study. Discrepancies in critical appraisal were resolved at a meeting between reviewers. Those studies had to meet the criteria to be included in the review.

Data extraction

Two reviewers extracted data independently, using a tool developed by JBI (Appendix 4). A third reviewer was asked to resolve any differences if the initial reviewers could not reach an agreement.

Data analysis

If two or more comparable studies were identified, data were pooled in statistical meta-analysis using Review Manager Software. Studies were considered comparable if they had drawn subjects from comparable populations, using similar interventions and had comparable outcomes measures. Double data entry was undertaken to minimize the risk of data entry errors.

Heterogeneity between combined studies was tested using standard chi-square test and visual inspective of the graphic presentation of the results. Where possible, odds ratio (for categorical outcome data) or weighted mean differences (for continuous) and their 95% confidence intervals were calculated for each study. If statistical pooling of results was not appropriate, the findings were summarized in a narrative form.

Definitions

- Supine means a positioning of the body; lying down with the face up.
- Prone means a positioning with the front of the body turned toward the supporting surface.
- Prone in a postural support nappy position means position that provides pelvic elevation and prevent external rotation of the hips and legs. In addition, flexion of lower limbs is promoted, producing a reduced area of weight-bearing of the inner surface of the thigh and knees.
- Prone in a postural support nappy and postural support roll position means a position that enables infants to lie in a quarter turn from the prone position that enables flexion to both the

upper and lower extremities, and positioning of lower extremities so that both knees and feet are facing the same direction.

- Supine hammock means placed supine in a hammock.
- Head-up body tilt position means infants were tilted head-up by using a foam wedge underneath the mattress and adjusting the incubator to a 30^{o} angle without changing the infant's head position.
- Oxygen saturation (SaO2) is defined as a relative measure of the amount of oxygen that is dissolved or carried in a given medium. It can be measured with a dissolved oxygen probe such as an oxygen sensor or an optode in liquid media, usually water.
- Desaturation is defined as the condition that SaO2 < 88% for at least 10 seconds.
- Apnea is defined as a pause in respiration indicated by a lack of nasal airflow of ≥ 5 seconds
    - Obstructive apneas - if there was no nasal airflow
    - Central apneas – if there was no nasal airflow and an absence of chest and abdominal wall movements
    - Mixed apneas – if there was a combination of Obstructive and Central Apneas
- Apnea index is defined as the number of apneas per hour of sleep.
- Periodic breathing is defined as an episode of three or more respiratory pauses lasting for 3 seconds or longer with intervention periods of normal respiration < 20 seconds.
- Arousal is defined as spontaneous body movements of ≥ 10 seconds.
- Awakening is defined as an arousal ≥ 10 seconds or crying.
- Quite sleep is defined as follows: eyes closed no body movements apart from the occasional startle and regular respiration without rapid eye movements.
- Active sleep is defined as follows: eyes closed, frequent small body movements, and irregular respiration with rapid eye movements.
- Indeterminate sleep is diagnosed if there is discordance between the EEG and the eye movements.

Results

The combined results from all databases resulted in the identification of 138 potentially relevant citations. These citations were independently assessed by two review authors, according to the selection criteria to determine which may be suitable for data extraction. This resulted in 39 studies which were included for data analysis, and 7 studies which were excluded. The review process outlined above resulted in a total of 32 articles that were considered as appropriate for inclusion as evidence. Sixty five point six three percent (65.63%) (21/32) were RCTs and 11 were quasi-experimental. The majority of the study (28) related to physiological outcomes and 6 related to promote sleep.

Meta-analysis was conducted where studies of treatments and outcomes could be pooled. Some studies provided inadequate data for analysis and these studies are presented in narrative summary form as additions.

The outcome measured and reported were not consistent and varied amongst studies.

1. The physiological outcomes affected by different positioning of preterm infants

1.1 Heart rate, Bradycardia, and Blood pressure

1.1.1 Supine versus prone positioning

There were 5 studies [30-34] that examined the influence of supine and prone position on heart rate. The findings were summarized in narrative form because the studies were presented in different terms. Two studies [31,33] indicated that the supine position was associated with a greater heart rate than the prone position. But during apnea in preterm infants, one study [34] found that the heart rate decreased slightly in the supine position, whereas in the prone position no change in heart rate could be observed. In addition, during acute pain of blood collection, prone and supine position did not affect heart rate significantly (p=0.08) [32]. However, a study by Fifer WP, et al [30] demonstrated that there were significant effects of both sleeping position and time after feeding on heart rate. Heart rate was higher and heart period variability was lower in the prone position, and the effects of sleeping position on cardiac functioning were more pronounced during the middle of the intrafeed interval.

Keene DJ, et al [23] demonstrated that no positional difference was noted in the overall incidence of bradycardia (p > 0.05). Furthermore there was no difference in the incidence of mild or clinically significant episodes of bradycardia between prone and supine positions (p >0.05). Both the duration of bradycardia and the lowest heart rate (61.7± 17.5 beats per minute versus 58.0±15.5 beats per minute) were also similar in the two positions.

Sahni, et al. [35] demonstrated that higher heart rates and less time and frequency domain measures of inter-beat interval variability were observed in the prone position as compared to the supine position, during both quiet and active sleep. During quiet sleep, preterm infants have higher heart rates in the prone versus supine position (t = 6.0, p <0.0001). Global RR interval variability was lower in prone position (t = 3.9, p <0.0002). The time domain measure of changes in beat-to-beat variability also demonstrated significant effects of sleeping position, with changes in beat-to-beat variability being lower in prone position (t = 5.3, p <0.0001). During quiet sleep, low-frequency (t = 5.1, p <0.0001), and high frequency (t = 2.5, p <0.02) spectral powers of RR interval were lower in the prone sleeping position. Similarly, significant positional differences were observed for heart rate and time and frequency domain variables during active sleep. In addition, an analysis of consecutive increases and decreases in the instantaneous heart rate revealed a lower incidence of sustained accelerations or decelerations in the prone position. Although consistent findings concerning inter-beat interval variability and sleeping position were obtained from all analytic techniques, the differences derived from analysis of consecutive inter-beat changes were the most robust.

1.1.2 Head elevated body tilt positioning

Schrod & Walter [36] found that after stabilization within several minutes, prolonged head elevated tilt position of 30^{o} did not result in any further significant changes of heart rate and blood pressure in preterm infants. Changing the position of preterm infants from horizontal to head elevated tilt position elicited an increase in lower frequency than higher frequencies activity reflecting a relative increase in sympathetic versus vagal activation.

1.1.3 Head elevated body tilt versus horizontal prone positioning

Jenni, et al [24] found that preterm infants experienced fewer bradycardic and hypoxemic events when nursed in head elevated body tilt position (prone, 15^{o}). There were 47.35 events per 24 hours in the horizontal prone position and 34.00 events per 24 hours in head elevated body tilt position. The mean reduction was 13.35 (95% CI: 5.87-20.80) episodes per 24 hours, or 28%, when the infant was in the tilted position.

1.1.4 Horizontally or vertically in a sling versus laterally in a pram positioning

The study by Stenning, et al [37] showed that the mean heart rate did not differ significantly among preterm and term infants while being carried horizontally or vertically in a slings or lying in a pram. In total, 3 episodes of bradycardia (<100 bpm) were seen in 2 infants (6%). As with desaturation episodes, only preterm infants were affected. The longest period of bradycardia lasted for 22 seconds with a minimum heart rate of 85 bpm.

1.2 Oxygen saturation

There were twelve studies [15,23,24,33,34,36-42] that measured oxygen saturation. The findings were summarized in narrative form because the studies presented in different terms.

1.2.1 Supine versus prone positioning

Five studies [15,33,38,39,42] compared oxygen saturation between supine and prone positions. Two studies [15,42] indicated that the supine position was significantly associated with lower oxygen saturation than the prone position. But three studies [33,38,39] reported that there was no significant difference in oxygen saturation between the two positions. There was also no effect of position, prone and supine positioning, on oxygen saturation of preterm infants with chronic lung disease (p=0.556) [39]. However, a study by Bhat RY et al [38] in the preterm infants with respiratory distress syndrome those requiring supplementary oxygenation (oxygen-dependent) showed that the median oxygen saturation (median 96% vs. 95%, p=0.015) and functional residual capacity (median 25 mL. /kg. vs. 23 mL./kg., p=0.019) was significant higher in the prone compared with the supine posture. The amount of supplementary oxygen given to the oxygen-dependent infants was significantly higher in the supine posture compared with in the prone posture (median 80 mL/min vs. 65 /min; p = 0.02).

