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The Effects of Vestibular Stimulations on Neurodevelopment, Growth and Vital Signs of Preterm Infants: A Systematic Review

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Abstract

Background: The purpose of the present study was to systematically review all published studies investigating the effects of only vestibular interventions on neurodevelopment, growth and vital signs in preterm infants (PIs).

Method: PubMed, SCOPUS, Web of Science, CINAHL and EMBASE databases were searched to find relevant studies published from 1980 and June 2022. In addition, reference lists of the articles were also checked.

Results: Twenty articles met the inclusion criteria. Fifteen of these articles reported studies conducted on stable preterm infants and five on unstable ones. Waterbed, rocking, hammock, air mattress and Vestibu_Guide stimulations were applied in eight, four, six, one, and one study, respectively. Twelve studies evaluated neurobehavioral development, five studies assessed neuromotor development, five studies evaluated the growth and fifteen studies assessed the vital signs in preterm infants using vestibular stimulations.

Conclusions: The results indicate that vestibular stimulations may improve neurodevelopment, growth and vital signs in premature infants, but there are still some disagreements among researchers, and further research is recommended.

Key Words: Air Mattress, Growth, Hammock, Neurodevelopment, Premature Infants, Preterm Infants, Rocking, Systematic Review, Vestibular Stimulations, Vestibu-Glide, Vital Signs, Waterbed.

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1- INTRODUCTION

Prematurity is defined as a delivery before 37 weeks of gestation by the World Health Organization (WHO) and is categorized into three groups: under 28 weeks as extreme prematurity, between 28-32 weeks as high prematurity and 32-37 weeks as moderate to late prematurity (1). The incidence of prematurity varies from 5% to 18% among 184 countries (1). The global birth rate of preterm infants (PIs) is estimated to be 10.6% (2). In some studies conducted on PIs, the sensory processing alterations were reported as an abnormal reactivity to tactile deep pressure, proprioception and vestibular stimulations (3, 4).

Vestibular reflexes are developed in the human embryo in the 19th week of gestational age and vestibular nerve is reported to be myelinated and matured (5). Vestibular system is one of the first systems to reach maturity (6). The vestibular system is located in a part of the inner ear and regularly transmits information about the movements and position of the head and body to the integrating centers in the brainstem, cerebellum and somatosensory cortex (7). Many studies indicated vestibular stimulations in PIs. In this study vestibular stimulation aims at one of the following stimulation: waterbed, air mattress, rocking, hammock and Vestibu-Glide; so that the vestibular system is stimulated by them. Many researches showed that these vestibular stimulations may result in improving neurobehavioral characteristics such as sleep pattern, pain response, visual and auditory orientation (8-14), increasing neuromotor development such as passive muscle tone, active motility, posture, oral motor function and neuromuscular maturity (15-18), improving vital signs of respiratory system and heart rate (13, 14, 18, 19), balance, body orientation, (20) sensory processing (21) and learning (22) in PIs. According to the literature, some studies conducted on multi-sensory interventions in PIs (23, 24) and some studies utilized only vestibular stimulations to improve the infant's wellbeing (16, 25, 26). Some studies indicated that vestibular stimulations can improve neurodevelopment of PIs (9, 11, 12, 27), but there is no general consensus among study findings. Therefore, the purpose of the present study was to systematically review all published studies investigating the effects of only vestibular interventions on neurodevelopment, growth and vital signs in PIs.

2- MATERIALS AND METHODS

2-1. Search Strategy

Available databases including PubMed, SCOPUS, WEB OF SCIENCE, CINAHL and EMBASE were searched to find studies investigating the effects of vestibular stimulations on neurodevelopment in PIs during the period of 1980 to June 2022. The search strategy consisted of text words, such as ("preterm infant" OR "premature infant" OR "low birth weight" OR "very low birth weight" OR "neonate" OR "neonatal" OR "newborn") AND ("vestibular stimulation" OR "rocking" OR "swing" OR "water bed" OR "air mattress" OR "hammock"). The search strategy was conducted based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA, 2020) guidelines (28) (**Fig. 1**).

