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The Effects of Asphyxia Neonatorum on Infant State Patterns

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THE EFFECTS OF ASPHYXIA NEONATORUM ON INFANT STATE PATTERNS

by

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VITA

The author, Richard John Sosnowski, is the son of Mathew J. Sosnowski and Kathleen V. (Brennan) Sosnowski. He was born August 20, 1959 in Chicago, Illinois.

His elementary education was obtained at Saint Victor's School, Calumet City, Illinois, and secondary education at Bishop Noll Institute, Hammond, Indiana, where he graduated in 1977.

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INTRODUCTION AND LITERATURE REVIEW

Asphyxia neonatorum defines a situation in which respiration has not begun within 30 seconds after birth. This deprivation of oxygen before, during, or immediately after delivery is an important cause of neonatal death or permanent brain damage in those who survive (Vulliamy, 1969).

Effects of Asphyxia on the Brain

Obviously, early detection of the degree of asphyxia in the newborn is extremely important. As well, an understanding of the physiological effects of the illness is crucial for diagnosing the extent of the brain damage it may cause. Asphyxia neonatorum will lead to a decreased amount of oxygen in the arterial blood and a retention of carbon dioxide (respiratory acidosis). The absence of oxygen and the abundance of carbon dioxide will cause an accumulation of lactic acid and eventually, metabolic acidosis (Lerch, 1974). Inhibition of glycolysis by acidosis limits the energy available to the myocardium and the brain (Eldelman & Hobbs, 1979), which can result in significant brain injury. The relation of perinatal asphyxia to serious brain damage can be seen in the extensive autopsies on the bodies of infants who had died from perinatal asphyxia conducted by Flodmark and his associates (1980). These autopsies revealed lesions throughout many areas of the brain.

The mechanisms whereby these lesions are mediated are elucidated in a study of asphyxiated primates. Mixed metabolic and "placental" respiratory acidosis were found to be associated with a decreased fetal umbilical oxygen uptake and lowered saturations and oxygen tensions occurred in the asphyxiated group. The umbilical blood flow is significantly lower inthe asphyxiated group and this leads to less oxygenated blood reaching the brains of these animals. Although there was no difference (between the asphyxiated and non-asphyxiated groups) in cerebral blood flow per gram of tissue, the blood which travelled to the brain was less well oxygenated (Behrman, Lees, Peterson, de Lannoy, & Seed, 1970).

Because of the increased pressure of the blood flow in the brain stem and the fact that the blood is less well oxygenated, many parts of the brain may be seriously damaged. Sechzner's (1973) study of monkey fetuses revealed that although asphyxia of 0-7 minutes during birth did not lead to any significant signs of brain damage or neurological deficit, longer period of asphyxia (lasting 8-11.5 minutes) did produce permanent brain injury. Bilateral and symmetrical lesions were produced in centers of the brain stem and diencephalon concerned with sensory input. The most vulnerable areas were those associated with the reticular area of the brain stem, namely the inferior colliculus, the ventrolateral thalamus, the sensory trigeminal and the medial cuneate (see Figure 1). Even more marked evidence of brain injury was found in infant monkeys that had been

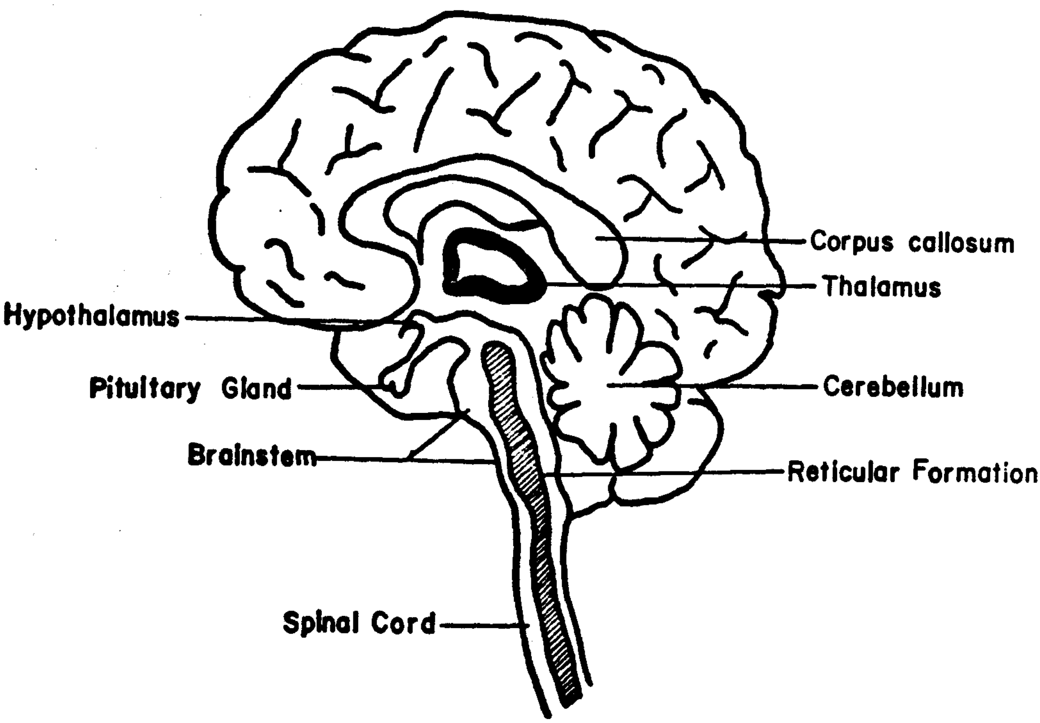

Figure 1. Major areas of the human brain.

asphyxiated for a time of 12-17 minutes. Again, the consistent pattern of bilaterally symmetrical focal lesions was found. The basic lesions of the thalamus, inferior colliculi, and other brain stem nuclei are more extensive and severe. The ventrolateral group of thalamic nuclei and the medial thalamic nuclear group was also affected.

Asphyxia and Sleep-Wake Cycles

As was mentioned earlier, one of the areas of the brain stem affected by asphyxia neonatorum is the reticular formation. The neurons of the reticular formation send out axons which descend to the lower medulla and ascend to terminate in the periacqueductal gray, subthalamus, hypothalamus, and nonspecific thalamic nuclei (Scheibel & Scheibel, 1958). This network of axons is called the reticular activating system. Moruzzi and Magoun (1949), found that electrical stimulation of the midbrain during nonREM sleep causes fast activity to replace slow waves in neocortical EEG, and the animal wakens. Lesions destroying the midbrain reticular formation were found to affect arousal response. Other studies have shown that REM sleep is decreased by lesions in the reticular formation (Siegel, 1979).

There has been much controversy about the role of the reticular formation and the reticular activating systems (if such a system truly exists) in the influence of sleep-waking cycles. It is believed that the reticular formation does have some effect on the regulation of these cycles (Jouvet, 1967); but it has not been determined how strong the effect may be (Siegel, 1979).

Types of Asphyxia

According to Fitzpatrick (1966), there are two types of asphyxia neonatorum, asphyxia livida and asphyxia pallida, the latter being more critical. Asphyxia livida is the milder form in which the infant's face and body are of livid hue; the vessels of the umbilical cord are distended with blood; and the muscle tone is good. Any attempt to open the mouth or move the extremeties will meet some resistance. Asphyxia pallida is a more severe case in which the body and face are of deathlike pallor; the vessels of the umbilical cord are empty; and the muscles are relaxed. In this state the infant is entirely limp.

The time at which the asphyxia occurs may have some effect on the amount and type of brain damage that results. Apnea is a term used to denote the temporary absence of respiration; it may be classified as early (occurring immediately after birth) or late (cessation of respirations for more than 30 seconds after spontaneous breathing has been established and sustained) (Lerch, 1974). There is reason to believe that the fetus and the newly born baby are better able to survive the effects of early asphyxia without the development of permanent neurological changes (Craig, 1969). However, the actual interval of apnea beyond which permanent central nervous system damage is certain to occur is unknown.