Two studies [23,34] evaluated sleeping position-dependent effects on oxygen saturation during apnea in preterm infants. The first study [34] indicated that in both positions, prone and supine position, there was a similar small decrease of oxygen saturation in association with apnea. Mean oxygen saturation was significantly higher in the prone position than in the supine position. The second study [23] found that the overall incidence of oxygen desaturation was greater in the supine position compared with the prone position (median 28.0 vs. 21.3, p <.05). This difference was primarily due to an increased incidence of mild desaturation in the supine position (median 21.0 vs. 15.0, p < .05), because there was no difference in the incidence of clinically significant episodes of desaturation between prone and supine position (median 7.1 vs. 6.3, p > .05). The lowest oxygen saturation in the prone position (62.5 ± 13.8) was not different from that in the supine position (58.8 ± 14.6).

1.2.2 Head elevated body tilt versus supine positioning

Schrod & Walter [36] found that after stabilization within several minutes, prolonged head elevated body tilt position of 30 degree did not result in any significant changes of oxygen saturation when compared with supine position (97% vs. 98%).

1.2.3 Head elevated body tilt versus horizontal prone positioning

Jenni et al [24] demonstrated that there were significantly fewer hypoxemic episodes in head elevated body tilt position compared with the horizontal prone position (12.48 vs. 24.23 episodes/24 hrs, p < .01). Therefore, a mean reduction of 48.5% or 11.74 events (95% CI: 6.06-17.4) per 24 hours was highly significant (p<.01).

1.2.4 Horizontally or vertically in a sling versus laterally in a pram positioning

Stening, et al [37] indicated that a significant decrease of oxygen saturation was observed while infants were carried in a sling with a mean oxygen saturation of 96.1% in a vertical and 96.1% in the horizontal sling positions compared with the mean oxygen saturation in the pram (97.1%). In term infants, this trend was seen only in the horizontal position. As with desaturation episodes, only preterm infants with low postconceptional age were affected.

1.2.5 Car seats versus supine positioning

Merchant 2001 [40] was the only study that evaluated the oxygen saturation of preterm infants in car seats compared with term infants. Both preterm and term infants required blanket rolls at the sides and head for secure positioning in the car seats. In addition, 36% of preterm and 16% of term infants required a blanket roll between the legs for secure positioning ($p = 0.0226$). Preterm and term infants did not differ in oxygen saturation values recorded in the supine position and in the car seat ($p = 0.68$). Mean oxygen saturation values declined significantly in both preterm and term infants from 97% in the supine position to 94% after 60 minutes in the car seat ($p < 0.0001$). Oxygen saturation values recorded in the car seat were significantly lower than those recorded in the supine position by 15 minutes in the car seat ($p < 0.05$). Seven infants (3 preterm and 4 term) had oxygen saturation values of <90% for longer than 20 minutes in the car seats. Six preterm infants (95% CI: 4.5%-24.3%) and no term infants had significant apnea or bradycardia in their car seats ($p = 0.0267$). There was no difference in the incidence of apnea or bradycardia between infants who were born at 35 (3 of 25) and 36 (3 of 25) weeks gestation.

1.3 Respiration and apnea

1.3.1 Supine versus prone positioning

Pichler G, et al [34] demonstrated that the incidence of apnea < 10 seconds of preterm infants was not significantly different between the prone and supine position ($p>0.05$). However, the mean apnea duration was significantly shorter during prone sleep position compared to supine sleep position (3.8 seconds vs. 5.6 seconds, $p<0.01$), which was mainly caused by significantly less periodic breathing and fewer incidences of apnea lasting longer than 10 seconds while in the prone position. In addition, Goto et al [31] found that there was no pathologic apnea, i.e., lasting > 15 seconds or accompanied by bradycardia and/or desaturation in either prone or supine position. In addition, there were no significant differences in periodic breathing between both prone and supine position with respect to both the number and percentages of periodic breathing as well as the longest duration of periodic breathing.

Keene DJ, et al [23] conducted a study to investigate the effects of positioning on the cardiorespiratory stability of preterm infants with symptomatic apnea or bradycardia. The overall incidence of apnea (≥ 10 seconds) was not different between the prone and supine position ($p > 0.05$), however, the incidence of mild episodes of apnea (<15 seconds) was greater in the prone position ($p < 0.05$). No difference in the incidents of clinically significant episodes of apnea (≥15 seconds) was found between the two positions ($p >0.05$). Duration of longest apnea was similar between prone and supine positions (26.8±14.4 seconds versus 31.4±16.1 seconds).

Bhat, et al [43] indicated that in the prone position, the preterm infants with bronchopulmonary dysplasia (BPD) had more central apneas (median: 5.6 vs. 2.2), but fewer obstructive apneas (1.9 vs. 0.7) when compared with supine position. Comparison of the differences seen between prone and supine position in the BPD and non-BPD infants did not reveal any statistically significant differences in the magnitude of the differences in the two positions. Therefore, there was little evidence of an interaction between the effect of sleep position and BPD status.

1.3.2 Car seats positioning

The study of Merchant JR, et al [40] demonstrated that twelve percent of preterm infants (95% confidence interval: 4.5%-24.3%) but no term infants had apneas or bradycardia events in their car seats.

1.3.3 Supine versus prone and side positioning

Kulgelman A, et al [44] found that there were more short apneas in the supine position with and without inclination and in side position as compared to the prone position ($p < 0.001$, $p<0.001$, $p <0.02$, respectively). There were also more apneas in the supine position as compared to the side position ($p < 0.008$). Apneas occurred less frequently in the prone position as compared to the supine and side positions in maturing infants. End-tidal carbon dioxide was higher in the prone position than in supine or side positions in infants between 33 and 35 week gestation ($p<0.001$).

1.4 Lung function

Levy, et al(45) was the only study that measured work of breathing in healthy premature infants. The results indicated that inspiratory, elastic, and resistive work of breathing were unaffected by prone versus supine positioning (p= 0.46, 0.36, and 0.87, respectively). Similarly, tidal volume, minute ventilation, and lung compliance did not differ between positions.

Leipala, et al [46] found that the median tidal volume was higher ($p <0.05$) in the prone position (7.6 vs. 6.5). No significant difference in inspiratory and expiratory times or minute volume was found between the prone and supine position. An imposed airway obstruction ($p < 0.05$) and maximum inspiratory pressure ($p < 0.05$) were lower in the prone compared to the supine position. In oxygen-dependent infants only, minute volume was higher in the prone position ($p< 0.05$).

Bhat, et al [38] indicated that in the oxygen-dependent preterm infants, the functional residual capacity (25 mL. /kg. vs. 23 mL./kg., $p < .05$) was significantly higher in the prone compared with supine posture. No significant difference related to posture was seen in the nonoxygen-dependent infants. There were no significant differences related to posture in the median compliance of the respiratory system or resistance of the respiratory system in either group. Superior oxygenation in the prone posture in oxygen-dependent premature infants before discharge could be explained by higher lung volumes.

Dimitriou G, et al(15) found that respiratory muscle strength assessed by measurement of maximum inspiratory pressure(PIMAX) was higher in the supine and supine with head up tilt of 45 degrees postures than in the prone posture ($p<.001$). Head position did not influence the effect of posture on PIMAX.

1.5 Airway

Tonkin, et al [41] demonstrated that the infants' upper airspace was wider when the infants quietly slept in the car seat with the insert in place compared with without the insert (5.2 ± 10.3 vs. 3.6 ± 1.4 mm; $p < 0.001$). With the insert in place, all infants were able to maintain their heads in neutral position. In the majority of infants, the head tended to slump forward, with the chin pressed on the chest. Cephalometric analysis of inspiratory radiographs showed that the distance between the space from nasion to the incisor in the lower jaw was reduced from 15.6±3.5 mm to 12.5±3.3 mm when the insert was removed ($p<.001$). Furthermore, the angle between the upper incisor to nasion to the lower incisor was increased from 9.1±2.4 to 12.3±3.5 ($p<.001$). These measurements indicated that on average, the jaw was being pushed backward and upward during quiet sleep in the car seat without the insert. This insert was associated with a significant reduction in the frequency of episodes of oxygen desaturation to < 85% (1.5 ± 2.1 vs. 3.5 ± 3.5 episodes/infant; p < 0.05).

1.6 Pain

There were two studies that examined the influence of position in preterm infants during acute pain of blood collection. Grunau RE, et al [32] demonstrated that the infants in supine and prone positions shifts statistically significant from more sleep or drowsy states during baseline to more aroused states following heel lance (Z = -4.76, p = 0.0001). However, there were no statistically significant main effects of position between the prone and supine groups in pain response during the invasive procedure of heel lance for blood sampling (p=0.35). But Comeoo P, et al [47] reported that the preterm infants positioned in a side-lying position and fenced with the roll blanket had a statistically significant lower mean of pain scores than non-positioned preterm infants in response to the heel pick at 6, 7, 8, 9 and 10 minutes (p < .05).