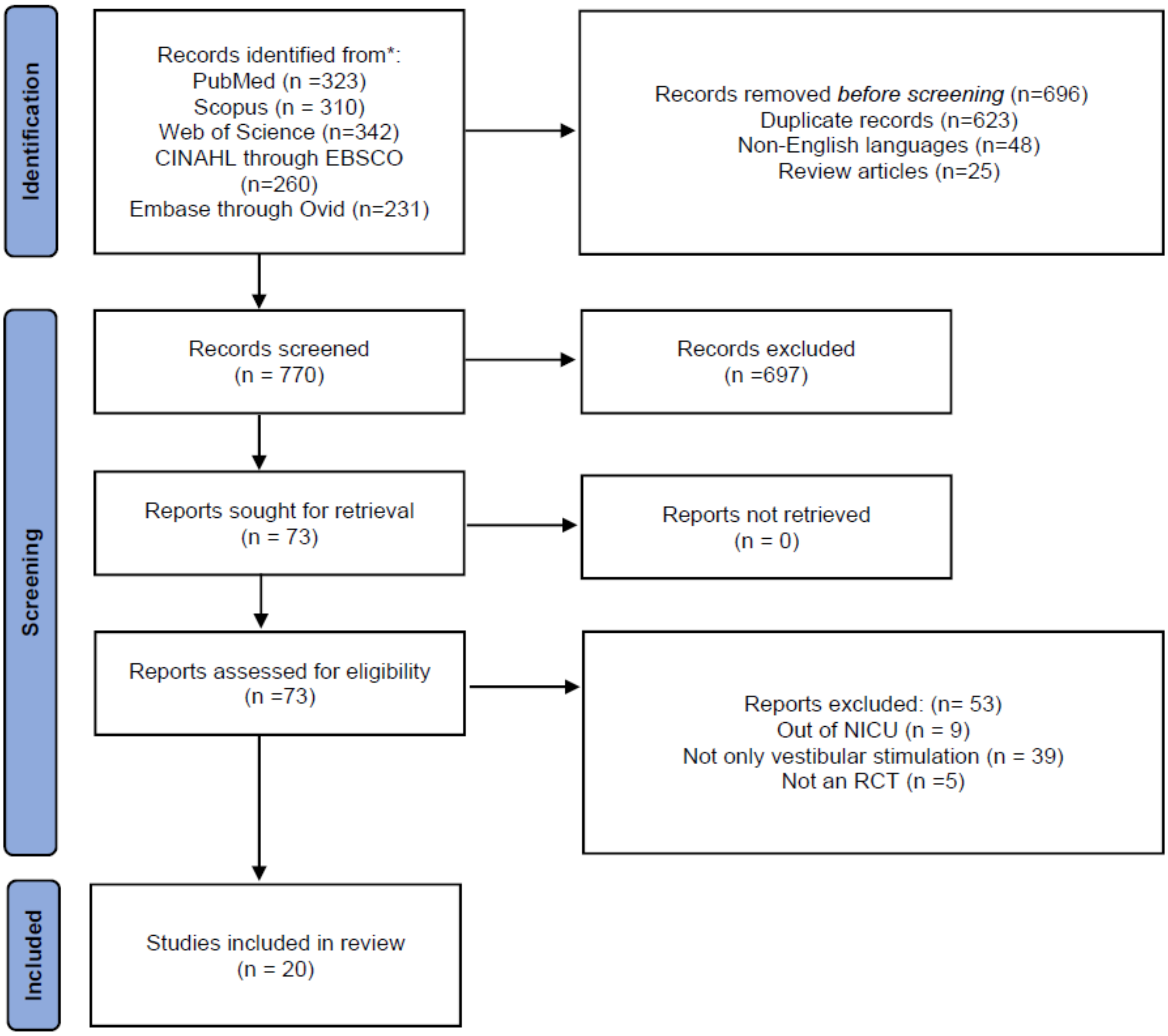

Fig.1: Framework of the study

2-2. Study Selection

All Randomized Controlled Trials (RCTs) investigating the effects of different kinds of vestibular stimulations such as waterbed, air mattress, rocking, hammock and Vestibu-Glide on neurodevelopment, growth and vital signs in hospitalized PIs were included. All included studies were published in the English language. The articles studied the effect of multisensory interventions, vestibular stimulations on mothers and stimulations on term infants were excluded. Article's abstracts published in conference or seminar proceedings were also excluded. Based on searching, 1466 articles were retrieved. Two reviewers (R.A & R.N) selected the relevant studies, independently. Some articles were excluded according to their titles and abstracts. If it was difficult to include/exclude a study based on the title or abstract, the full text of the article was read by the above reviewers and then checked by a third reviewer (M.B.M.A). A consensus meeting was held to resolve any conflicts among all reviewers.

