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ABSTRACT

This study was designed to explore the effects of vestibular stimulation on the developmental behavior, respiratory functioning, weight and length gains, and morbidity and mortality rates of premature infants. A total of 20 infants participated in this study in 4 groups of 5 infants each. Group A infants were placed in a motorized hammock within their incubators and were rocked gently for 30 minutes, three times a day. Group B infants were placed in the same type of hammock but were free to remain still or initiate motion themselves by any slight bodily movement. Group C infants were placed in a stationary hammock to control for variables such as extra handling and the fetal position assumed when in the hammock. Group D was the control group in which the infants received traditional nursing care. The findings indicated that the infants in Group A had higher pH levels and greater linear growth than the infants in any of the other groups and that the Group B infants showed the greatest weight gain. These data are interpreted as suggesting that the development of integrating biological behaviors of the small premature infant may be influenced by a specific motion pattern. (JMB)

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Vestibular Stimulation and Development of the Small Premature Infant

by

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Vestibular Stimulation and the Development of the Small Premature Infant

This was a pilot study designed to determine the relationship between a regimen of vestibular stimulation imposed upon and self-actuated by the 28-32 week gestational age infant and four variables: (variable 1) developmental behavior as measured by general maturation, auditory and visual responses, muscle tension responses and irritability responses (Graham Neonatal Behavioral Test as modified by Rosenblith) and motor and mental development (Bayley Scales of Infant Development); (variable 2) respiratory functioning as determined by pH, Pco_2 and Po_2; (variable 3) weight and length increments, and (variable 4) morbidity and mortality.

This small infant is known to have developmental problems and has been listed in a high risk group for mental retardations since 1964.[2] Gesell referred to the premature infant as the fetal-infant, an infant born and living in the fetal period.[3] Can the environment of the fetal infant be altered to approximate that of the living rhythmical environment of the pregnant uterus? If the environment is to be altered, what parameter(s) should be studied? Such was the primary question considered for the study.

It has long been believed[4] that the movement of the maturing muscle cells of the embryo may have a directive influence on the nerve fibers and that the micromovements of growth during the embryonic stage provide the underlying structures of behavior forms so that the later capacity of neuroblasts and neurons to grow is dependent upon this early developmental stage. Neurological growth has been shown to be dependent upon stimulation both for its development and its maintenance.

The vestibular cells are those mostly related to the functioning of equilibrium, or more simply stated, that of body motion. After the ninth week of fetal life the vestibular apparatus is anatomically developed[5] and the labyrinth reflexes and vestibular responses are reportedly present.[6] Larroche reports that the vestibular root is the first of the cranial nerves to be myelinated.[7] This is part of the orderly progression of neural development and it represents important beginning neural functioning.

It has long been known that fetal movement is essential for the unborn infant. A lack of fetal movement in the second and third trimesters signals distress and is of major concern to the physician and/or midwife. It is also known that the unborn infant receives a certain amount of stimulation from the living rhythmical environment of the uterus. The very mild contractions of the uterus and the constant flow of amniotic fluid are two such examples. The mother's physical activity is added to this, particularly in the third trimester. Who has not watched a mother heavy with pregnancy as she walks and gently swings her body to the right, then left, then right? The motion and influence of the rhythmical environment of the uterus may be one of the most important factors contributing to the neurological development of the child. In view of this it seemed imperative that a study be undertaken to determine the relationship between total body motion that would excite the vestibular cells and the developmental behavior of the fetal-infant. Thus, a primary question was asked, could stimulation of a specific nature that is directly related to general body motion (self-actuated motion or lack of it) have some influence on this developing fetal-infant?

Vestibular stimulation has been studied by Pomerleau, Malcuit and Clifton[8] in relation to heart rate and they determined that the infants had a decelerative cardiac response following the stimulation. Korner and Thomas determined that vestibular-proprioceptive stimulation provided by placing the infant in an upright position on the shoulder or horizontally imposed total body motion in the upright position had significant soothing influence on the two-to four-day-old healthy neonate.[9] Korner with Grabstein also learned that those infants who are picked up and held upright on the shoulder of the caretaker become visually alert.[10] Thus, vestibular stimulation has been shown to produce cardiac deceleration, soothing effects and visual alerting in the newborn. Each of these or the composite of these may have a direct bearing on the development of the newborn.