1.7 Electrocortical activity

Sahni, et al [48] was the only study to evaluate the effects of prone and supine sleeping positions on electrocortical activity during active and quite sleep in preterm infants. In the prone sleeping position, preterm infants showed significantly lower total EEG power(p<0.0003), decreased absolute powers in frequency bands 0.01-1.0 Hz (p<0.0003), 4-8 Hz(p<0.0005), 8-12 Hz(p<0.005), 12-24 Hz(p<0.001), increased relative powers in 1-4 Hz(p<0.0003), and a decrease in spectral edge frequency (p<0.0001) when compared with supine position during active sleep. Similar trends were observed during quite sleep, although they did not reach statistical significance.

1.8 Cerebral homodynamic

Pichler G, et al [34] was the only study that evaluated sleeping position-dependent effects on cerebral homodynamic during apnea in preterm infants. The mean decrease of hemoglobin oxygenation index (-1.57±1.82 vs. -1.18±1.77) and of cerebral blood volume (-0.120±0.137 vs. -0.080±0.095) in the supine position was significantly pronounced compared to the prone position. There was no correlation between postnatal and postconceptional age and the degree of cerebral blood volume and cerebral hemoglobin oxygenation neither in prone nor in supine sleeping position (r2 ≤ 0.01).

One study measured cerebral hemoglobin content as an outcome [36]. After stabilization within several minutes, prolonged head elevated body position of 30^{o} did not result in any further significant changes of cerebral hemoglobin content. Only preterm infants ≤ 1500 gm. showed a significant decrease of regional cerebral oxygen saturation of about 2-5% from day 2 to 8. As this mild decrease in regional cerebral oxygen saturation is clinically significant, there was no severe side effect of prolonged tilting in stable preterm infants even during the first days of life.

1.9 Feeding performance

Daley [49] indicated that there was a relationship between position and feeding performance present in term of feeding duration and signs of distress. The infants finished their feedings sooner and showed fewer distress signs when fed in the ARM position (infant held in the arms of the nurse) compared to the LAP (infant held on the nurse's lap with the head supported by one hand). The relationship did not appear to change with increased postconceptual age.

1.10 Gastro-esophageal reflux and gastric residual

There were three studies [11,50,51] that reported the effects of body position on clinically significant gastroesophageal reflux in preterm infants. Two studies [11,51] indicated that preterm infants in the left lateral position had significantly reduced the severity of gastroesophageal reflux (GER) when compared with infants in the right lateral position. The study by Omari, T. I., et al.(51) demonstrated that preterm infants in the right lateral position had significantly ($p < .01$) more GER, a higher proportion of liquid GER ($p < .05$), and faster gastric emptying ($p < .005$) when compared with infants in the left lateral position. Similarly, transient lower esophageal sphincter relaxation (TLESR) was more common in the infants position on their right sides and triggered more liquid GER in this position. In a similar study, Ewer, et al [11] found that prone and left lateral position significantly reduced the severity of GER by reducing the number of episodes and the duration of the longest episodes. The median reflux index (RI) (mean% (SEM)) was significantly less in prone (6.3 (1.7)) and left lateral positions (11.0 (2.2)), when compared with the right lateral position (29.4 (3.2)); $p <0.001$. The mean (SEM) longest episodes (mins) of GOR were reduced by prone and left lateral positions (8.6 (2.2)) and (10.0 (2.4)), respectively compared with the right lateral position (26.0 (3.9)); $p <0.001$. The mean (SE) number of episodes was reduced by prone (15.4 (2.8)) and left lateral positions (24.6 (3.5)) when compared with right (41.6 (4.6)) ($p <0.001$). In addition, Cohen, et al(50) found that at 1 hour after initiation of feeding, right lateral decubitus led to less significant gastric residuals than the left lateral decubitus and the prone position led to less residual than left lateral decubitus. The amount of gastric residuals 1 hour after meal appears to be in the following decreasing order: left lateral , supine, prone, and right lateral.

1.11 Neuromuscular outcomes

Keller, et al [52] demonstrated that the supine hammock position was associated with a significantly higher neuromuscular maturity score than the prone position, ($p < 0.003$) and a more relaxed condition, as expressed by a significantly lower heart rate ($p < 0.05$) and respiratory rate ($p < 0.01$).

Monterosso, et al [53] revealed that very preterm infants nursed with a postural support roll and a postural support nappy demonstrated improved hip posture to 5 weeks post-intervention and term postmenstrual age compared with infants nursed with either a postural support roll only, or a postural support nappy only. Infants nursed with a postural support roll either with or without a postural support nappy demonstrated improved shoulder posture to term equivalent age.

Vaivre-Douret, et al, 2004 [54] was the only study to compare the treatment group reposition in back, and side with the control group positioned in a prone position. The results in sensory-motor skills examinations showed significant abnormalities in the control group including 1) dominance of the extensor muscle due to muscle shortening, 2) hyper abduction and flexion of the arms, and 3) global neuromuscular rigidity. Psychomotor and neurological exams showed delayed developmental muscular acquisitions for preterm infants in the prone position.

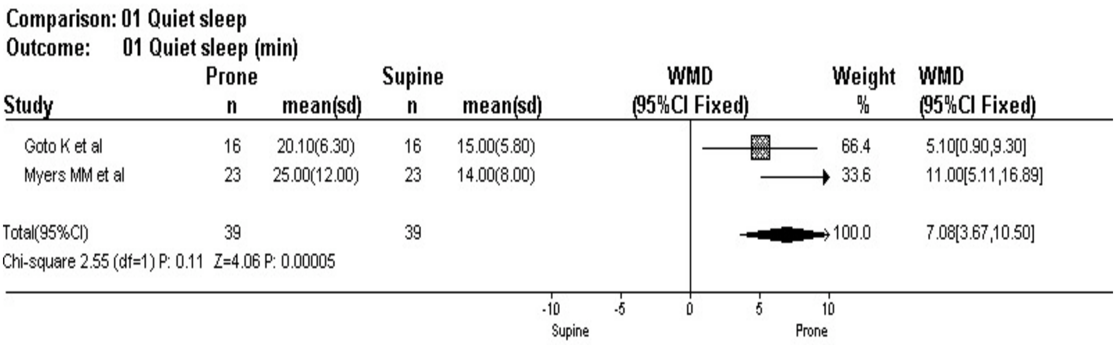
Constantin, et al, 1999 [55] was the only study that demonstrated head turning into the face-down position could put the infants at risk of asphyxiation. The preterm infants turned their heads much less frequently than the term infants: 0 (0-0.4) versus 6.2 (4.3-7.9), $p < 0.001$, full head turns per hour of sleep, and 0 (0-0.6) versus 1.7 (0.7-2), $p < 0.004$, half head turns per hour of sleep. About half of preterm infants did not turn their heads during sleep in the prone position, but all preterm infants turned their heads at least once during wakefulness. In addition, the premature infants rarely adopted the face-straight-down position when sleeping prone, and the face-near-straight-down episodes were less frequent in the preterm infants compared with the term infants. The findings of this study showed that prematurely born infants rarely assume face-down positions when sleeping prone at approximately 40 weeks' postconceptional age.

Dusing S, et al [56] was the only study that compared trunk position in supine of infants born preterm and at term. The results showed that infants born at term, but not preterm, spent significantly more than two-thirds of the time with their trunk in either a flexed or neutral position ($p < .05$). No significant difference between infants born preterm and at term in total duration of flexion or extension or in flexion event duration was observed.

2. Sleep

Four studies [31,32,42,43] demonstrated that preterm infants slept significantly longer in the prone position than in the supine position. Bhat, et al(43) and Goto, et al [31] indicated that in the prone position, preterm infants had longer sleep time than supine position. This result was consistent with Grunau RE, et al [32] who reported that more infants in the prone position were in deep sleep (44%) than in the supine position (6%). In addition, Woragidpoonpol [42] found that the duration of deep sleep was higher in the prone than the supine position after feeding. When changed from prone to supine, the amount of sleep decrease, but when changed from supine to prone the amount of deep sleep increased further.