Following achieving consensus on eligible studies, articles were qualitatively assessed based on the Physiotherapy Evidence Database (PEDro) scale. This scale has 11 items to assess methodological quality of RCTs. Ten items scored 0 or 1, but the first item was answered with “yes” or “no”. Articles with more-than-8 scores were considered excellent and those with scores 6 to 8 were evaluated as good, the scores of 4 and 5 were considered fair and finally, scores less than 4 were evaluated as poor (29). The results of the PEDro checklist are presented in **Table 1**.

3- RESULTS

From a total of 1466 studies, 623 articles were duplicated and removed. Out of the remaining 843 studies, 770 articles were excluded based on titles and 53 were excluded based on abstracts and full texts. Finally, 20 RCTs met the inclusion criteria and were reviewed. The details of the eligible studies are provided in chronological order in **Table 2**. The studies were divided into four domains including: neurobehavioral, neuromotor, growth and vital signs.

The gestational age of PIs in reviewed studies was between 22 to ≤37 weeks. Nine articles used the vestibular interventions for infant's ≤ 28 week (8, 16, 19, 25, 26, 30-33) and in eleven articles, the interventions were delivered for infants between 28 to ≤37 weeks (9-15, 17, 18, 27, 34). Fifteen of the 20 studies were conducted on medically stable PIs (8, 9, 11-18, 25-27, 30, 31), the remained five articles were performed on infants suffering from idiopathic apnea (19), severe respiratory distress syndrome (32), intra ventricular hemorrhage (10), Bronchopulmonary Dysplasia (33), RDS, and asphyxia (34).

In eight articles, waterbed was used (8, 9, 11, 12, 27, 30-32), air mattress was employed in one article (26), four studies investigated the effects of rocking (10, 15, 19, 25), hammock was utilized in six studies (13, 14, 16, 18, 33, 34), and one article employed Vestibu-Glide (17).

Out of the thirteen articles studied on the vital signs, five studies reported no effect (8, 25, 26, 31, 34), one study demonstrated negative effects (33), and seven articles showed positive effects of vestibular interventions on vital signs (12-14, 16-19).

Twelve studies were conducted on the effect of vestibular stimulations on neurobehavioral systems (sleep status, pain response, visual and auditory stimuli) and growth (8-14, 18, 25-27, 32). In five articles, neuromotor, neuromuscular characteristics of PIs were investigated (15-18, 30).

4- DISCUSSION

This study was performed to systematically review the studies published from 1980 to June 2022 to evaluate the effects of vestibular stimulations on neurodevelopmental characteristics in PIs. The results of the present systematic review demonstrated that vestibular stimulations may have an important role in the development of the behavioral system (especially quiet sleep and pain response), neuromotor, growth, and vital signs. The main outcomes and results are discussed separately as follows.

4-1. Neurobehavior

Korner et al. (8, 11), Edelman et al. (9), and Deiriggi et al. (12) applied waterbeds with or without oscillation to assess the sleep state. The results demonstrated improvement in quiet sleep and the energy conservation in PIs. The findings of their studies were not in agreement with the results of the study conducted by Cordero et al. (10), Saigal et al. (26) evaluating the effect of air mattress on sleep status in PIs. They reported no significant difference between the experimental and the control groups. Some factors such as unstable PIs, different onset and type of vestibular stimulations, short term vestibular inputs were considered as probable causes of inadequate effects of vestibular stimulations on sleep.