Pederson studied the amplitude and frequency of vestibular stimulation in the two-month-old infant. He learned that high frequency of vestibular rocking was more effective than low frequency in decreasing activity in these infants.[11] Such stimulation is discussed in relation to the mother-infant dyad and the power each of these members has in lowering activity. Brackbill's work shows that arousal levels may be reduced both behaviorally and physiologically when stimulation is offered continuously while intermittent stimulation raises rather than lowers the arousal level.[12]

Barnard placed the premature infant on an oscillating bed that moved forward and backward within the incubator and introduced auditory inputs.[13] Scarr-Salapatek and Williams studied visual, tactile and kinesthetic stimulation for the low-birth-weight infants.[14] Results of these studies show greater developmental progress for the experimental than the control group.

In a former study by Neal, a compound motion that would excite the vestibular cells was begun on the fifth day of life, 30 minutes, three times daily, and was continued until the 36 week total age (gestational age plus living age) for 31 experimental infants. Both 31 control and 31 experimental infants, who were studied in four hospital premature centers, were tested for developmental behavior responses at the 36 week total age (252 days conceptual age) by use of the Graham Test as modified by Rosenblith.[15,16,17] This test evaluates a number of parameters of complicated behavior that can be exhibited by the neonate.

On the basis of that study it was concluded that developmental behaviors were significantly greater in the experimental infant. These findings indicate that the excitation of the vestibular cells by means of a total compound body motion may have a bearing on the development of the premature infant. Although two additional variables were not predetermined for study, the weight gain of the experimental infant was found to be significantly greater than the control infant, and it was noted that seven control infants had late-edema, a symptom not found in any of the experimental infants.

Present Study

Assumptions underlying the study include: (1) the premature infant is deprived of a period of time in the living rhythmical environment of the uterus in which vestibular cells may be constantly stimulated, (2) vestibular stimulation results in increased neural activity in the vestibular cells in the small animal, and (3) that in spite of the quiet environment in which we place the premature infant, he has an almost continuous pattern of uncoordinated bodily movements.

In this pilot study there were four groups of five infants each. Infants were (1) between 28 and 32 weeks of gestational age as determined by Dubowitz Score, (neurological and physical assessments) and/or agreement with gestational age by Nadar's (LMP) rule, and (2) free from abnormalities or disease as determined by the physician at 96 hours of age at which time they were placed on study. Need for intravenous feeding, oxygen therapy or monitoring equipment did not disqualify an infant from the study. Eligible infants were assigned as admitted per birth order to the groups in descending-ascending-descending order.

The experimental group A received total body motion. A motorized mechanism provides a hammock within an incubator with 120 degrees horizontal and 30 degrees vertical oscillatory motion thirty times per minute. Thus, a gentle compound rocking motion that would excite the vestibular cells was provided to infants resting in the hammock. This motion was imposed upon infants in group A 30 minutes, 3 times a day.

Group B was the experimental group in which the infants were placed in the same type hammock as infants in group A but instead of motion being imposed upon them, they were free to remain still or initiate motion themselves by any slight bodily movement which results in swinging of the hammock. This was termed the actuated motion group.

Group C infants were placed in the same type hammock as those infants in group A and B but the hammock is stationary so that no motion of the hammock can take place even if the infant moves about. This group was added to control for the variables of extra handling of infants in the study and the fetal position they tend to assume when in the hammock.

Group D was the control group in which nothing out of the ordinary occurred as far as positioning or handling the infants was concerned. They were not placed in a hammock and received traditional nursing care as did the infants in group A, B, and C in regard to feeding, diapering, handling and necessary medical care.

There were a total of 9 male and 11 female infants studied; 14 were singleton births and 6 were twin.

Data were gathered on all groups in the following manner:

(1) To determine developmental behavior, the Graham Test, as modified by Rosenblith was administered on 252 days total age (gestational age plus living age) - about 37 weeks.