There were three studies [8,31,43] that measured sleep states, which were classified as either awake, active sleep, intermediate sleep, or quite sleep. Myer, et al [8] found that prone sleeping position is associated with a 79% increase in quiet sleep and a 71% decrease in time awake. However, this effect was significant only within the first hour and again near the end of the interfeed interval. The study by Goto et al in 1999 [31] and Bhat RY, et al [43] demonstrated the number of awakenings was significantly higher in supine compared with the prone position. There was no significant difference in the percentage of active sleep and intermediate sleep state between the supine and the prone position. The duration of quite sleep was significantly longer in the prone position[8,31,43]. The meta-analysis that included two studies[8,31] demonstrated that the infant spent quiet sleep in the prone position more than in the supine position (WMD 7.08, 95% CI 3.67-10.50).



Three studies[8,31,42] compared the awakening and arousal in the prone and supine position in preterm. The number of awakenings (i.e., arousal ≥ 60 seconds) was significantly higher in the supine compared with the prone position ($p < .05$). But the number of arousals per 100 minutes of active sleep, indeterminate sleep and quite sleep in the prone position were not significantly different from these values in the supine position(31). In addition, two studies(8, 42) found that crying significantly increased when infants were placed in supine position.

Bhat, et al [43] showed that in the supine position, infants with bronchopulmonary dysplasia had more awakening (8.5 vs. 3.5) and arousals per hours (13.6 vs. 8.5), and the infants spent a lower proportion of sleep time in quiet sleep (15.1% vs. 26.2%). In addition, the infants had less central apnea when supine (median: 1.2 vs. 2.3), but more obstructive apneas (1.9 vs. 0.7).

The study by Elder, et al [39] reported the effects of prone and supine positioning on preterm infants with chronic lung disease (CLD). There was a significant interaction of gestational age and sleep position with less mature infants spending less time in quite sleep in supine position (p=0.006). This effect was irrespective of CLD statue. These less mature infants also had a higher apnea hyperpnoea index (p = 0.0333). There was no differences due to position (p=0.092) or CLD status (p=0.267) and no additional effects of gestational age on arousal index (p=0.780).

Conclusion

One of the essential components of the preterm infants care is correct positioning as positioning can affect an infants' body system positively or negatively. By different positioning of preterm infants, there are a variety of physiological outcomes affected including respiratory function, homodynamic, neuromotor development, gastric function and sleep characteristics. Therefore, the goals of adaptive position are: improving physiologic status, enhancing motor control, reducing stress, and weight gain. The optimal posture for promoting sleep among preterm infants is also discussed in this study. In addition, the advantage and disadvantage of supine, prone, side lying and head elevated body tilt position including positioning in the car seats are summarized. Although a number of gaps are apparent in the research findings to date, some useful and consistent results are evident.

This analysis of available data provides evidence that prone positioning in preterm infants is beneficial in improving ventilation and lung mechanics. Studies have documented an increase in arterial oxygen tension and lower respiratory rate in the prone position in preterm infants compared with the supine position. The better oxygenation could be explained by the improvement of ventilation perfusion, decrease of asynchronous chest wall movement, higher lung volume, and increase in the functional residual capacity. In addition, superior oxygenation in the prone posture in oxygen-dependent premature infants before discharge could be explained by higher lung volumes. Improvement in oxygen saturation and lung volume in the prone position also has been documented in preterm infants with chronic lung disease, respiratory distress syndrome, and oxygen-dependent as well.

It has been shown that the incidence of apnea was not different between prone and supine position[23,31,34)]. However, the apnea duration was significantly shorter during prone positioning compared to supine positioning, which was caused by less periodic breathing and fewer incidence of apnea lasting longer than 10 seconds. In addition, apnea occurred less frequently in the prone position as compared to the supine and side positions in maturing infants. The higher rates of apnea in the supine position may be due to neck flexion resulting in upper airway obstruction. There was no difference between prone and supine positioning with respect to clinically significant apnea, bradycardia, or desaturation in preterm infants with symptomatic apnea or bradycardia. The preterm infants with bronchopulmonary dysplasia (BPD) in the prone position had more central apneas, but fewer obstructive apneas when compared with supine position. Nevertheless, with regard to cerebral blood volume and oxygenation in associated with apnea no negative effects of prone sleeping position could be observed in preterm infants.

There was little evidence of an interaction between the effect of sleep position and bronchopulmonary dysplasia status. Prone position compared with supine position in the preterm infants with bronchopulmonary dysplasia had more central apneas but fewer obstructive apneas. Prone positioning may be of mechanical advantage by increasing thoracoabdominal synchrony and rib cage motion for the preterm infant who, as a result of respiratory musculoskeletal immaturity, is predisposed to diaphragmatic fatigue and respiratory failure. This decreased asynchronous chest wall movement and higher lung volume in the prone position may enhance the ventilation/ perfusion ratio, resulting in improved oxygenation. Improvement in arterial oxygen tension and tidal volume in the prone position has been documented in infants with chronic lung disease as well. The influence of posture on lung volume in prematurely born infants has been debated. It has been suggested that lung volume might be lower in the prone position because of the compressing effect of the infant's bodyweight on the compliant chest wall. In contrast, others have suggested that lung volume would be higher in the prone posture, as there would be reduced cephalic stress by the abdominal organs allowing greater diaphragmatic excursion. The respiratory efforts of the premature infants may be more effective in the prone position.

The influence of supine and prone position on heart rate summarized in narrative indicated that the supine position was associated with a greater heart rate than the prone position. Heart period variability is lower in the prone position. However, the effects of sleeping position on cardiac functioning are more pronounced during the middle of the intrafeed interval which may be amplified because of their lack of experience in the prone position. Interactions between the autonomic effects related to time after feeding and of sleeping in the unfamiliar prone position might contribute to the greater risk of SIDS.

The prone position promotes longer and deeper sleep than in the supine position. The longer sleep bouts and fewer awakenings associated with prone position would support higher vulnerability for preterm infants to life-threatening events during prone sleep. The prone position offers the most contact with the supporting surface and is most effective for reducing purposeless motor activity, including tremors, twitches and startle. Therefore, prone positioning not only enhances oxygenation but may ultimately lead to reduced oxygen consumption due to the more restful behavioural state the prone induces.

There has been concern about half of preterm infants who did not turn their heads during sleep in the prone position, but all preterm infants turned their heads at least once during wakefulness. In addition, the premature infants rarely adopted the face-straight-down position when sleeping prone at approximately 40 weeks' postconceptional age. Therefore, it is possible that preterm infants have an increase in face-straight-down position episodes after NICU discharge and are at increased risk for SIDS as head turning and face–down episodes increase in frequency with maturity.

Placement in prone position is not a sufficient environment comfort intervention for painful invasive procedures such as heel lance for blood sampling in the NICU. But preterm infants positioned in a side-lying position and fenced with the roll blanket had statistically significant lower mean of pain scores than non-positioned preterm infants in response to the heel pick. Therefore, preterm infants require other environmental supports to promote coping with this stressful event.

Infant car safety seats play an important role in protecting young infants from injury and death in motor vehicle accidents. However, preterm infants are susceptible to oxygen desaturation and bradycardia and had disturbed sleep with frequent arousals in car seats. Flexion of the head on the body is a significant contributor to these episodes and that the mechanism is posterocephalic displacement of the mandible, leading to narrowing of the upper airway. Therefore, all preterm infants should be observed for respiratory instability and securely fitted in their car seats.

The use of carrying slings is not associated with an increased risk of clinically relevant cardio-respiratory changes in term and preterm infants. However, desaturation episodes were observed in preterm infants with low postconceptional age. Therefore, the slings should be used with caution for carrying preterm infants before they reach term postconceptional age.

The prone position promotes a shift in EEG activity towards slower frequencies. These changes in electrocortical activity may be related to mechanisms associated with decreased arousal in the prone position and, in turn, increased risk of SIDS. Cerebral blood volume in the supine position was lower than the prone position. The head elevated body position of 30^{o} can decrease intracranial pressure because of hydrostatic pressure changes and improvement of venous return. Prolonged tilting has no undesirable effects in preterm infants with stable circulation including very immature infants of 25 weeks gestation. Thus, the orthostatic stress associated with kangaroo care, involves head-up body position up to 20-45^{o}, is insignificant in clinical stable preterm infants if abrupt tilting is achieved by slow position changes.