Causes of Asphyxia

There are numerous causes of asphyxia neonatorum (Craig, 1969). Those which operate before delivery include dysfunction and premature separation of the placenta; interference with circulation in the umbilical cord by compression; and inadequate oxygenation of the maternal blood. Other causes of asphyxia not necessarily associated with anoxia (deprivation of oxygen) before birth are prematurity and congestion or hemmorrhage. Also anasthetics or analgesics administered to the mother may cause a sluggish respiration in the infant at birth. In a recent article by Chernick and Craig (1982), it was found that endrogenous opiates appear to play a role in the ventilatory response of neonates. This was shown in the neonatal rabbit when primary apnea induced by asphyxia was nearly abolished by naloxone, an opiate antagonist.

After delivery asphyxia can result from obstruction of the respiratory passages by meconium (mucus) inhaled during or after birth. Prolonged labor prior to delivery and, to a lesser extent, postmaturity are among other factors which can contribute to the occurrence of neonatal asphyxia.

Assessing the Degree of Asphyxia

In trying to correlate various forms of cerebral dysfunction in the developing infant with the degree of anoxia suffered at birth, some accurate form of assessment is helpful. Most widely used is that of the Apgar (see Table 1), in which the evaluation is made at a set time (usually 1 and 5 minutes) after delivery of the head. This assessment enables the physician to recognize and select the babies with an abnormally low score who are in need of immediate resuscitation. Vulliamy (1969) states that a score of 5 or under on this scale suggests a degree of anoxia sufficient to increase significantly the chances of some permanent impairment of cerebral function.

Assessing the Condition of the Newborn

Behavioral state patterns are widely used measures of present physical condition, since they are the infant's most continuous characteristic (Berg & Berg, 1979). Because of their value in assessing the condition of the newborn. These patterns in infants have been studied by many researchers. In the area of sleep states, two major categories have been identified: (1) an active sleep state, generally characterized by irregular respiration, low muscle tone, and the occurrence of rapid eye movements (REMs) and (2) a quiet sleep state, characterized by a lack of motor movement, absence of eye movements, and regular respiration. Thoman (1975) found that full-term normal infants spend approximately 82% of total observation time in some form of sleep. It was also found that 40% of this sleep time was spent in quiet sleep. In addition, Thoman (1975) observed that infants spend about 5% of the time in a state of drowsiness and 13% of the time is spent in an awake state (alert

TABLE 1

Apgar Classification of the Newly Born Infant

Sign	Score 0	1	2
Heart rate	Absent	Under 100/min.	Over 100/min.
Respiratory Effort	Absent	Weak, irregular	Strong, regular
Muscle Tone	Limp	Some flexion	Active movement
Reflex Irritability	No response	Weak movement	Cry
Color	Blue/pale	Body-pink Extremeties-blue	Completely pink

with motor activity, alert without motor activity, or crying/fussing).

Effects of Asphyxia Sequelae on Infant State Patterns

The state patterns that have been observed in normal newborn infants may be disrupted by stress due to perinatal illness. For example, Prechtl, Theorell, and Blair (1973) observed that bilirubinaemic babies showed a drastic reduction in the amount of time spent in awake states. Prechtl and his associates also observed a group of high-risk infants which included several babies with severe neonatal asphyxia. He discovered that this high-risk group spent abnormally short periods of time in active sleep and none of the infants studies produced a long sleep cycle. Also, the amount of time spent in awake states varied greatly.

The Present Study

As the above mentioned literature indicates perinatal asphyxia may affect infant state patterns through two means: (1) Asphyxia neonatorum is associated with various forms of illness and thus may indirectly alter state patterns; (2) A more direct effect of asphyxia is that it may lead to the formation of lesions in areas of the brain, including the reticular formation. In addition, there is strong evidence to support the theory that the reticular activating system is partially responsible for the control of the cyclical sleep-waking patterns in humans. Therefore, it seems likely that infants who suffer asphyxia neonatorum will show state patterns which differ significantly from those of non-asphyxiated infants. To test this hypothesis, a study was designed in which several groups of non-asphyxiated infants were compared to babies who were asphyxiated at birth. Three groups of asphyxiated infants were selected: (1) premature infants (PT); (2) healthy full-term infants (HFT); (3) full-term infants who suffered from perinatal illness (FT/ICN). Each group of babies was observed and their state patterns were recorded using a 10-state classification scale.

By comparing the state patterns of the asphyxiated group to those of the healthy full-term group, similarities and differences were found. The states that differed in the asphyxiated group were then compared to those in the FT/ICN group. Again similarities and differences were found. The states that were found to be different in the asphyxiated group were next compared to those of the PT group. Finally, differences were found that could not be attributed to either of the two groups/factors FT/ICN (perinatal illness unrelated to asphyxia) or PT (prematurity). These state differences may be direct results of asphyxia neonatorum itself (see Figure 2).

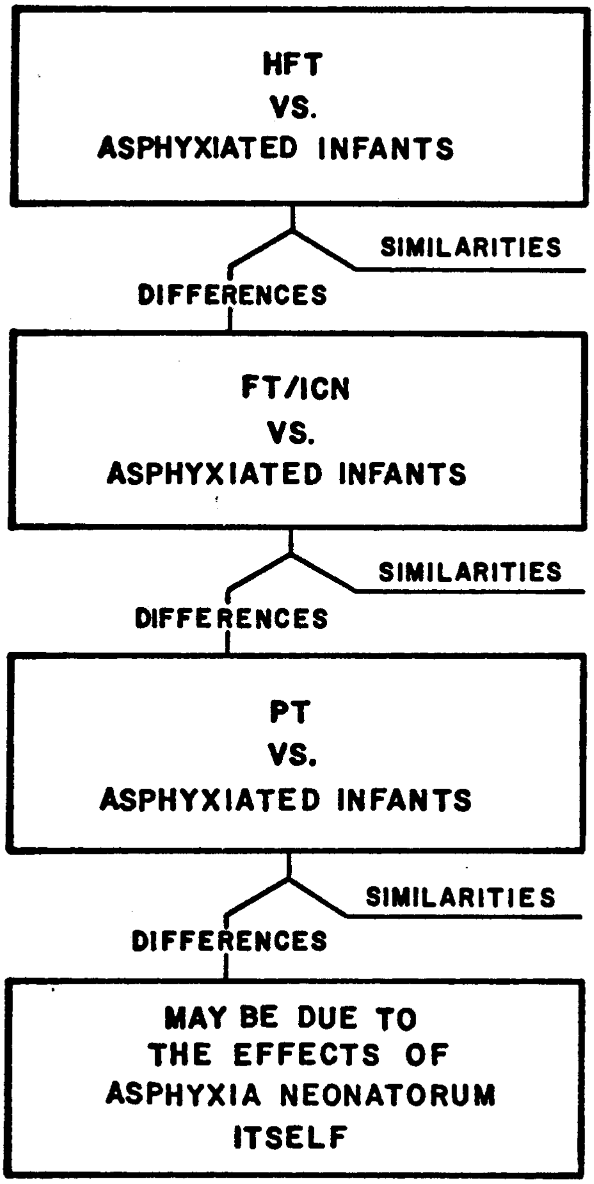

Figure 2. A schematic diagram of the design of this study.

METHOD

Subjects

A total of 24 subjects were examined. Six of the subjects (2 males and 4 females) recruited suffered from asphyxia neonatorum. The data on 18 additional infants were selected randomly from a pool of observations collected in a previous study (Holmes, Nagy, Sosnowski, & Slaymaker, submitted). This group of 18 non-asphyxiated infants can be separated into three categories on the basis of their perinatal conditions: (1) 6 preterm infants (2 males and 4 females) whose gestational ages ranged from 29 to 36 weeks (PT); (2) 6 full-term infants who suffered some degree of perinatal illness (2 males and 4 females) (FT/ICN); and (3) 6 normal healthy full-term infants (2 males and 4 females) (HFT). All of the infants were from white middle socioeconomic status families, were of birth weights appropriate for their gestational ages, and were without congenital anomalies or CNS damage. (See Table 2 for a more precise description of the subject population.)