(2) To measure respiratory functioning, the pH, Pco_2 and Po_2 determinations (by micro techniques with use of present equipment in the nursery) providing an indication of respiratory stress were made on the infant on the 5, 12 days of life and every 7 days thereafter while they are in the hospital up to the 252 day total age. These determinations are done one-half hour before feeding time.

(3) To measure physical growth, weight and length increments were determined weekly on infants while hospitalized (same day as blood gas determinations).

(4) Morbidity and mortality records have been and are still being kept on these infants up to 30 months of age.

Data were gathered in the nursery over a 20-month period. Some longitudinal developmental data are still being gathered.

Findings and Discussion of Findings

Originally ten infants were to be in each study group. However, over the period of time of data gathering the kind of medical and nursing care changed in the nursery. The nursing staff started to talk to infants, rocked them in rocking chairs and provided new and different kinds of stimulation. Therefore, infants were not admitted to the study after an N of 20 had been obtained, an N of 5 in each study group. Such a small N limits statistical analysis and influences; however, data produced may show important trends that should lead to further study.

The first variable, that of development, was measured by the Graham Neonatal Behavioral Tool as modified by Rosenblith and by the Bayley Infant Scales. There was high interscorer reliability (above .90) on the Graham Test, prior to any testing. None of these scorers had prior knowledge of group assignment of study subjects. The Graham Tool was administered in the nursery; the Bayley Infant Scales in a studio located in the School of Nursing Building. In addition, many of the latter were also videotaped.

The Graham Test, the Behavioral Test for Neonates, as modified by Rosenblith has norms based on some 279 infants and meets the following criteria (established by Rosenblith). (1) behaviorally oriented (2) requires a minimum of equipment (3) relatively quantitative; and (4) takes a minimum amount of time to administer.

For motor coordination there is a general score. Group A had the highest mean for these scores for general maturation. This includes motor and tactile adaptive behaviors. This finding is consistent with the original Neal study as was the auditory response. The visual item, fixation with horizontal and visual persuit, had highest mean score, 10, in the control group, D, and a 9.6 mean for group B. Only the items, Pushes Feet, scaled 1-5, and Pull-to-Sitting, scaled 106, had scores approximating those of normal infants. Rosenblith utilized quartiles in presentations of her data. No attempt was made in the present study to follow this method of data presentation. The visual item should have further study. These infants are kept in 24-hour daylight conditions with lights overhead so that the infant may be closely observed. Such conditions provide for possible, constant visual stimuli that may not promote diurinal maturation of sleep-wake states. These conditions may also inhibit the use of the infant to visual cues. (See Tables #1 and #2)

The Bayley Index for each of the study groups (N=5 per group) at 6 months of age indicated that 60 per cent of the infants in group A and 40 per cent of the group D infants were below the 50th percentile for both mental and motor scores. However, by 12 months of age, 100 per cent of the infants in group A and 80 per cent of the infants in group D were above the 50th percentile. (See Table #3).

Table 1

Graham Scores (mean) for Infants on Vestibular Stimulation Study

Group	Motor Score (Possible score of 8)	Tactile Adaptive score (Possible score of 9)	General Maturation (Possible score of 17)	Auditory (Possible score of 5)	Visual (Possible score of 22)	Pushes Feet (Scale 1-5)	Pull to Sitting (Scale 1-C 4 best)
A - Total N=5	4.75	6.8	11.4	4.0	5.2	2.6	3.5
A - Exclude Twins N=4	5.0	8.0	12.5	4.25	6.0	2.5	3.75
B - Total N=5	4.2	6.1	10.3	2.6	9.6	1.8	3.4
B - Exclude Twins N=2	4.7	5.25	10.0	2.5	8.0	2.0	3.5
C - Total N=5	4.0	7.4	11.4	2.2	5.4	2.2	2.0
C - Exclude Twins N=4	4.5	7.5	12.0	2.25	6.25	2.5	2.6
D - Total N=5	4.0	6.4	10.4	3.4	10.0	1.8	2.4
D - Exclude Twins N=4	3.5	7.5	11.25	3.25	6.5	1.75	2.6