Because of the effect of gravity along with neuromuscular characteristics, preterm infants are risk for positioning disorders which affect later development outcomes. Preterm infants placed in prone position had a higher incidence of postural abnormalities, orthopaedic abnormalities of the feet, and delayed developmental than when place on the back or side. It was found that a properly supported position is a posture that ensures functional support of all parts of the body as well as ensuring physical safety. Preterm infants should be exposed to a variety of positions to enrich their sensorimotor experiences and prevent the development of fixed postural patterns. Regular changes in posture, while retaining correct functional positions, allowed maintenance of normal neuromuscular and osteo-articular function and permitted the development of spontaneous and functional motor activity in low-risk preterm infants. It is possible to ameliorate postural abnormalities associate with flattened posture in the short term by using support materials. One study indicated that both a postural support roll and a postural support nappy be used when caring for very preterm infants to improve hip posture and shoulder posture up to term equivalent age. In addition, hammock positioning provided infants born preterm with very low birthweight with a new positional-motional experience. Maintaining preterm infants with very low birth weight in supine position in a hammock was associated with a significantly higher neuromuscular maturity score than the prone position and a more relaxed condition. This technique can help infants born preterm better overcome the effects of lack of the containment and of extra uterine forces and other sensory influences on the immature developing brain.

Feeding premature infants in the ARM position facilitate infants to complete their feedings sooner, thus helping infants to conserve calories for weight gain. The ARM position may help to enhance a smoother transition to full nipple feedings by promoting a positive feeding experience that involves less distress and providing a more nurturing position that supports the infant's developmental organization.

Although side lying is difficult to organize a stable posture, it is the best alternative to prone positioning in the NICU. The studies indicated that prone and left lateral position significantly reduce the severity of gastroesophageal reflux (GER) by reducing the number of episodes and the duration of the longest episodes. Right-side positioning is associated with more transient lower esophageal sphincter relaxation and GER but faster gastric emptying. Therefore, the left lateral position can be adopted in addition to prone for refluxing premature infants and while they are in hospital nursing position can be alternated between the two.

Summary

The findings of this systematic review are summarized as follows:

Findings are categorised using JBI levels of evidence (Appendix 5).

- The prone position in preterm infants improve arterial oxygen saturation, improved lung and chest wall synchrony of respiratory improvements, decreased incidence of apnea in infants with a clinical history of apnea, promote sleep, and decreased gastroesophageal reflux However, prone position increased postural abnormalities, orthopaedic abnormalities of the feet, and delayed developmental muscular. The change in body position from horizontal to head-up tilt in very immature and unstable infants may affect cerebral homodynamic. (Level II).

- The management of position per se may not be sufficient for assisting preterm neonates to cope with the painful procedures (Level III.I).
- Combined use of a postural support roll and a postural nappy improved hip posture of very preterm infants up to term postconceptual age. In addition, use of a postural support roll improves shoulder posture up to term equivalent age (Level I).
- The preterm infants should not be left unattended in a car safety seats because they may experience episodes of oxygen desaturation, apnea, or bradycardia. In addition, the use of carrying slings should be used with caution for carrying preterm infants before they reach term postconceptional age (Level II).

Recommendations

These results suggest that it may be prudent to reevaluate our policy for symptomatic preterm infants, especially those approaching discharge.

The healthy preterm infants should be positioned in supine during sleep while in the neonatal intensive care unit because more awakenings and lower threshold for arousal may provide some benefit for the infant responding to a life-threatening event. But the symptomatic preterm infants with signs of respiratory distress, very low birth weight and severe gastroesophageal reflux may benefit from the prone position during sleep. However, due to the association of the prone position with SIDS, it is recommended that all preterm infants placed in the prone position should have continuous cardio-respiratory and oxygen saturation monitoring. In addition, the lower arousal rate in the prone position emphasizes the importance of regular change in posture. However, the change in body position from horizontal to head-up tilt should be induced smoothly in very immature and unstable infants, because this intervention may affect cerebral perfusion.

Preterm infants should be placed in a properly supported position to ensure functional support of all parts of the body as well as ensuring physical safety. In supine and prone position, knees must be held forward and lower than the pelvis. Both a postural support roll and a postural support nappy are used to position very preterm infants in a quarter turn from prone position as soon as their condition permits placement in the prone position. The left lateral position can be adopted in addition to prone for reducing gastroesophageal reflux in premature infants and while they are in hospital nursing position can be alternated between the two.

Prematurely born infants should be carefully assessed prior to discharge to ensure a policy of advising that supine sleeping following discharge does not compromise some infants, and that in those identified as compromised, appropriate interventions could be instituted to ensure safe supine sleeping. The currently recommended supine sleeping position for discharge of the maturing infant should be applied in the NICU at least a few days prior to discharge while the infant is under monitoring and observation. This trial will also facilitate the infant's supervised adaptation to this position. Preparing families for discharge is an ongoing component and information about reducing the risk of SIDS should be carefully given. Parents of preterm infants should be advised about sleeping positions after discharge from hospital because SIDS may become more frequent after NICU discharge as head turning and face-down episodes increase in frequent with maturation. Along with supine sleep position, it is essential to provide supervised prone playtime as well as other position changes during the day to avoid gross motor milestones delays. Furthermore, if home oxygen therapy is being considered, parents need to be warned that the level of supplementary oxygen required maintaining an adequate oxygen saturation level will vary according to the infant's posture.

Preterm infants should not remain in car seats for extended periods of time when they are not traveling. Travel should be minimized during the first months of life. However, the frequency of episodes of desaturation in a standard newborn car seat can be substantially reduced by placement of a simple foam insert that allows the infant to maintain the head in a neutral position on the trunk during sleep. Therefore, it is reasonable practice to assist parents at the time of hospital discharge with the correct use of their car safety seat.

Large multicentre, randomized controlled trials are required to better assess the effects of positioning very preterm infants in the prone position. Further research should be conducted to examine:

1. The physiological processes linking prone sleep position and SIDS.
2. Longitudinal physiologic studies of the definite sleep position of preterm infants
3. Positional effect on the physiologic measures in preterm infants at older ages.
4. The effects of preterm infant positioning and discharge teaching on the incidence of SIDS in the first year of life.

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Appendix 1

Inclusion criteria

A systematic review of positioning of preterm infants for optimal physiological development.

Author……………………………………Year……………..Record No……

Types of participants

Infants less than 37 weeks gestational age admitted to newborn nurseries. ❒

Infants less than 37 weeks gestational age admitted to neonatal intensive care units. ❒

Infants less than 37 weeks gestational age admitted to medical clinics. ❒

Types of interventions

Prone position ❒

Supine position ❒

Side-lying position ❒

Head elevated tilt position ❒

Other (specify)………………………. ❒

Types of outcome measures

Physiologic effects including respiratory function (oxygen saturation, tidal volume, functional residual capacity, respiratory rate), Hemodynamic (heart rate, blood pressure), neuromotor Development (motor activity), gastric function (gastroesophageal reflux, gastric residual) ❒

Sleep states classified as awake, active sleep, quiet sleep or indeterminate sleep. ❒

Types of studies

RCTs ❒

Quasi-experimental design ❒

Appendix 2

Critical appraisal form for Quasi-experimental design

Title of article……………………………………….Record No………..……..

Author……………………...……………………. ..Year…………………….

1.Were the criteria for inclusion in the sample clearly defined?

Yes ❒ No ❒ N/A ❒

2.Other than research intervention, were participants in each group treated the same?

Yes ❒ No ❒ N/A ❒

3.Were the outcomes measured clearly defined for all participants? (see also # 8., p27)

Yes ❒ No ❒ N/A ❒

4.Was an appropriate statistical analysis used?

Yes ❒ No ❒ N/A ❒

5.Was there adequate follow up of participants? (if less than 80% will be No)

Yes ❒ No ❒ N/A ❒

6.Was the study based on a random sample?

Yes ❒ No ❒ N/A ❒

Question 1 to 5 must be answered "yes" for study to be include in the systematic review

Summary Total Yes…………….. No……… N/A…………………

Included…………………………Rejected………………………………

Comments……………………………...……………………………………

……………………………………………………………………………….

……………………………………………………………………………….

Reviewer's name……………………………………………………………

Appendix 3

Critical appraisal form for RCTs

Title of article…………………………………… Record No……………………

Author………………………. ……………….….Year……………………..

1. Was the assignment to treatment groups random?

Yes ❒ No ❒ N/A ❒

2. Were participants blinded to treatment allocation?

Yes ❒ No ❒ N/A ❒

3. Was allocation to treatment groups concealed from the allocator?

Yes ❒ No ❒ N/A ❒

4. Were the outcomes of people who withdrew described and included in the analysis?

Yes ❒ No ❒ N/A ❒

5. Were those assessing outcomes blind to the treatment allocation?

Yes ❒ No ❒ N/A ❒

6. Were the control and treatment groups comparable at entry?

Yes ❒ No ❒ N/A ❒

7.Were groups treated identically other than for named intervention?

Yes ❒ No ❒ N/A ❒

8.Were outcomes measured in the same way for all groups?

Yes ❒ No ❒ N/A ❒

9.Were outcomes measured in a reliable way?