Table-1: Summary of the articles' findings

Articles PEDro Criteria	Jones 1981	Tuck et al. 1982	Korner et al. 1982	Edelman et al. 1982	Korner & Schneider 1983	Pelletier et al. 1985	Bottos et al. 1985	Cordero et al. 1986	Saigal et al. 1986	Clark et al. 1989	Korner et al. 1990	Deiriggi 1990	Darrah et al. 1994	Zanadro et al. 1995	Johnson et al. 1997	Keller et al. 2003	Zimmerman & Barlow 2012	Costa et al. 2016	Ribas et al. 2019	Costa et al. 2019
Eligibility criteria	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Random allocation	0	0	0	1	0	1	0	1	1	0	1	0	1	0	1	0	0	0	1	1
Concealed allocation	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Baseline similarity	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Blinding of subject	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Blinding therapists	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Blinding of assessors	1	0	1	0	1	0	0	1	1	1	0	0	1	0	1	1	0	0	1	1
Measures of key outcome from more than 85% of subjects	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intention-to-treat analysis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Between-groups statistical Comparisons	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Point measures and measures of variability	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	7	6	6	7	8	7	5	8	8	7	7	6	8	6	10	7	6	6	9	8

Table-2: Details of the studies in chronological order

Author (year)	Purpose	Participants (Preterm infants/gestational age)	Interventions	Measurements	Conclusions
Jones et al, (1981)	The effect of waterbeds on apnea in PIs.	N=14 (≤32 Wk)	Waterbed Rate:12-14 pulse/ min Amplitude: 1-2mm Duration: 23 hours	Electrocardiogram and impedance pneumography.	Unaffected response to waterbed was demonstrated by maturity of infants, severity of apneas and receiving Theophylline.
Edelman et al, (1982)	The effect of waterbeds on sleep and motility in PIs.	N=12 (29-34 Wk)	Waterbed Rate:12-14 pulse/min Amplitude: 2.4 mm Duration: 4 days on and 4 days off	Behavioral observation	A significant increase in the longest quiet sleep and decrease in the percentage of fuss/cry was found using a waterbed.
Korner et al, (1982)	The effect of waterbeds on sleep duration, restlessness and motility in PIs.	N=17 (26-32 Wk).	Waterbed Rate: 8-10 pulse/min Amplitude: 2.4mm Duration: 4 days on and 4 days off	Behavioral observation	Sleep, and motility were improved in babies treated with theophylline, but the incidence of REMs, HR, RR and weight did not differ using waterbeds
Tuck et al, (1982)	To prevent apneic attacks using vestibular stimulations in PIs.	N=12 (26-32 Wk)	Rocking bed Rate: 10-22 pulse/min Amplitude: ≤ 3 degrees in either direction Duration: 4-8 hours	PO2, HR and Impudence Pneumogram	The rocking bed may be helpful to diminish the recurrent apnea and its frequency
Korner & Schneider, (1983)	The effect of waterbed on the neurobehavioral development in PIs.	N=56 (22-33 Wk)	Waterbed Rate: 12-14 pulse/min Amplitude: ≤ 2.4 mm Duration: 24 hours	Neurobehavioral assessment	The neurobehavioral characteristics would be enhanced using waterbeds in PIs
Bottos et al, (1985)	The effect of hammock on respiration of PIs.	N=40 (29-37 Wk)	Hammock Duration: 23 min on the hammock and 23 min in supine position on matt	Recording cutaneous oxygen levels and breathing	The hammock position did not disturb the respiration. The cutaneous oxygen level was increased in PIs without RDS
Pelletier et al, (1985)	The immediate effect of waterbed on avoidance movements in PIs.	N=22 (29-33 Wk.)	Waterbed Rate: 16±4 pulse/min Amplitude: unclear Duration: 30 min	Assessment of Premature Infant Behavior (APIB)	All approaches and avoidance movements were reported to be better except for finger splay.