The six infants in the asphyxiated group all had additional medical problems which, in most cases, were related to the asphyxia itself. Also, there were problems experienced by many of the mothers before or during deliveries. In order to study the effects of asphyxia neonatorum on the state patterns of the group as a whole,

TABLE 2

Medical Events Summaries: Means and Standard Deviations (S.D.) for Preterm Infants (PT), Sick Full-term Infants (FT/ICN), Healthy Full-terms (HFT), and Infants who were Asphyxiated at Birth (ASPX)

Variable	Statistic	PT	FT/ICN	HFT	ASPX
Gestational age (in weeks)	Mean	33.17	39.83	40.50	41.16
	S.D.	3.13	1.72	0.55	1.33
Birthweight (in grams)	Mean	2005.83	3283.50	3352.83	3069.33
	S.D.	866.40	656.29	431.28	1270.41
Birth Length (in cm)	Mean	43.17	49.70	51.60	46.90
	S.D.	5.27	1.68	1.82	9.40
Birth Head circumference (in cm)	Mean	30.47	28.80	34.58	34.50
	S.D.	3.59	14.15	0.74	3.50
Obstetric complications scale score	Mean	86.83	115.50	120.67	73.00
	S.D.	14.89	30.11	27.78	11.80
Postnatal complications score	Mean	93.83	84.50	160.00	76.17
	S.D.	32.62	12.03	0	18.32
1-min. APGAR score	Mean	6.83	6.83	8.83	2.17
	S.D.	1.60	2.85	0.41	2.04
5-min. APGAR score	Mean	8.00	8.83	9.33	4.67
	S.D.	0.89	0.75	0.52	3.14
Conceptional age at discharge (in weeks)	Mean	38.17	41.67	40.50	35.50
	S.D.	1.94	1.03	0.55	16.99
Days in hospital	Mean	31.67	11.83	4.00	17.33
	S.D.	27.25	7.41	1.55	11.08

the individual circumstances surrounding each baby in this group must be examined.

Subject#1 was a male whose gestational age (GA) at birth was 39 weeks; his birth weight was 3870 grams. He was delivered by primary Cesarian section (low cervical transverse) because of maternal problems. During the delivery the infant experienced primary fetal stress in the form of hemorrhagic shock due to velamentous insertion of the umbilical cord. At birth he was described as being markedly depressed and "shocky"; his heart rate was a meager 60 beats/minute and he was immediately "bagged" (hand resuscitated) with 100% oxygen, after which he was intubated. After resuscitation his heart rate rose to 100 beats/minute and he was transferred from the delivery room to the infant special care nursery (ISCN) where he showed some signs of spontaneous activity but remained markedly pale. Because of hypocalcemia Subject#1 experienced seizures characterized as multifocal chronic. Also, he experienced acute blood loss which lead to hypovolemia and shock.

Table 3 describes 1 and 5 minute Apgar scores for each subject. It demonstrates that Subject#1's respiratory effort was scored as 0 for 1 and 5 minutes alike. Thus, for at least the first 5 minutes of life Subject#1 was not breathing at all. Apnea occurred early and was eventually reversed by resuscitation. Asphyxia pallida would be the appropriate diagnosis in this case.

TABLE 3

Apgar Scores of Each Asphyxiated Infant

Scores: 1 minute/5 minutes

Subject	#1	#2	#3	#4	#5	#6
Heart rate	1/2	1/2	0/1	2/2	1/2	2/2
Respiration	0/0	0/0	0/0	0/0	1/1	0/2
Muscle tone	0/0	1/1	0/0	0/1	1/1	0/1
Reflexes	0/0	0/1	0/0	0/0	0/0	0/1
Color	0/0	0/1	0/0	0/0	1/2	0/0
Total Score	1/2	2/7	0/1	2/3	4/6	2/6
Diagnosis	Asphyxia pallida	Asphyxia livida	Asphyxia pallida	Asphyxia pallida	Asphyxia livida	Asphyxia livida

Subject#2 was a small-for-gestational-age female (GA = 40 weeks; birth weight = 1500 grams) who was the second born of twins. After the spontaneous delivery of her sibling, a vaginal examination revealed that Subject#2 had converted during delivery to transverse lie, back down, with prolapsed arm and umbilical cord. Gentle attempts to convert her to the normal position were unsuccessful. Therefore, a Cesarian section was immediately performed. The fact that she was small for gestational age was most likely related to a twin-twin transfusion, with resulting postmaturity and dysmaturity. After birth, Subject#2 was diagnosed as having suffered chronic fetal asphyxia. She was intubated and resuscitated for 1-2 hours. In the ISCN she showed vigorous respiratory effort and was extubated in 50% oxygen. Subject#2 was described as scrawny, hyperalert, and "wasted" in appearance.

As can be seen in Table 2, at 1 minute after birth, Subject#2 was not engaging in any respiratory effort as indicated by her score of 0 for respiratory effort. By 5 minutes her score on this item rose to 2, indicating that she was breathing in a strong regular manner. Also her color was pink and her muscle tone did show some flexion. Because of the nature of this medical information, it is possible to conclude that in comparison to Subject#1, Subject#2 suffered from the milder form of asphyxia, asphyxia livida.

Subject#3 was a female who was slightly small for gestational age (GA = 42 weeks; birth weight = 2610 grams). After a spontaneous delivery, asphyxia was evidenced by a thick meconium and no heart rate. She was intubated and resuscitated with a ventilator, cardiac massage, epinephrine, calcium injections, and transfusions of bicarbonate and glucose. By 15 minutes of age, Subject#3 had developed good heart tones and stable blood pressure. An EEG reading completed during the newborn period showed a mild reduction of amplitude in the left hemisphere. Also, a CT scan revealed small amounts of blood over convalutions on the left side of the cerebral hemisphere (a small subarachnoid hemorrhage).

As can be seen in Table 2, Subject#3's Apgar scores were 0 on every item at 1 minute. By 5 minutes, she had improved slightly and only in heart rate. These scores reveal that after birth this infant was limp, bluish in color, and had no respiration or heart rate. These signs signal that Subject#3 suffered from asphyxia pallida.

Subject#4 was a large-for-gestational-age, postmature (GA = 42 weeks; birth weight = 3656 grams) female. She suffered from pneumonic meconium aspiration at birth which caused severe respiratory distress. One of the causes of her asphyxia was the location of her umbilical cord which was wrapped around her neck and shoulder. Other asphyxia-related problems experienced by Subject#4 were anoxic encephalopathy, thrombocytopenia, and hypoxia. After birth the Subject was immediately "bagged" and given a mixture of 40% oxygen. It was later found that her heart was mildly enlarged. Subject#4 experienced chronic multifold seizures while in the ISCN. A CT scan showed evidence of subarachnoid hemorrhaging and brain ischemisa within the frontal lobes. Also, an EEG reading revealed bilateral independent epileptiform discharges, which are often seen in neonatal seizure disorders due to fresh cerebral lesions. These discharges were at a maximum in the following regions: central, frontal, and temporal regions of her brain's right hemisphere and in the central and occipital regions of the left hemisphere. She was diagnosed as having fairly widespread cerebral damage due to asphyxia enonatorum.

Table 2 lists the Apgar scores for Subject#4. It can be seen that at birth she did not engage in spontaneous respiration or crying. Her color was pale and cyanotic; and her limbs were limp. By 5 minutes she did show some flexion in muscle tone, but all of her other vital signs remained poor. Because of these observations, Subject#4's asphyxia can be classified as the pallida type.

Subject#5 was a small-for-gestational-age male (GA = 34 weeks; birth weight = 1940 grams). His mother was a smoker who experienced bleeding during the first trimester of her pregnancy, and noticed decreased fetal movement for the two months prior to her son's birth. At birth, Subject#5's amniotic fluid was meconium stained and he required some resuscitation in the delivery room where he was masked and "bagged" with oxygen. He did, however, produce a weak cry and had clear lungs and a regular heart beat. His medical records indicate that he was dysmature and suffered from encephalitis, congestive heart failure, possible congenital infection, myocardopathy, and hypotonia.

Metabolic acidosis due to perinatal asphyxia lead to seizures with periods of prolonged stiffening. A CT scan completed during the newborn period revealed acute subarachnoid hemorrhages which filled the interhemispheric fissures and the cortical sulci. Furthermore, an EEG reading showed severe cerebral abnormality with cerebral activity depressed in the posterior head regions.

From looking at Subject#5's Apgar scores (see Table 2), it seems that he suffered from the mildest form of asphyxia, asphyxia livida. He did have a constant heart rate, was pink in color, and showed some respiration and crying.