Table 2

Original Study of Regimen of Vestibular Stimulation

31 Experimental Infants
31 Control Infants

Graham Test

Test Items	Statistical Test	Significance
Motor	Analysis of variance	<.001
Tactile Adaptive	Analysis of variance	N.S.
General Maturation	Analysis of variace	<.001
Auditory	Analysis of variance	<.01
Visual	Analysis of variance	<.001
Muscle Tension	Analysis of variance	N.S.
Pushes feet	Analysis of variance	N.S.
Pull to sitting	Analysis of variance	<.01
Displacement of limbs		
arms	Analysis of variance	<.001
legs	Analysis of variance	<.05
Irr'tability	Chi Square	N.S.
Quality of cry	Chi Square	N.S.
Pitch of cry	Chi Square	N.S.

Table 3

Infants Within Plus or Minus One
Standard Deviation of Bayley Scores at 6, 12, 18 Months

Mean = 100

Standard Deviation - 16

	Mental	Motor
Group A		
6 mos.	0	0
12 mos.	0	0
18 mos.	0	1
Group B		
6 mos.	0	0
12 mos.	1	0
18 mos.	0	0
Group C		
6 mos.	0	0
12 mos.	1	0
18 mos.	1	1
Group D		
6 mos.	0	0
12 mos.	1	1
18 mos.	0	0

These are disturbing data. The infant who does not sit alone at 12 months is of concern to his mother and her well-meaning friends as well as to those who are professionally concerned about his growth and development. Will this infant catch up in his developmental pattern and approximate those scores of a full term infant? This answer is not known. A closer look at the raw data and percentile scores suggests these infants may not have a comparable developmental pattern to that of the full-term infant. Is there a focus on motor development for a longer period of time following a focus on mental development? These may not parallel each other in development for this small infant.

What about the test itself and its administration? These two questions may require further consideration for finer discrimination in test items. These infants were tested in the school studio. Would they have had a better performance if testing were done in the home? Recent work by Hunt [20] shows that these preterm infants have higher scores than those obtained in this pilot study. With an N of 60, testing being done in the home, scores adjusted for conceptual age rather than chronological age, she obtained data that suggest these infants are within a normal range of development. Two other variables in Hunt's study may have had some influence beyond the testing in the home and the adjustment for age, the time of the day that the test was administered and the personal characteristics of the examiner. All scoring in this pilot study was done at 9:00 a.m. on a Thursday morning.

There are a host of questions that may be asked about the development of these infants. Works by Drillien, Lubchenco and others show that even with a normal I.Q. they have a one-year lag in school performance.

The second variable studied was respiratory functioning. Promotion of viability of the young infant, particularly of the 27-28th week gestational age, is focused on lung functioning - the adequate exchange of gases. At this age there is the first potential for this because of lung development which now provides capillary proliferation and a potential for this because of lung development which now provides capillary proliferation and a potential airway for respiration. This development progresses through the 40th week of gestation to a point where adequate exchange is normally provided. In any given nursery for high-risk infants of low gestational age there are several infants being monitored because of respiratory or potential respiratory difficulty. As the infant grows and develops so do the lungs so that older infants in this same nursery are not in need of this monitoring and additional assistance with gas exchange by the provision of increased oxygen concentration within the incubator. The number of articles published yearly by physicians attest to lung functioning as a major problem in the infant of low-gestational age.

One means of measuring lung functioning is that of the level of blood gases. The PO_2 (partial pressure) and PCO_2 in arterial blood plus pH gives an indication of this actual exchange while the venous and capillary readings give a less accurate picture of this exchange. Apnea periods, both in number and duration, also give clues as to this functioning.

The blood gas levels, Po_2, Pco_2 and pH determinations were obtained weekly while the infants were hospitalized. These show that the study subjects within group A achieved a pH level higher than 7.4 and consistently maintained it throughout a four-week interval. However, it was not until the 5th week interval of the testing period that the study subjects within group D showed a pH of 7.4 and the ability to maintain it. Respiratory acidoses, a level from 7.4 or lower characteristically depresses neural activity. This variable merits further scrutiny. (See Table #4).