Saigal et al, (1986)	The effect of oscillating mattresses on apnea, growth and neurodevelopment in PIs.	N=122 (27-33 Wk.)	Air mattress Rate:14-16 pulse/min Amplitude: unclear Duration: at least 7 days	Cardiorespiratory monitoring, the Albert Einstein Neonatal Neurobehavioral Scale, and Bayley scales.	The oscillatory air mattress could not reduce the apnea, not improve the growth development and sleep.
Cordero et al, (1986)	The effect of rocking stimulation on sleep patterns in PIs.	N=17 (28-33Wk.)	Rocking Rate: 15 pulse/min Amplitude: ±22.5 degrees directed about the longitudinal axis Duration: three 15 min daily	Behavior, respiration and Electrocardiogram, Impedance pneumograph.	A significant increase was reported in the sleep patterns and a significant decrease in active sleep of PIs.
Clark et al, (1989)	The effect of vestibular stimulation on acceleration of postnatal development in PIs.	N=26 (28-33 Wk.)	Sinusoidal oscillation Rate:15 pulse/min Amplitude: 45° Duration: 15 min daily	Neuromuscular development examination (Dobowitz).	Alertness, defensive reaction, visual and auditory orientation were demonstrated to be different between the two groups.
Deiriggi, (1990)	The effect of waterbed on energy expenditures of the PIs.	N=22 (29-34 Wk.)	Waterbed Duration: 3 days	HR, Motor activity scale, behavioral state scale	Waterbed flotation could be considered as an effective intervention to improve energy conservation, active sleep and HR.
Korner et al, (1990)	The effect of waterbed on sleep and irritability in PIs	N=52 (29-33 Wk.)	Waterbed Rate: unclear Amplitude: unclear Duration: 4 days	Behavior assessment	Improvement in sleep was found in PIs compared with the control group, but the continuously oscillating waterbed had the most reduction in irritability and restlessness.
Darrah et al, (1994)	The effect of waterbeds on neuromotor development in PIs.	N=107 (<32 Wk.)	Waterbed Duration: not equal for all infants	Dubowitz, INFANIB, MAI, Peabody scales.	No significant influences of waterbed were found on the motor development of very low-birth weight infants.
Zanardo et al, (1995)	The effect of the hammock on oxygen saturation in PIs.	N=15 (27-30Wk.)	Hammock Duration:15 min	HR, RR and skin temperature.	PIs with BPD showed severe hypoxemia in the hammock.
Johnston et al, (1997)	The effect of sucrose alone, rocking alone and the combination of sucrose and rocking on pain	N=85 (25-34Wk.)	Rocking: 15 min Rate: 12 pulse/min Amplitude: 2 cm Duration:15 min	Physiological (HR and SO2) and behavioral responses.	No significant difference was found between the rocking and placebo groups for behavioral responses. A non-significant effect was found with

	response in PIs				a combination of rocking and sucrose on pain response.
Keller et al, (2003)	The effect of hammock on neuromuscular maturity, growth and autonomic stability in PIs.	N=20 (26-30 Wk.)	Hammock Duration: three hours daily	Weight gain, neuromuscular maturity scale.	Positive effects were demonstrated on HR, RR and Neuromuscular Maturity Score
Zimmerman and Barlow, (2012)	The effectiveness of vestibular stimulation on respiratory and oromotor systems in PIs.	N=27 (28-34 Wk.)	Vestibulite Rate: 0.5 to 0.95 pulse/sec Amplitude: 1.98 to 8.07cm Duration: three 15 min per day	RR, Chest wall motor pattern, SpO2, oral feeding.	Vestibular stimulation made by Vestibulite could provide the effective modulation in RR and reset the respiratory central pattern generator with inducing the changes in chest wall kinematics.
Costa et al, (2016)	The effects of hammock on neuromuscular maturity and stability in PIs.	N=30 (32-35 Wk.)	Hammock Duration: 40 min after diapering	N-PASS assessment, NANDA international Taxonomy.	The PIs in hammock showed a significant improvement in stress, posture and disorganization compared with the nests.
Ribas et al, (2019)	The effect of hammock on pain, sleep_wake state, heart rate, respiratory frequency and SpO2	N=26 (30-37 Wk.)	Hammock Duration: 2hours every day for 5 consecutive days	Premature Infant Pain Profile, Neonatal Facial Coding System scales, Brazelton Neonatal Behavioral Assessment Scale, HR, RR and SpO2.	The PIs in hammock had significantly less pain and a better sleep-wakeful state, Statistically significant differences in HR, RR, and SpO2 compared with the traditional position group.
Costa et al, (2019)	The effect of hammock on sleep and wake state, HR and SpO2	N= 20 (32-37WK.)	Hammock Duration: 10 min after diaper change as a stress stimulation	Systematic Observation - Microanalytical Encoding of Behavioral Variables, HR, SpO2.	Positive effects were demonstrated on behavioral responses, HR and SpO2.