Subject#6 was a large-for-gestational-age female (GA = 42 weeks; birth weight = 4840 grams) whose mother was a diabetic with a pregnancy further complicated by hypothyriodism and obesity. During most of her pregnancy, this mother was taking synthroid. Her blood pressure increased to 150/100 during the three weeks before delivery. At birth, there was thick meconium stained fluid and Subject#6 had to be intubated and hand respirated in the delivery room. In addition, the delivery was complicated by shoulder dystocia. The subject was described as being lethargic and extremely large with petechrae covering her head and upper extremeties. At 9 hours of age she became cyanotic and began seizing. These seizures were probably secondary to her birth asphyxia. Other medical problems experienced by Subject#6 were: anoxic encephalopathy, thrombocytopenia, polythemia, and scleral hemorrhaging. A CAT scan completed during the newborn period showed a diffuse bifrontal lycenices and subarachnoid bleeding. Furthermore, an EEG recording revealed activity which is usually seen after wide spread cerebral damage.

In Table 2, Subject#6's Apgar scores for each item are listed. A total score of 6 at 5 minutes, leads to a diagnosis of asphyxia livida. At 5 minutes, she had a strong respiratory effort, a heart rate over 100/minute, and did show some movement.

From the preceding information, it can be seen that three of the asphyxiated babies were classified as having suffered from mild asphyxia (asphyxia livida); the other three were diagnosed as having the more severe form of asphyxia (asphyxia pallida). Each baby had a unique set of additional medical complications which were usually either a cause or effect of their asphyxia.

Of the remaining 18 infants, none showed any signs of birth asphyxia and were without known damage to the central nervous system. All had 5 minute Apgar scores of 7 or higher. In the FT/ICN group there were a variety of medical problems found: 2 of the infants suffered from sepsis of the blood; 1 had a depressed skull fracture; 2 experienced pulmonary hemorrhaging; and 1 suffered from essophageal atresea.

Procedure

Every week that the baby spent in the infant special care nursery, his or her state patterns were assessed at three different time periods (i.e., morning, afternoon, and evening) for approximately 5.5 hours of total observation time. All of the observers were trained to 90% reliability and used the following state categories by Holmes, et al. (submitted).

(1) Quiet sleep. Respiration is normal and the infant's eyes are closed and still. There is little or no motor activity (i.e., no more than a startle or slight movement of one limb).

(2) Active sleep without REM. Respiration is shallow and irregular. The infant's eyes are closed and still. Motor activity is present.

(3) REM sleep. The infant's eyes are closed, although they may open briefly, and rapid eye movements are present. Motor activity may or may not occur during this epoch.

(4) Drowsy. The infant's eyes may be partially open or fully open but dazed in appearance. Rapid eye movements and/or motor activity may or may not occur.

(5) Alert inactivity. The infant's body and face are relatively quiet and inactive; and the eyes are "bright and shining" in appearance (Wolff, 1966).

(6) Alert activity. The infant's eyes are wide open and generalized motor activity is present.

(7) Crying and fussing. The infant's eyes are generally open, but may be closed. There is usually motor activity and cry bursts or agitated vocalizations occur during this epoch.

Each infant's predominant state was recorded every 10 seconds onto computer scored optical scan sheets. Because of the short recording interval (10 seconds) and the general disorganization of state in young infants, there was much movement in and out of the different states. Many of the transitions appeared to be more artificial than real (e.g., within a crying episode the infant paused in his crying to catch his breath). Therefore, it was decided to consider only those transitions as "real" when the infant remained at least 30 seconds in that state.

A computerized smoothing procedure was programmed to reduce the extraneous variability in state transitions. The result of this smoothing procedure was a revised data stream, showing fewer state transitions, unambiguous transitions between states, and longer within epochs the occurrence of a state epoch was defined as a minimum of three consecutive epochs in that state. State observations not falling into an epoch by this definition were recorded and appended to the preceding epoch or prefixed to the subsequent epoch. Recoding was accomplished through a decision hierarchy based upon the similarity and temporal proximity of non-epoch observations and adjacent epochs, as well as within subject estimates of transition likelihood.

Once smoothed and recoded according to the procedures just described new means, standard deviations, and variances were calculated for the percentages of time spent in each state by every infant. Averages for all four groups were computed for each state and for combinations of various states. Analyses of variance were performed on those data in which differences were observed

RESULTS

The amount of time spent in each state was averaged across all observations for each infant, and the percentage of total observation time spent in each state was determined. Each state was examined separately in order to highlight specific similarities and differences between the asphyxiated and the non-asphyxiated groups. These findings enabled the author to propose several hypotheses concerning the state patterns of infants who have suffered from perinatal asphyxia.

Sleep States

A significant difference between groups was obtained in the amount of time spent asleep ($F = 3.432$, $p < .05$). The means and the standard deviations for the percent of the total observation time spent in each sleep state are presented in Table 4. When all sleep states are combined, it can be seen that the mean percent for total sleep for the asphyxiated babies (66.17%) was similar to that for HFT infants (63.57%). The asphyxiated babies did, however, differ significantly from both groups of sick infants. The PT (86.36%) and FT/ICN (85.88%) spent significantly more time sleeping ($t = -2.037$, $p < .05$). Figure 3 depicts this finding, and also shows the data obtained from each infant in the asphyxiated group. The three infants who suffered from asphyxia pallida (#'s 1, 3, and 4) are found at the outer edges of the distribution, while the babies with asphyxia

TABLE 4

Means and Standard Deviations for Percent of Total

Observation Time Spent in Sleep States

State/Group	Statistic	PT	HF/ICN	HFT	ASPX
Total Time	Mean	0.8636	0.8588	0.6357	0.6617
Asleep	S.D.	0.1177	0.0777	0.3015	0.3033
Quiet	Mean	0.6588	0.5823	0.3762	0.4687
Sleep	S.D.	0.0854	0.1077	0.1905	0.2472
Active	Mean	0.1141	0.0395	0.0368	0.0426
Sleep	S.D.	0.0657	0.0276	0.0170	0.0366
REM	Mean	0.1807	0.2370	0.2227	0.1504
Sleep	S.D.	0.0940	0.0989	0.1474	0.1474