Table 4

Mean pH of 20 Study Infants at 7 Day Intervals

	Placed on Study	2nd week	3rd week	4th week	4th week
Group A	7.366	7.415	7.454	7.42	7.39
N	5	5	5	4	2
Group B	7.44	7.388	7.4	7.319	7.395
N	5	5	5	4	2
Group C	7.37	7.36	7.40	7.40	7.35
N	5	5	5	5	3
Group D	7.366	7.39	7.37	7.37	7.40
N	5	4	4	5	4

Table 5

Weight Gain in Grams of 20 Study Infants
When Placed on the Study and at 252
Days Total Age (Gestational Age Plus Living Age)

Group A	Mean Weight when placed on study	Mean Weight at 252 days total age	Mean Weight gains
Received Imposed Motion	1288.4	1977.4	689
Group B			
Self Actuated Motion	1297.6	2041	755.75
Group C			
Fixed Hammock	1269.2	1777.6	508
Group D			
Control	1277.8	1950.8	673

The third variable was weight gain and length increments. (See table #5 and #6). Group B, the self-actuated MOTION infants exhibited the greatest weight increase and group C, the fixed hammock infants, the least. Infants who had the imposed MOTION in the original Neal study (1965-1967) had a greater weight gain than the control group. These earlier findings are corroborated in the present study as illustrated by the comparison of the weight gains between group A and group C. Mean length increments were greatest for group A. This particular study group demonstrated the lowest mean length among all the groups when placed on the study. Whether or not length increment is related to growth hormone production or even due to chance contingencies in this study can only be a conjecture at this time.

The fourth variable morbidity and mortality was indirectly measured during the length of intial stay in the hospital. An infant is discharged to his home when he is deemed healthy and able to adjust to a home environment. All infants in group A were discharged prior to the 6th week of hospitalization. Only one infant in group B had a hospitalization beyond the 5th week of life. In group D, no infants were discharged until after the 6th week of life.

After discharge from the hospital morbidity and mortality data were kept on these infants, mostly as reported by mothers at time of Bayley Testing (see Table #8). There was one Sudden Infant Death, group B, a twin. Another infant was diagnosed as failure to thrive.

Table 6

Mean Length in Centimeters of 20 Study Infants When Placed on the Study and at 252 Days Total Age (Gestational Plus Living Age)

	Mean length when placed on study	Mean length at 252 days total age (c.m.)	Mean increment
Group A			
Imposed Motion	39.5	43.7	4.2
Group B			
Self Actuated Motion	40.5	43.5	3.0
Group C			
Fixed Hammock	40.4	42.9	2.5
Group D			
Control	40.1	42.7	2.6

Infants in this pilot study are being followed after they are 30-months of age until they reach 6 years for diagnosis and evaluations within a system of health care in Maryland. This effort is being coordinated by nurse faculty in the School of Nursing at Maryland.

These data suggest that the development of integrating biological behaviors of the small premature infant may be influenced by a specific motion pattern. The infant in group A had a higher pH (blood gas determination) level and a greater linear growth than did the infant in any of the other groups. The group B infant showed the greatest weight gain. This could actually be due to muscle mass gained through his efforts to actuate the hammock into motion and maintain this for a half hour period three times a day. The group C infant had lesser weight gain and linear growth but showed a mean pH (blood gas) of 7.4 by the third week of the study. It would seem that infants in groups A, B, and C all had a tendency to have respiratory difficulty in the 5th week of life; the mean pH was less than 7.4 while at this age the infants in group D had 7.4 as a mean for the first time. Subsequent patterns of pH levels should no doubt be studied over longer periods of time in an effort to learn more about the infant's respiratory functioning. Other variables should also be considered, the hematocrit level and nitrogen balance being two important ones.

It seems apparent that some patterns and trends require further study. Mental and motor developmental data show delays and they also suggest some catch-up patterns of mental and motor development that are not parallel nor are they consistent with that of the full-term infant.

Other motion patterns should be studied. Would the infant have greater developmental achievement and more desirable physiological functioning if he had a combination of imposed total body motion that would excite the vestibular cells and self-actuated motion that would complement this?

These data, although only trends because of the small number of infants studied, suggest that psychology, medicine and nursing must collaborate in these research efforts.

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