PIs=preterm infants; N=numbers; Wk.= week; SO2= saturation of oxygen; PO2 = partial pressure of oxygen; SpO2= saturation of arterial blood with oxygen; HR= heart rate; RR= respiratory rate; REMs= rapid eye movement; RDS= respiratory distress syndrome; INFANIB= infant neurological international battery; MAI= movement assessment; PCA= postconceptional age; AA=adjusted age; BPD= Bronchopulmonary dysplasia; N-PASS= neonatal pain, agitation and sedation scale; NANDA= North American nursing diagnosis association.

In a study conducted by Johnston et al. (25), the effect of rocking stimulation (15 min) before and during heel stick procedure on pain response in PIs was evaluated. No significant effect of rocking stimulations on facial expressions during painful procedures was reported. Pelletier et al., (27), Ribas et al. (13), Costa et al. (14) and (18), investigated the effect of 30 min rocking stimulations after heel stick, 2 hours every day for 5 consecutive days, 40 min hammock and 10 min hammock after diapering on pain response, respectively. The results were not in agreement with the findings reported by Johnston et al. (25). Maybe the short-term duration of rocking stimulation (15 min) could be considered as the possible cause for reporting different findings. Therefore, it seems that the duration of vestibular stimulations should have a positive effect on pain responses. Korner & Schneider (32) applied waterbed on the visual and auditory orientation in PIs with severe respiratory distress syndrome (RDS). The findings demonstrated a significant improvement in the neurobehavioral outcomes.

Fundamental changes like the critical neural connections and neural tracts myelination occur during the second half of gestation (35). In PIs, the neurodevelopmental outcomes would be impaired because of the brain disorganization due to the brain adaptation to hypoxia (36). In the neonatal period, the frontal region cerebral white matter could be developed with applying the mild low stressed interventions (37). Orientation skills including interacting with the environment, bounding with the parents and the visual tracking behavior were reported to be lower in PIs than full term ones (38). Therefore the early supervised vestibular stimulations in the form of rocking would be helpful to improve motor and neurobehavioral development (39).

4-2. Neuromotor

In studies conducted by Clark et al. (10), Keller et al. (16), Zimmerman et al. (17) and Costa et al. (18), various types of vestibular stimulations (e.g., sinusoidal oscillation, hammock, Vestibu Glide) on passive muscle tone, active motility, posture, oral motor function, neuromuscular maturity and posture in PIs were investigated. The results showed that vestibular stimulations may improve neuromotor development in PIs who were at risk of developmental and motor delay. In a study carried out by Darrah et al., waterbed stimulation was used in PIs and no improvement was reported for neuromotor outcomes (30). According to the results, the duration of intervention was not equal in all infants and the age of infants was less than the age of the participants selected in the other studies (26-31week). Probably, age of infants as well as the type and duration of vestibular stimulations might inhibit the effect of vestibular stimulations on neuromotor development.

Previous studies have demonstrated higher rates of neurosensory motor development disorders in PIs born at ≤32 gestational weeks in comparison to the term babies (40). There is a critical effect of early life experiences and external overstimulation on the brain and especially the sensory system maturation; therefore, the sensory stimulations have an important role in the growth and neurodevelopment of PIs (41). These excessive and inappropriate stimulations may have some awkward effects on the immature brain which cannot filter these deleterious inputs (41). Particularly, the traditional Neonatal Intensive Care Unit (NICU) was not a compatible environment to develop the brain and nervous system's expectations; and it seems that the environment, schedules, and treatment programs in NICU may be the most important factors which may inhibit the influence of vestibular stimulation interventions in PIs (42, 43). Therefore, it is recommended to assess and follow up neuromotor criteria in the early stage of the PIs (44).

4-3. Growth

Out of four studies (8, 12, 16, 26), only one (12) reported that using non-oscillatory waterbed stimulation improved energy conservation and weight gain in PIs. In the three remaining articles, no improvement was found with applying different types of vestibular stimulations like waterbed and airbed with oscillation, hammock and rocking on the growth factors in PIs. It seems that unexplained energy intake of infants, inadequate cumulative duration of interventions, ages less than 28 weeks, and type of stimulation might be considered as probable reasons for different reported results.