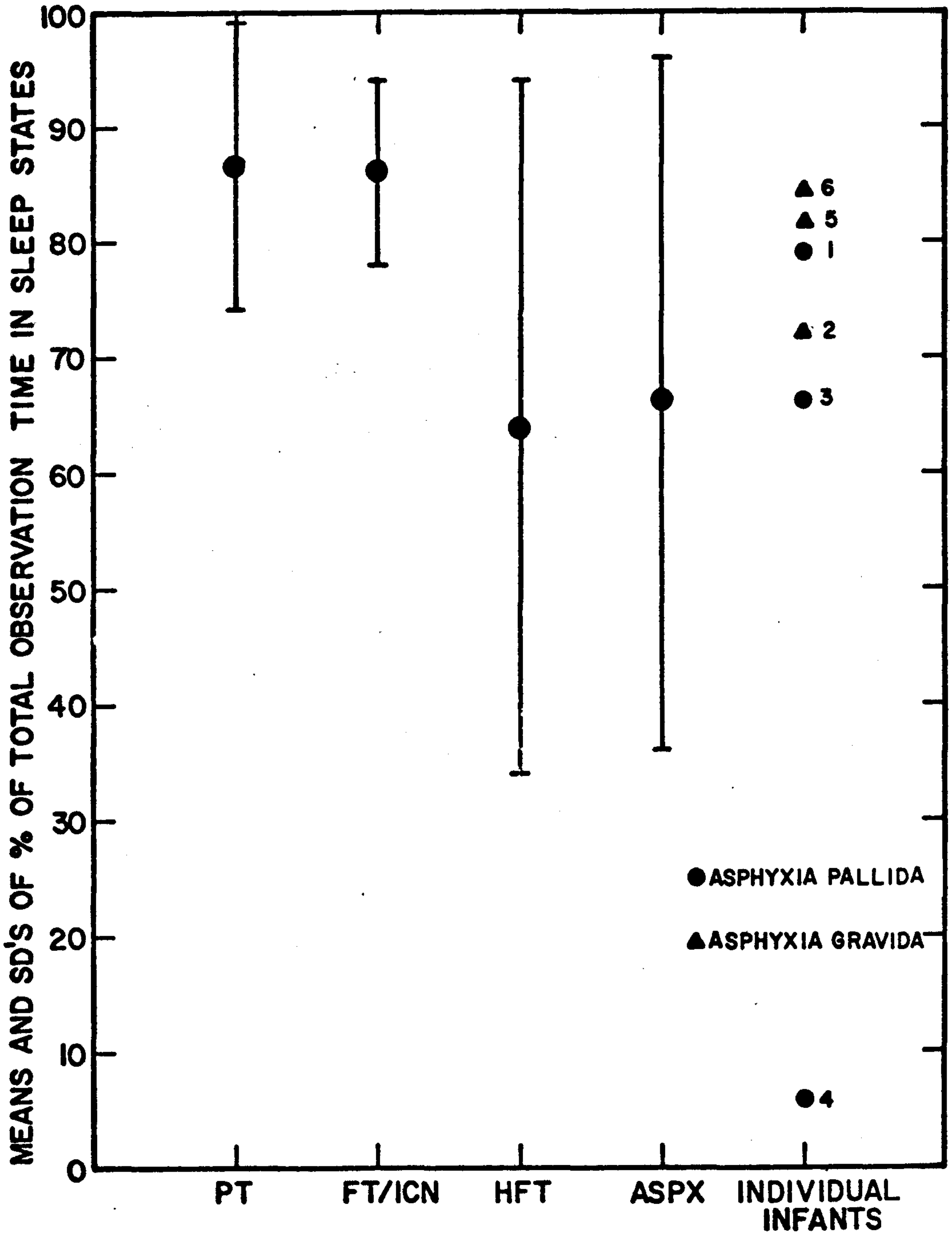

Figure 3. Means and standard deviations for percent of total observation time spent in sleep states.

livida (#'s 2, 5, and 6) fall in the center of the distribution.

Quiet sleep. A oneway analysis of variance showed a significant group difference (F = 3.241, p< .05) for the state of Quiet Sleep. However, there were no significant differences found in the comparison of the asphyxiated and the non-asphyxiated groups (PT, FT/ICN, and HFT) (t = 0.636). It can be seen from Figure 4 that the asphyxiated group did have the largest standard deviation of the four groups, largely as a result of the very deviant performance of Subject#4, who suffered from the more severe degree of asphyxia. When the percent of total sleep time spent in Quiet Sleep was calculated, it was found that the asphyxiated babies spent 65.49% of their sleep time in this state, which was similar to the average of 64.23% for the other three groups (see Table 5).

On the basis of these data, it was concluded that in the state of Quiet Sleep, the asphyxiated group spent a similar amount of time when compared to the non-asphyxiated groups. Time spent in Quiet Sleep appears not to be affected by asphyxia neonatorum.

Active Sleep. A significant group difference was found for the amount of active sleep (F = 6.551, p< .05). Planned comparisons indicated significant differences between the PT and the asphyxiated groups (t = -3.128, p< .05), while all other contrasts (FT/ICN vs. ASPX; HFT vs. ASPX; and Non-asphyxiated vs. Asphyxiated) were nonsignificant. Figure 5 shows group means and standard deviations as well as the individual percent of time for the asphyxiated infants contrasted

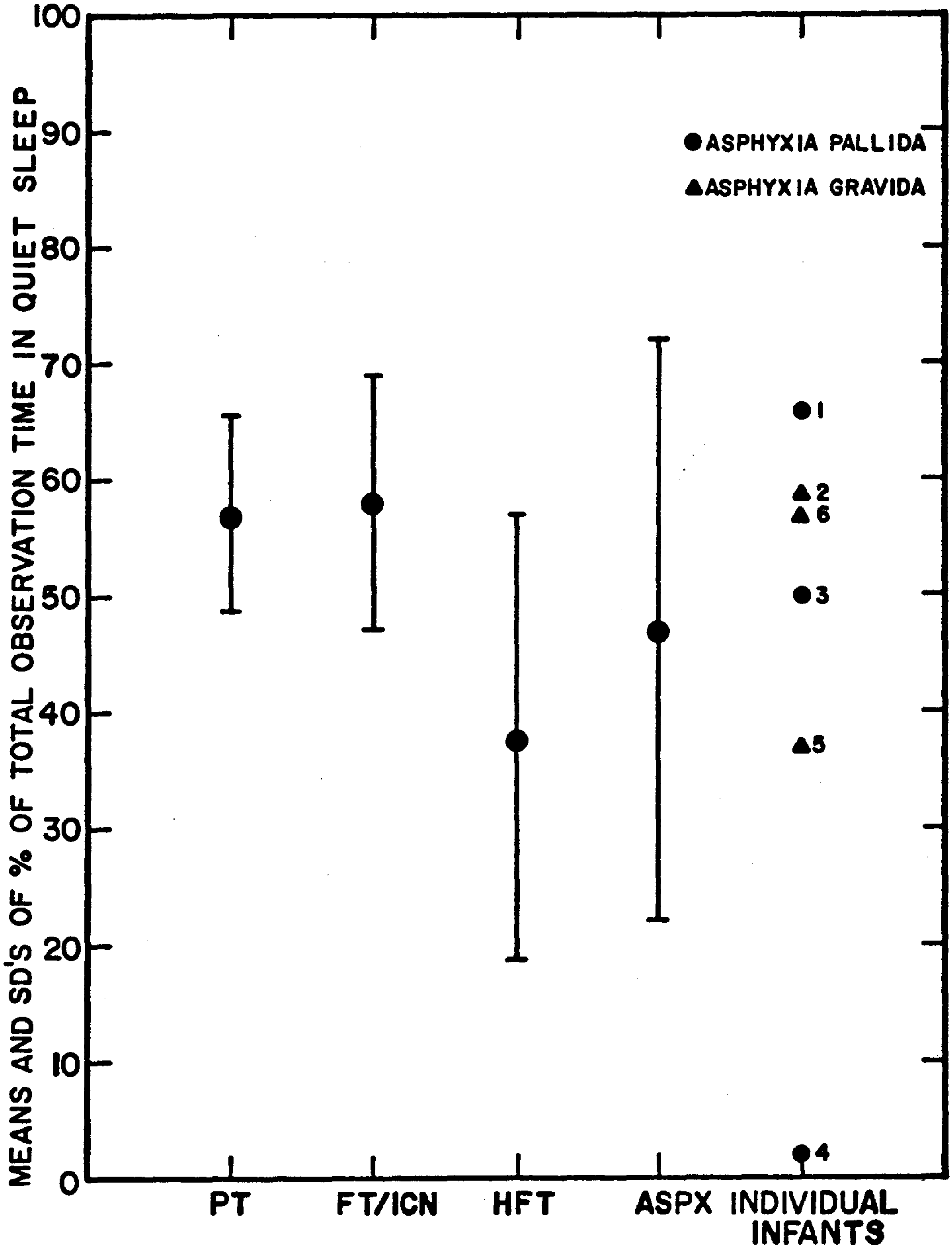

Figure 4. Means and standard deviations for percent of total observation time spent in quiet sleep.