Yes ❒ No ❒ N/A ❒

10.Was appropriate statistical analysis used?

Yes ❒ No ❒ N/A ❒

Summary Total yes…………….. No………… N/A………………………..

Included………………Rejected…………………………………………….

Comments…………………………………………………………………

……………………………………………………………………………

Reviewer's name…………………………………………………………

Appendix 4

Data extraction form

Title of article……………………………………….Record number……………

Author……………… ……………………………………………………………

Journal…………………………………………..Year…………Volume…..…

Method of study…………………………………………………………………

Setting……………………………………………………………………………

Participants………………………………………………………………………

Number of participants

Group A…………………………………………………………………………

Group B…………………………………………………………………………

Description of interventions

Intervention A……………………………………………………………………

……………………………………………………………………………………

Intervention B……………………………………………………………………

……………………………………………………………………………………

Outcome measures

Outcome description	Scale/measure

Results

Dichotomous data

Outcome	Treatment group Number/Total number	Control group Number/Total number

Continuous Data

Outcome	Treatment group Number/Total number	Control group Number/Total number

Author conclusions

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……………………………………………………………………………………

Comments……………………………………………………………………

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Reviewer's name………………………………………………………………

Appendix 5

JBI Levels of Evidence

Studies were categorized according to the strength of evidence based on the following classification system:

Level I	Evidence obtained from a systematic review of all relevant RCTs
Level II	Evidence obtained from at least one properly designed RCT
Level III-1	Evidence obtained from well designed pseudo-randomised controlled trials (alternate allocation or some other method)
Level III-2	Evidence obtained from comparative studies with concurrent controls and allocation not randomised (cohort studies), case-control studies or interrupted time series with a control group
Level III-3	Evidence obtained from comparative studies with historical control, two or more single-arm studies or interrupted time series without control group
Level IV	Evidence obtained from case series, either post-test or pretest and post-test

Appendix 6

Reference excluded from analysis

The following are references that were excluded from the analysis:

Study	**Comparison/Report**	**Reason for exlusion**
Frerichs I, Schiffmann H, Ochler R, Dudykevych T, Hahn G, Hinz J, et al (57)	Lung ventilation Supine vs Prone vs Right lateral	Include fullterm infants
Ariagno RL, Mirmiran M, Adams MM, Saporito AG, et al (58)	Sleep, heart rate variability and QT interval Suine vs Prone	Study at home
Ariagno RL, van Liempt S, Mirmiran M (59)	Spontaneous arousals Supine vs Prone	Study at home
Ratliff-Schaub K, Hunt C, David C, Golub H, Smok-Pearsall S, Palmer P et al (60)	Motor development Supine vs Prone	Study at home
Page M, Jeffery HE (61)	Airway protection Supine	Include fullterm infants
Mizuno K, Inoue M, Takeuchi T (62)	Sucking behaviour Supine vs Prone	Include fullterm infants
Fallang B, Saugstad OD, Hadders-Algra M (63)	Postural adjustment Supine	Study at post-term

Appendix 7

Table of included studies

Author	Method	Setting	Samples	Intervention	Findings
Myers MM, Fifer WP, Schaeffer L, Sahni R, Ohira-Kist K, Stark RI et al. 1998(8)	RCT	Medical center	23 preterm infants, GA: range 28-33 weeks Postconceptional age at study: range 31-36 weeks	Supine vs. prone;	Prone sleeping is associated with a 79% increase in quiet sleep and a 71% decrease in time awake. While the decreases in time awake are seen throughout the interfeed interval, increases in quiet sleep in the prone position are found only within the first hour and near the end of the interfeed interval. The two non-sleep states (awake and cry) were both significantly increased when babies were placed in supine position. In contrast, the incidence of quiet sleep was almost doubled in the prone position.
Ewer AK, James ME, Tobin JM 1999(11)	RCT	NICU	18 preterm infants Mean GA were 28 weeks (range 25-32 weeks) Postnatal age at study were 27 days (range11-73 days)	Prone vs. left lateral vs. right lateral.	The median reflux index (RI) (mean% (SEM)) was significantly less in prone (6.3 (1.7)) and left lateral positions (11.0 (2.2)), when compared with the right lateral position (29.4 (3.2)); p <0.001. The mean (SEM) longest episodes (mins) of GOR were reduced by prone and left positions (8.6 (2.2) and 10.0 (2.4), respectively) compared with the right position (26.0 (3.9)); p <0.001. The mean (SE) number of episodes was reduced by prone (15.4 (2.8)) and left positions (24.6 (3.5)) when compared with right (41.6 (4.6)) (p <0.001).
Dimetriou G, Greenough A, Pink L, McGhee A, Hickey A, Rafferty GF, 2002(15)	Quasi-experimental	Hospital	10 preterm infants Mean GA: 33 weeks (range 30- 36weeks Postconceptional age at study: 36 weeks (range 35-39 weeks)	Supine vs. supine with head up tilt of 45 degrees vs. prone	Compared with in the prone posture, the maximum inspiratory pressure (PIMAX) was higher in the supine posture both with the head in the midline (p<0.01) and with the head to the right (p<0.01), and oxygen saturation was lower in the supine posture both with the head in the midline (p<0.01) and with the head to the right (p<0.05). In the supine position, there was no significant difference in PIMAX measured with the infant's head in the midline or to the right.
Keene DJ, Wimmer JE, Mathew OP. 2000(23)	RCT,	Hospital	22 preterm infants with symptomatic apnea or bradycardia, Mean GA: 26.9 weeks (SD.= 1.8 weeks) Postconceptional age at study: 31.9 weeks (SD.=3.0 weeks)	Supine vs. prone;	No significant differences (p > 0.05) in the incidence of clinically significant apnea, bradycardia, or desaturation between supine and prone positions were seen in these preterm infants.

Jenni OG, Siebenthal KV, Wolf M, Keel M, Duc G, Bucher HU 1997(24)	RCT	Hospital	12 preterm infants Mean GA: <31 weeks (range 26-31 weeks) Postnatal age at study were 17.8 days(range6-38 days)	Horizontal position vs. head elevated tilt position (HETP)	There were significantly fewer bradycardic and/or hypoxemic episodes (28.2%) in head elevated tilt position compared with the horizontal position (mean difference, 3.35 episodes/24 hours; 95% CI 5.9-20.8). The decrease was largest for isolated hypoxemic episodes 48.5%; mean difference, 11.74 episodes/24 hours; 95% CI 6.1-17.4). Isolated bradycardic episodes (mean difference, 2.17 episodes/24 hours; 95% CI: -0.78-5.31) and mixed events were not decreased significantly in head elevated tilt position.
Fifer WP, Myers MM, Sahni R, Ohira-Kist K, Kashyap S, Stark RI et al. 2005(30)	RCT	NICU	20 preterm infants Mean GA: 28-33 weeks) Postconceptional age at study: 31-36 weeks	Supine vs. prone	There were significant effects of both sleeping position and time after feeding. Heart rate is higher and heart period variability is lower in the prone position, and the effect of sleeping position on cardiac functioning are more pronounced during the middle of the intrafeed interval.
Goto K, Mirmiran M, Adams MM, Longford RV, Baldwin RB, Boeddiker MA et al. 1999(31)	RCT	Nursery	16 preterm infants, Mean GA: 32.2 weeks (SD.= 3.0 weeks) Postconceptional age at study: 36.5 weeks (SD.= 0.6 weeks)	Supine vs. prone .	There were no significant in the percentage of each sleep state between supine and prone position. However, the number of awakenings and the ratio of total awakening time to total sleep time were significantly higher in the supine compared with the prone position. Regarding sleep characteristics, the duration of the first quiet sleep was significantly longer in the prone position. In addition, the prone position was associated with the longest bout of quiet sleep and less awakening in the first quiet sleep in comparison with the supine position. There was no pathologic apnea, accompanied by bradycardia, and/or desaturation in either position. In addition, there were no significant differences in periodic breathing between the two sleeping positions with respect to both the number and the percentages of periodic breathing as well as the longest duration of periodic breathing.
Grunau RE, Linhares MBM, Holsti L, Oberlander TF, Whitfield MF. 2004(32)	Quasi-experimental	NICU	38 preterm infants Mean GA were 29 weeks (range25-32 weeks) Postconceptional age at study: 36 weeks	Supine vs. prone;	Prone position was associated with significantly more deep sleep during baseline, compared with supine position, but there were no differences in sleep-wake state during lance. Minor increased facial activity was shown in some time segments of baseline for infants in supine compared with prone, but did not differ overall between positions. Prone and supine position did not affect heart rate significantly during baseline or lance events.