Some studies demonstrated extra uterine growth retardation in most PIs (45) due to the pathological factors including gestational age, birth weight, nutrition during hospitalization, degree of disease, growth status before discharge, and their motor and neurodevelopmental outcomes (46, 47).

4-4. Vital signs

4-4.1. Respiration

In a study carried out by Tuck et al., rocking bed was used on unstable PIs with idiopathic apnea, and the results showed that rocking movements could provide the effective modulation in respiratory rate and changes in chest wall kinematics (19). The above findings may be attributable to the stimulation of diaphragm associated by rocking (48) and increased coordination between diaphragm muscle and upper-airway. In four studies carried out by Keller et al. (16), Costa et al., (14, 18), and Ribas et al. (13), hammock simulations were employed to investigate the respiratory status. The positive effects on respiratory rate were reported in stable PIs.

Also, Zimmerman et al. demonstrated the positive effect of Vestibu_Glide with different acceleration, rate and horizontal glide displacements on the respiratory and oral motor systems (17). The finding of this study was in agreement with the results of the previous studies. Some items such as ages less than 28 weeks at the beginning of stimulation, receiving medications (e.g., theophylline) before and during simulations, subjective assessment of respiratory system, and more adaptations occurred in types and durations of simulations might be associated with inadequate effect of vestibular stimulations on respiratory system.

4-4.2. Heart Rate (HR)

Korner et al., (8) and Jones (31) investigated the effect of waterbeds with oscillation (12-14 cycles/min) on HR and no difference was determined between the experimental and the control groups. In a study carried out by Johnson et al., 15-min-rocking stimulation before and during pain induction was applied using heel stick procedure (25). No difference was reported for HR between the experimental and the control group. It seems that the infant's HR may increase during pain (49) and this can be considered as a positive effect of applying vestibular stimulations during heel stick needling (25).

In another study, the negative effect of hammock stimulation on vital signs (HR, respiration and temperature) in PIs with Bronchopulmonary Dysplasia (BPD) was reported (33). In the same line, Bottos et al. reported no effect of hammock stimulation on HR and respiration in PIs with respiratory distress syndrome (RDS) (34), but significant effects were demonstrated on infants without RDS in some other studies (13, 14). The negative findings reported in those studies might be mainly attributable to the methodological flaws occurring in the design of the studies.

According to the findings, more relaxation and HR adjustment were demonstrated in infants applying different types of vestibular stimulation. Stability of HR may be associated with the following items: improvement in quiet sleep, ages above 28 weeks, stable PIs, receiving no medication before and during the procedure, and type of vestibular stimulations.

Age of PIs at the beginning of intervention (vestibular inputs) might be an important factor to show the effects of vestibular stimulations. Type of vestibular stimulations might be considered as an influencing factor for having better results in vital signs. Using waterbed stimulations may be associated with reduced body temperature and lead to apneic attacks (50), but no changes in temperature were found using rocking stimulation in this population.

5- CONCLUSION

Literature has demonstrated that vestibular therapy can improve the function of the central nervous system, though few research studies have been conducted on the effect of vestibular stimuli on neurobehavioral and neuromotor development as well as the growth in PIs. This systematic review showed that there is still no general agreement for the effects of vestibular stimulations and their characteristics (rate, amplitude, duration and type) on the neurodevelopmental status in PIs with different gestational ages. In all PIs, sleep, neurobehavioral, neuromotor, and vital signs were improved following the vestibular stimulation. It seems that ages between 28 to 37 weeks, long duration of vestibular inputs and stable samples without RDS at the time of intervention, were considered as important items to improve the neurodevelopment in PIs.

6- AUTHORSHIP

All authors declare that this is original work and that they meet the criteria for authorship. Mohammad A Mohseni-Bandpei, Aida Ravarian and Nahid Rahmani designed the study, extracted the data, conducted the analyses and wrote the manuscript. Farin Soleimani and Firozeh Sajedi conducted the analyses and wrote the manuscript. All authors read and approved the final manuscript.

7- CONFLICT OF INTEREST

None

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