TABLE 5

Means and Standard Deviations for Percent of Total

Observation Time Spent in Each Sleep State

State/Group	Statistic	PT	FT/ICN	HFT	ASPX
% Quiet	Mean	0.6661	0.6762	0.5847	0.6549
Sleep	S.D.	0.1016	0.0927	0.1284	0.2076
% Active	Mean	0.1286	0.0449	0.5847	0.6549
Sleep	S.D.	0.0685	0.0313	0.1848	0.0557
% REM	Mean	0.2053	0.2789	0.2909	0.2844
Sleep	S.D.	0.0916	0.1194	0.1791	0.2492

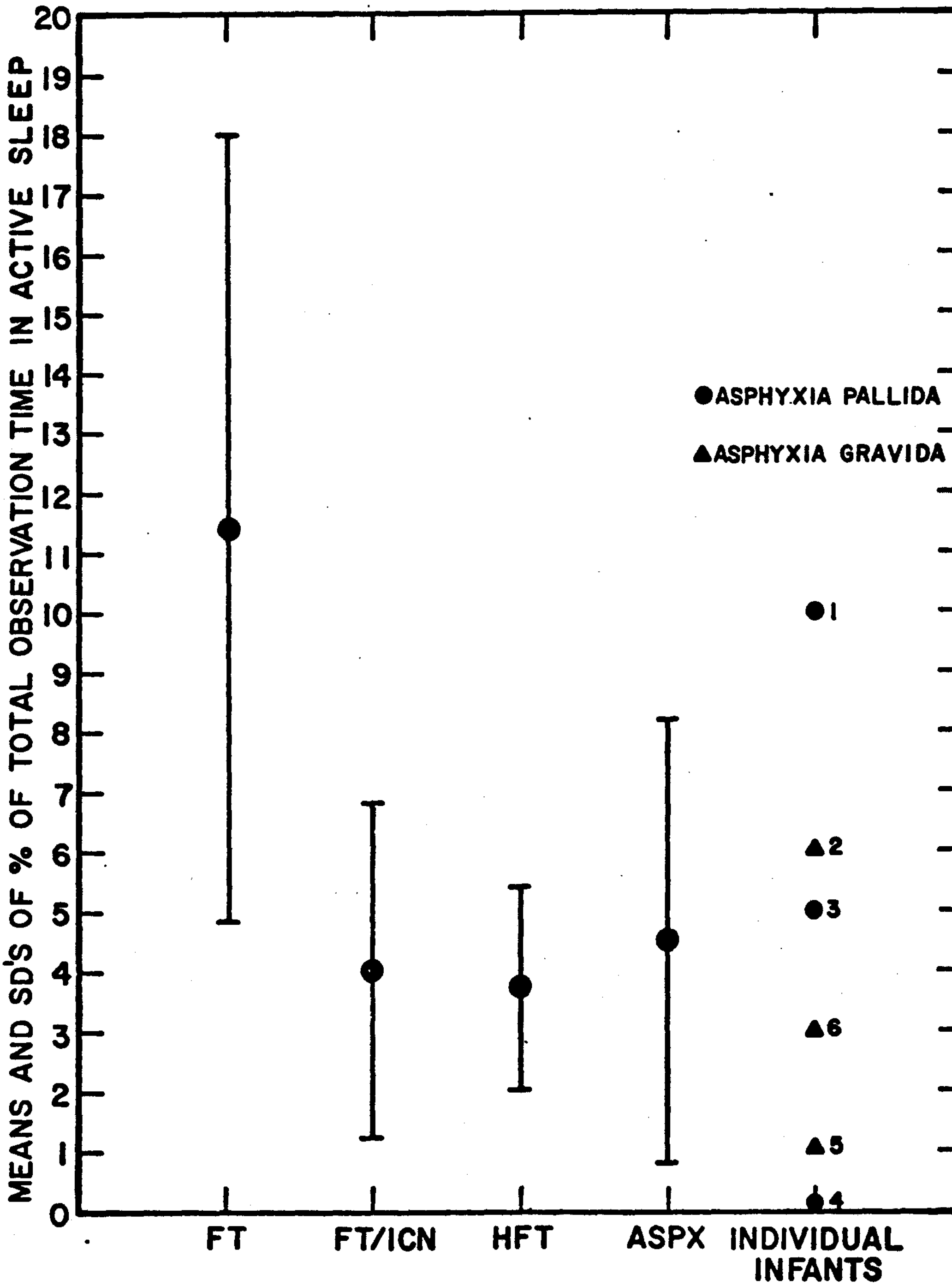

Figure 5. Means and standard deviations for percent of total observation time spent in active sleep.

to the three non-asphyxiated groups. For this state, Subject#1 is the only infant who is more than one standard deviation from the mean of the asphyxiated group. Table 4 shows the means and the standard deviations of the percent of total sleep time in Active Sleep for each group. The asphyxiated group (6.07%) spends more time than the FT/ICN group (4.49%), but less time than the PT (12.86%) and the HFT (12.44%) groups.

From these data, it can be seen that in the state of Active Sleep, most of the asphyxiated babies spent similar amounts of time when compared to the full-term non-asphyxiated babies. Premature infants are unlike the asphyxiated infants, spending much more time in Active Sleep.

REM Sleep. For the state of REM sleep, neither the overall analysis (F = 0.83, n.s.) nor any of the contrasts (PT vs. ASPX; FT/ICN vs. ASPX; HFT vs. ASPX; and Non-asphyxiated vs. Asphyxiated) proved significant. It can be seen from Table 4 that the asphyxiated babies spent the least amount of time in this state (15.04%) when compared to any of the non-asphyxiated groups, PT (18.07%), FT/ICN (23,70%), HFT (22,27%). When the percent of total sleep time spent in REM Sleep was examined, again none of the contrasts proved significant. Table 5 reflects the fact that the asphyxiated group spent approximately the same amount of sleep time in this state (28.44%) as the other full-term groups, FT/ICN (27.89%), HFT (29.09%). In general, the asphyxiated group did spend the least amount of time of all the groups in the state of REM sleep; but those differences were not statistically significant.

Awake States

An overall analysis of variance demonstrated a significant difference between groups for amounts of time spent in the awake states. Table 6 presents the means and the standard deviations for the percent of total observation time spent in all awake states. When the percent of total alert time is examined (see Figure 6). It can be seen that the mean for the asphyxiated infants at 33.83% is similar to the mean for the HFT babies (36.43%). The asphyxiated group spends significantly more time awake, when compared to the PT and FT/ICN groups ($t = -2.307$, $p < .05$). It can be seen that all of the asphyxiated infants, except Subject#4, fall within one standard deviation below the mean for both the asphyxiated and HFT groups.

Drowsy. No significant differences between groups were obtained for the Drowsy state ($F = 1.143$, n.s.). Table 6 presents the means and the standard deviations for the percent of time each group spent in this state. The asphyxiated infants spent the most time in the Drowsy state (11.91%) compared to the PT (7.47%), FT/ICN (6.50%), and HFT (6.27%) groups. Table 7 presents the means and the standard deviations for the percent of awake time spent by each group in the Drowsy state. Although none of the four planned comparisons mentioned earlier proved to be significant, it can be seen that the babies in the asphyxiated group spend approximately the same amount of time

TABLE 6

Means and Standard Deviations for Percent of Total Observation Time Spent in Awake States

State/Group	Statistic	PT	FT/ICN	HFT	ASPX
Total Time Alert	Mean	0.1364	0.1412	0.3643	0.3383
	S.D.	0.1177	0.0777	0.3015	0.3033
Drowsy	Mean	0.0747	0.0650	0.0627	0.1191
	S.D.	0.0672	0.0410	0.0438	0.0851
Alert Inactivity	Mean	0.0256	0.0313	0.0927	0.1281
	S.D.	0.0451	0.0276	0.0958	0.1823
Alert Activity	Mean	0.0130	0.0103	0.0037	0.0414
	S.D.	0.0211	0.0081	0.0063	0.0634
Fussing & Crying	Mean	0.0227	0.0342	0.2058	0.0490
	S.D.	0.0297	0.0237	0.2064	0.0634