Maynard V, Bignall S, Kitchen S, 1999(33)	RCT	Hospital	10 preterm infants Mean GA were 26.83 (SD.=0.63 weeks) Postconceptional age at study were 19.6 days (SD.=5.3 days)	Supine vs. prone	There was no significant difference in oxygen saturation as a function of position. In contrast, there was a significant increase in heart rate on supine positioning, with a mean reduction of 6.28 breaths per min (p<0.05). In addition, there was a significant reduction (p<0.05) in asynchrony on prone positioning, with a similar significant increase (p<0.05) in asynchrony on supine positioning. Intra-subject variability of thoraco-abdominal motion, as a function of position assessed in each infant by return to the original test position, demonstrated no significant difference (p>0.5) on return to supine or on return to prone position (p>0.1).
Pichler G, Schmolzer G, Muller W, Urlesberger B 2001(34)	RCT	NICU	15 preterm infants during apnea Mean GA were 31 weeks (range 27-37 weeks) Postconceptional age at study were 35 weeks (range 32-37 weeks)	Supine vs. prone	In both positions there was a predominance of decrease in cerebral blood volume (CBV) and cerebral hemoglobin oxygenation (cHbD) in association with apnea. The mean decrease of cHbD (-1.57±1.82 □mol/l) and of CBV (-0.120±0.137 ml/100g brain) in the supine position was significantly pronounced compared to prone position (changes in cHbD:-1.18±1.77 □mol/l, changes in CBV: -0.080±0.095 ml/100g brain). The degree of changes in CBV and changes in cHbD did no correlate with postconceptional or postnatal age. In both position there was a similar small decrease of oxygen saturation in association with apnea. In the supine position heart rate decreased slightly during apnea, whereas in the prone position no change in heart rate could be observed.
Sahni R, Schulze KF, Kashyap S, Ohira-Kist K, Fifer WP, Myers MM. 1999(35)	RCT	Hospital	61 preterm infants Mean GA were 31(range 30-38 weeks) Postconceptional age at study were 34.5 weeks (range 30-38 weeks)	Supine vs. prone;	During quiet sleep preterm infants have higher heart rates (p <0.0001) in the prone versus supine position. Global RRi variability was lowered in prone position (p <0.0002). The time domain measure of changes in beat-to-beat variability (rMSSD) also demonstrated significant effects of sleeping position, with rMSSD being lower in prone position (p <0.0001). During quiet sleep, low-frequency (p <0.0001), and high frequency (p <0.02) spectral powers of RRi were lower in the prone sleeping position. Similar, significant positional differences were observed for heart rate and time and frequency domain variables during active sleep.

Schrod L, Walter J 2002(36)	Quasi-experimental	Hospiatl	36 infants Median GA: 32.5 weeks (range 25-35 weeks) Postnatal age at study: 2-12 days	Supine vs. horizontal position vs. head elevated body tilt position of 30°	After stabilization within several minutes, prolonged tilting did not result in any further significant changes of total cerebral hemoglobin content, heart rate, man arterial pressure and oxygen saturation measured by pulse oxymetry. Respiratory frequency was reduced by 6-12%. Heart rate variability revealed a greater increase in low frequency than high frequency activity following head elevated body tilt position. Only preterm infants≤1500 grams showed a significant decrease of regional cerebral oxygen saturation of about 2-5% from day 2 to 8.
Stenning W, Nitsch P, Wassmer G, Roth B 2002(37)	RCT	Hospital	<u>Group 1</u>: 24 preterm infants Mean GA: 47 weeks (range 6-13 weeks) Postnatal age at study: 20 days (range 6-42 days) <u>Group 2</u>: 12 term infants Mean GA: 40 weeks (range 38-42 weeks) Postnatal age at study: 20 days(range 6-42 days)	Vertically in a sling faced turn to the mother/father vs. horizontally in a sling, in the supine position vs. laterally in a pram	The use of infant slings was not associated with a clinically relevant drop of oxygen saturation. A significant decrease of oxygen saturation was observed while infants were carried in a sling with a mean oxygen saturation of 96.3% in the vertical and 96.1% in the horizontal sling position compared with the mean oxygen saturation (97.1%). The degree and the incidence of desaturation and bradycardia did not change while infants were carried. Both types of episodes were seen only in preterm infants.
Bhat RY, Leipala JA, Singh NR, Rafferty GF, et al 2003(38)	RCT cross over design	Hospital	10 Oxygen dependent preterm infants and 10 non-oxygen-dependent preterm infants Mean GA: 35 weeks (range 27-32 weeks) Postconceptional age at study: 35 weeks (range 32-38 weeks)	Supine vs. prone	The median oxygen saturation and functional residual capacity were significantly higher in the prone position, compliance of the respiratory system and resistance of the respiratory system were not significantly affected by posture. Differences in oxygen saturation and functional residual capacity were significantly higher in the prone posture in the oxygen-dependent, but not the oxygen-dependent infants.
Elder DE, Campbell AJ, Doherty DA. 2005(39)	Quasi-experimental	Neonatal unit	<u>Group 1</u>: 7 preterm infants with chronic lung disease (CLD) Mean GA: 27 weeks (range 24-31 weeks) Postconceptional age at study: 39 weeks(range 36-44 weeks) <u>Group 2</u>: 8 non-CLD infants Mean GA: 29 weeks (range 27-31 weeks) Postconceptional age at study were 36 weeks(35-39 weeks)	Supine vs. prone;	Neither oxygen saturation nor apnea hypopnoea index (AHI) was position dependent and no group differences were noted with respect to CLD status. There was a significant interaction of GA and sleep position with less-mature infants spending less time in quiet sleep in supine position (p = 0. 006). These less-mature infants also had a higher AHI (p=0.033). The AHI and arousal index (AI) were higher in active sleep (p ≤ 0.001, p=0.013, respectively) and mean oxygen saturation was lower (p=0.001).

Merchant JR, Worwa C, Porter S, Coleman JM, deRegnier R-A O 2001(40)	Quasi-experimental	Newborn nursery	The treatment group comprised of 50 preterm infants, Mean GA: 35-36 weeks Postconceptional age: 30-37 weeks The control group comprised of 50 full-term infants. GA:≥ 37 weeks, Postconceptional age at study: 38-42 weeks	Supine vs. car seat	Mean oxygen saturation values declined significantly in both preterm and term infants from 97% in the supine position (range; 92%-100%) to 94% after 60 minutes in their car seats (range: 87%-100%). Seven infants (3 preterm and 4 terms) had oxygen saturation values of less than 90% for longer than 20 minutes in their car seats. Twelve percent of the preterm infants (95% confidence interval: 4.5%-24.3%) but no term infants had apneic or bradycardic events in their car seats.
Tonkin SL, McIntosh CG, Hadden W, Dakin C, Rowley S, Gunn AJ. 2003(41)	RCT	Hospital	17 preterm infants Mean GA were 32.0 weeks (SD.= 3.5 weeks) Postnatal age at study were 38 days (SD.= 40 days)	Car seat	Placement of the insert in the car seat was associated with a larger upper airway space compared without the insert (mean±standard deviation, 5.2±1.3 vs. 3.6±1.4 mm. p<0.001). This radiologic improvement in the frequency of episodes of oxygen desaturation to < 85% (1.5±2.1 vs. 3.5± 3.5 episodes/infant), of bradycardia <90 bpm (0.1±0.3 vs. 1.0±1.7), and of arousal (median [25^{th}, 75^{th}], 2.5[1.3, 4.0] vs. 5.0 [4.0, 7).
Woragidpoonpol P. 2001(42)	Quasi-experimental	Nursery	13 healthy infants, Mean GA: 31.21 (range 25-36) weeks. Postnatal age: 20.85 (range 5-50) days	Supine vs. prone;	When in a prone position with supportive rolled soft blankets and a 15-degree elevated bed head, on sleep state, infants had significantly higher mean oxygen saturation (p = 0.005) only on the second day of this study. No crying occurred during sleep in the prone position, but did occur in the supine position. When changed from prone to supine, the amount of sleep decrease, but when changed from supine to prone the amount of deep sleep increased further.
Bhat RY, Hannam S, Pressler R, Rafferty G, Peacock JL, Greenough A. 2006(43)	RCT	NICU	24 preterm infants: 14 infants with bronchopulmonary dysplasia (BPD) and 10 non-BPD infants. Median GA =27 weeks Postconceptional age at study were37 weeks	Supine vs. prone	In the supine position, both the BPD and the non-BPD infants had more awakenings and arousals, and the infants spent a lower proportion of sleep time in quite sleep. In the BPD infants only, a significant effect of sleep position on the occurrence of apnea was seen. Comparison of the differences seen between the 2 position in the BPD and non-BPD infants did not reveal any statistically significant differences in the magnitude of the differences in the 2 positions, that is, there was little evidence of an interaction between the effect of sleep position and BPD status.