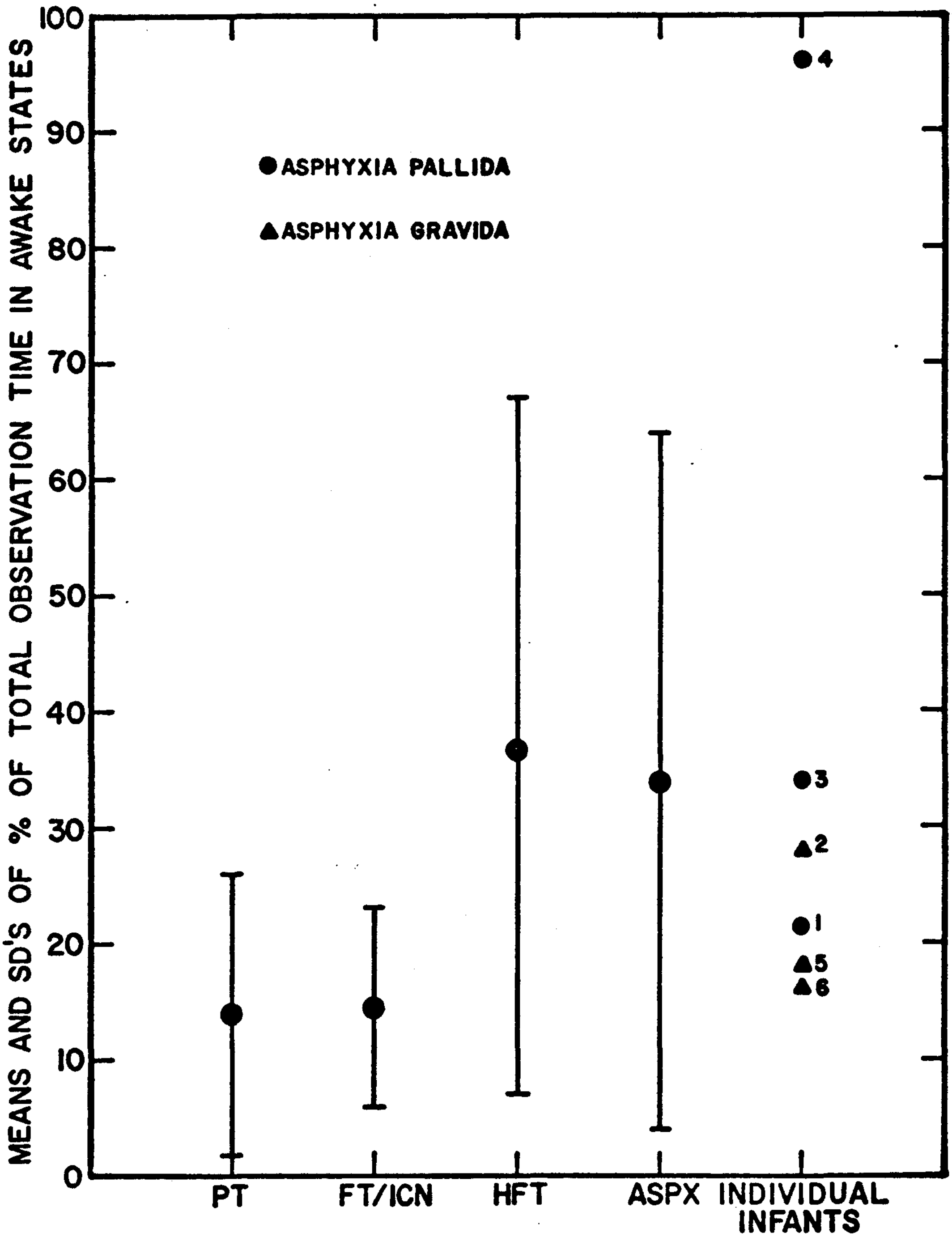

Figure 6. Means and standard deviations for percent of total observation time spent in awake states.

TABLE 7

Means and Standard Deviations for Percent of Total

Awake Time Spent in Each Awake State

State/Group	Statistic	PT	FT/ICN	HFT	ASPX
% Drowsy	Mean	0.5895	0.4415	0.1729	0.4673
	S.D.	0.3083	0.2080	0.0971	0.3327
% Alert Inactivity	Mean	0.1217	0.2563	0.2124	0.3066
	S.D.	0.1426	0.2665	0.1829	0.2171
% Alert Activity	Mean	0.0616	0.0766	0.0154	0.0975
	S.D.	0.640	0.0616	0.0217	0.1130
% Fussing & Crying	Mean	0.1704	0.2253	0.6024	0.1238
	S.D.	0.2271	0.1140	0.2496	0.1586

(46.73%) as the infants in the FT/ICN group (44.15%); preterm infants spent more time than the latter two groups at (58.95%); healthy full-terms spent the least time in the Drowsy state (17.29%). Even though it was not statistically significant, the asphyxiated group did spend more time (total observation time) than any of the other groups in the state of Drowsy ($t = -1.851$, $p = .073$). This could be due to the degree of the illness, which may make it difficult for them to sleep because of discomfort.

Alert Inactivity. A oneway analysis of variance between groups found no significant differences for the state of Alert Inactivity ($F = 2.608$, n.s.). However, when all of the non-asphyxiated groups were compared to the asphyxiated group, a significant difference was found for the amount of time spent in Alert Activity ($t = -2.001$, $p < .05$). It can be seen from Figure 7 that the proportion of time in this state for asphyxiated group was spread over a large range (4% to 18%). Table 6 lists the percent of time each group spent in this state. It can also be seen that the asphyxiated infants spent the most time (total observation time) in Alert Inactivity at 12.81%, while the HFT group was closest at 9.27%. The PT (2.56%) and FT/ICN (3.13%) groups spent much less time in this state. Indeed, a planned comparison of PT versus the Asphyxiated group showed significant differences ($t = 2.254$, $p < .05$). Table 7 shows that the asphyxiated infants spent more of their awake time than any of the other groups in this state, Asphyxiated (30.66%), PT (12.16%), FT/ICN (25.63%), and HFT (21.24%).

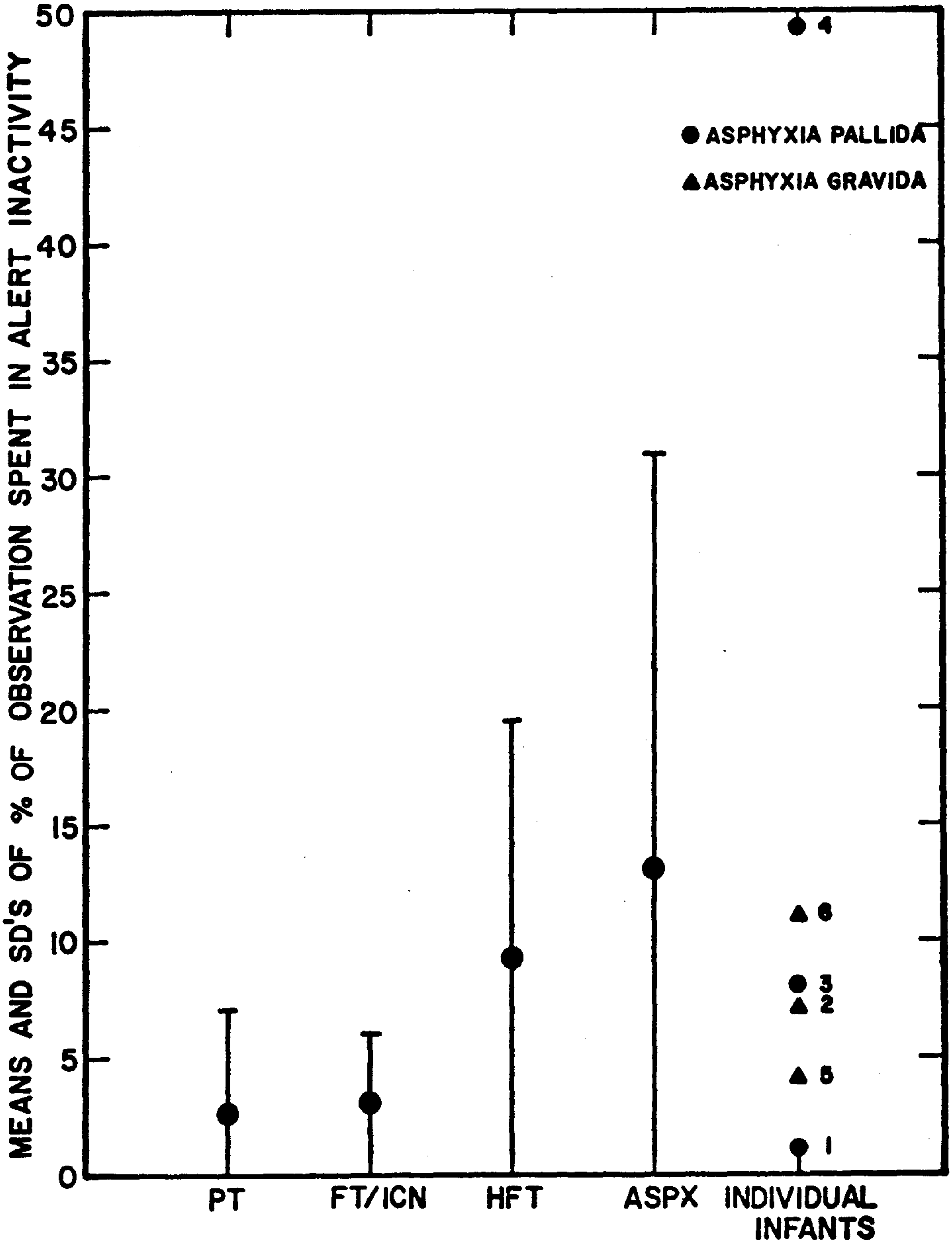

Figure 7. Means and standard deviations for percent of total observation time spent in alert inactivity.