Kugelman A, Bilker A, Bader D, Cohen A, Tirosh E. 2002(44)	RCT	Hospital	The treatment group comprised of 20 preterm infants, Mean GA: ≥32 weeks (range 32-37 weeks) Postconceptional age: 30-37 weeks The control group comprised of 39 healthy full-term infants. Mean GA: not stated Postconceptional age at study: 38-42 weeks	Supine vs. supine with inclination vs. side vs. prone positions.	Apnea frequency decreased during maturation, and was less prevalent in the prone than in the supine and side positions in preterm as well as in term infants ($p<0.05$). No clinically significant apnea episodes were found. End-tidal carbon dioxide ($EtCO_2$) in term infants was lower than that in preterm infants ($p<0.05$) and was not affected by sleep position in the most premature (<33 wk) and in term infants (>36 wk). $EtCO_2$ was higher in the prone position than in supine or side positions in infants between 33 and 35 wk gestation ($p<0.01$).
Levy J, Habib RH, Liptsen E, Singh R, Kahn D, Steele AM et al. 2006(45)	RCT	NICU	19 premature infants; Mean GA: 29.7 weeks (SD.=2.1 weeks) Postnatal age at study: 33.6 days (SD.=1.4 days)	Supine vs. Prone	Inspiratory, elastic, and resistive work of breathing were unaffected by prone versus supine positioning (p=0.46, 0.36, and 0.87, respectively). Similarly, respiratory rate, tidal volume, minute ventilation, and lung compliance did not differ between positions.
Leipala JA, Bhat RY, Rafferty GF, Hannam S, Greenough A. 2003(46)	RCT	Hospital	20 infants : 6 infants were oxygen-dependent and 14 infants were nonoxygen-dependent Mean GA: 29 weeks (range25-32 weeks) Postconceptional age at study: 36 weeks (range 33-39 weeks)	Supine vs. prone;	Overall, the tidal volume was higher ($p<0.05$), but the respiratory rate ($p<0.05$), the pressure generated in the first 100 msec of an imposed airway obstruction ($p<0.05$), and maximum inspiratory pressure ($p<0.05$) were lower in the prone compared to the supine position. There were no significant differences in inspiratory or expiratory times between the two postures. In oxygen-dependent infants only, minute volume was higher in the prone position ($p<0.05$).
Comeoo P, Tilokskulchai F, Vichitsukon K, Boonyarittipong P. 2004(47)	Quasi-experimental	NICU	30 preterm infants Mean GA:33.9 weeks (range 30-36 weeks) Postnatal age at study: 5 days(range 2-7) days)	Side-lying vs. supine	There were statistically significant differences of mean of pain scores between positioned premature infants and non-positioned premature infants in response to the heel prick at 6, 7, 8, 9 and 10 minutes ($p < 0.05$)
Sahni R, Schulze KF, Kashyap S, Ohira-Kist K, Fifer WP, Myers MM. 2005(48)	RCT crossover design	Hospital	63 preterm infants Mean GA: 30.5 weeks (range 26-37 weeks) Postconceptional age at study: 34.5 weeks (range 31-38 weeks)	Supine vs. prone;	In the prone sleeping position, during active sleep, infants showed significantly lower total EEG power, decreased absolute powers in frequency bands (0.01-1.0 Hz, 4-8 Hz, 8-12 Hz, 12-24 Hz, increased relative powers in 1-4 Hz, and a decrease in spectral edge frequency. Similar trends were observed during quite sleep, although they did not reach statistical significance.

Daley HK. 2002(49)	Quasi-experimental design	Hospital	51 preterm infants, Mean GA:30-35 weeks Postconceptional age at study: 33-38 weeks)	ARM position (held in the arms of the nurse) vs. LAP position (held on the nurse's lap with the head supported by one hand);	When fed in the ARM position, infants finishing their feeding sooner and showing fewer distress signs compared to the LAP position. No consistent relationship was found for volume intake, physiological signs, or behavioral state. Feeding performance was noted to improve with increasing postconceptual age, as shown by increased volume intake and decreased number of distress signs.
Cohen S, Mandel D, Mimouni FB, Solovkin L, Dollberg S. 2004(50)	RCT Crossover design	Hospital	31 preterm infants.	supine vs. prone vs. right vs. left lateral decubitus	At 1 hour, right lateral decubitus led to less significant residuals than left lateral decubitus and the prone position led to less residual than the left lateral decubitus. The amount of gastric residuals 1 hour after a meal appears to be in the following decreasing order: left, supine, prone, right.
Omari TI, Rommel N, Staunton E, Lontis R, Goodchild, Haslam RR et al. 2004(51)	Quasi-experimental	Hospital	10 healthy preterm infants Mean GA: 35.8 weeks (SD.=0.2 weeks) Postconceptional age at study: 35.8 weeks (SD.= 0.2 weeks)	Right lateral vs. left lateral position	Preterm infants in the right lateral position had significantly more gastroesophageal reflux (GER) ($p < .01$), a higher proportion of liquid GFR ($p < .05$), and faster gastric emptying ($p < .005$) when compared with infants in the left lateral position. Similarly, transient lower esophageal sphincter relaxation were more common in the infants position on their right side and triggered more liquid GER in this position.
Keller A, Arbel N, Merlob P, Davidson S. 2003(52)	RCT	NICU	20 healthy preterm infants Mean GA: < 31weeks Postconceptional age at study: 32.7 weeks(range 31.2-33.9 weeks)	Supine in a hammock vs. prone	Compared with nested prone positioning, supine positioning in a hammock was associated with a higher neuromuscular maturity score ($p < 0.003$) and a more relaxed condition, as expressed by a significantly lower heart rate ($p < 0.05$) and respiratory rate ($p < 0.01$).
Monterosso L, Kristjanson LJ, Cole J, Evans SF. 2003(53)	RCT	NICU	123 preterm infants Median GA;< 31 weeks) Postconceptional age at study: Not stated	Postural support nappy only vs. postural support roll only vs. prone with a postural support nappy and postural support roll	Infants nursed in prone with a postural support roll and a postural support nappy demonstrated improved hip posture to term equivalent age compared with infants nursed with either a postural support roll only, or a postural support nappy only. Infants nursed with a postural support roll either with or without a postural support nappy demonstrated improved shoulder posture to term equivalent age.

Vaivre-Douret L, Ennouri K, Jrad I, Garrec C, Papiernik E. 2004(54)	RCT	Hospital	60 preterm infants, Mean GA: 34.09 weeks (31-36 weeks) Postconceptional age at study: not stated	Back vs. prone vs. side lying position; .	The sensory-motor skills examinations showed significant abnormalities in the prone position including 1) dominance of the extensor muscle due to muscle shortening, 2) hyper abduction and flexion of the arms, and 3) global neuromuscular rigidity. Psychomotor and neurological exams showed delayed developmental muscular acquisitions for infants in the prone position.
Constantin E, Waters KA, Morielli A, Brouillette RT. 1999(55)	Quasi-experimental	NICU	Group 1 15 preterm infants, Mean GA: 29 weeks (SD.= 0.6 weeks) Postconceptional age at study: 40 weeks (SD.=1.0 weeks) Group 2 10 term infants Mean GA: not stated Postconceptional age at study: not stated	Prone position	The preterm infants turned their heads much less frequently than the term infants: 0 (0-0.4) versus 6.2 (4.3-7.9), $p < 0.001$, full head turns per hour of sleep, and 0 (0-0.6) versus 1.7 (0.7-2), $p < 0.004$, half head turns per hour of sleep. In addition, the premature infants rarely adopted the face-straight-down position when sleeping prone, and the face-near-straight-down episodes were less frequent in the preterm infants compared with the term infants.
Dusing S, Mercer V, Yu B, Reilly M, Thorpe D 2005(56)	Quasi-experimental	Hospital	The treatment group comprised of 18 preterm infants Mean GA were 31.9 weeks (range 25.0-34.6 weeks) Postconceptional age at study were 41.69 weeks (SD.=0.65 weeks) The control group comprised of 15 term infants Mean GA 38.9 weeks(range 37.3-40.6 weeks) Postconceptional age at study were 40.97 weeks (SD.=1.06 weeks)	Trunk position	Infants born at term spent more than two-thirds of the time in either flexed or neutral trunk positions. No significant differences were found between infants born preterm and those born at term in total duration of flexion or extension or in flexion event duration.