When the data for the state of Alert Inactivity is examined, the observed trends are similar to those found in the Drowsy state, but in the case of Alert Inactivity the differences between the asphyxiated and non-asphyxiated groups are statistically significant. Again, the asphyxiated group spent the most time in this awake state. One hypothesis is that when infants born with asphyxia neonatorum were in the alert inactive state, they were not visually processing stimuli to the degree that the HFT and possibly infants from the other groups were. The asphyxiated babies quantity of time in Alert Inactivity may have been more; but their quality of time was probably less. The main qualitative differences observed was that the HFT babies were seen as being awake <u>and</u> alert. Their eyes hold a "bright and shining" quality. The ASPX babies seemed to be merely awake, not alert. Their eyes lacked the bright and shining quality associated with the processing of sensory information.

<u>Alert Activity</u>. The overall analysis of variance between groups was insignificant for Alert Activity (F = 2.016, n.s.). Table 6 lists the percent of time spent by each group in the state of Alert Activity. Compared to all of the other groups, the asphyxiated group spent the greatest amount of time in this state; ASPX (4.14%), PT (1.3%), FT/ICN (1.03%), and HFT (0.37%). Comparing HFT to the Asphyxiated infants, a significant difference was found (t = -2.192, p < .05). When the asphyxiated group was compared to the PT group, again there was a significant difference found (t = 2.077, p< .05). However, no significant differences were found between the FT/ICN

and Asphyxiated groups. Figure 8 presents the mean and the standard deviations for all groups, with the ASPX subjects displayed individually. It can be seen that most of the asphyxiated infants fell within one standard deviation of their group mean. Three of these infants (2 livida, 1 pallida) were near the mean of the HFT group. When the percent of awake time spent in alert activity was examined (see Table 7), it was found that the babies in the asphyxiated group spent more of their awake time in this state than any of the non-asphyxiated groups; Asphyxiated (9.75%), PT (6.16%), FT/ICN (7.66%), and HFT (1.59%).

The data from this state (Alert Activity) are difficult to interpret because of the wide range of time spent by the subjects in Alert Activity. Three of the infants spent under 1% (#'s 1,2, and 5) whereas three other infants range from 5-18% (#'s 3,4, and 6). This variability is assumed to be representative of the asphyxiated infant population as a whole. If the overall mean is examined, it can be said that the asphyxiated babies spend more time than the non-asphyxiated babies in Alert Activity. Again, this may be due to the extent of their illness and inability to sleep because of physical discomforts or other factors.

Crying and Fussing. A oneway analysis of variance demonstrated significant group differences ($F = 7.595$, $p < .05$). The HFT group spent significantly more time fussing and crying when compared to the Asphyxiated group ($t = 3.250$, $p < .01$). Table 7 shows the means and

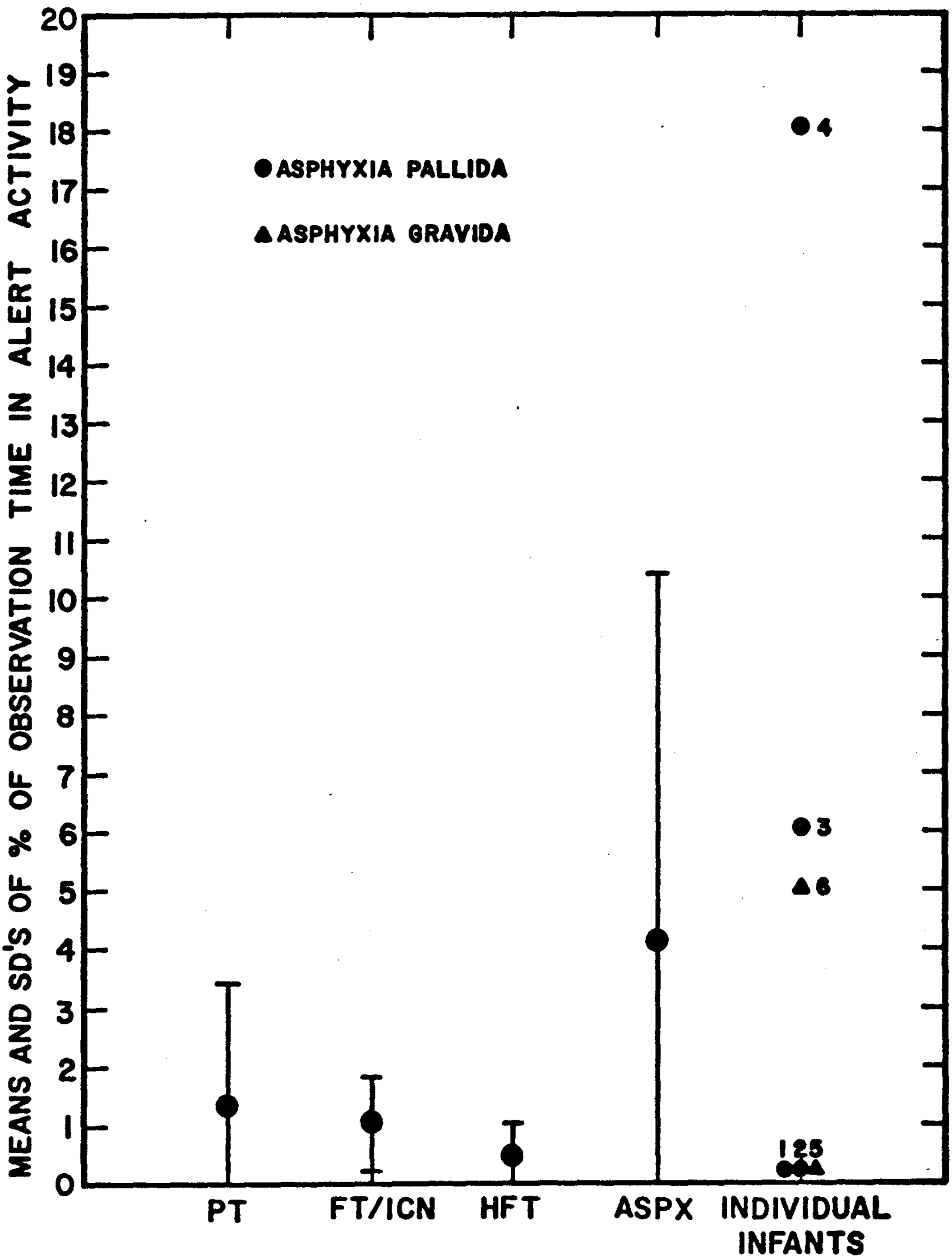

Figure 8. Means and standard deviations for percent of total observation time spent in alert activity.

the standard deviations for the percent of time spent in these states by each group. It can be seen from this table and from Figure 9, that the asphyxiated spent more time fussing and crying than the other two sick groups, Asphyxiated (4.90%), PT (2.27%), and FT/ICN (1.03%). It can also be seen that all of the asphyxiated infants fell below the mean of the HFT group in percent of time spent in Fussing and Crying. For the percent of awake time spent in Fussing and Crying, the asphyxiated babies fall well below the means of the non-asphyxiated infants; Asphyxiated (12.38%), PT (17.04%), FT/ICN (22.53%), and HFT (60.24%) (see Table 7). A contrast of the non-asphyxiated groups versus the asphyxiated group shows a significant difference ($t = 2.34$, $p < .05$).

The asphyxiated infants like the other two groups of sick infants (PT and FT/ICN) spent much less time crying and fussing when compared to the HFT group. This could be due to weakness caused by illness, making the act of crying require more energy than they can spare.

The following are some interpretations of the results for the individual infants who suffered from one of the two forms of asphyxia (pallida or livida).

<u>Asphyxia Pallida</u>

With Apgar scores of 1/2, Subject#1 was diagnosed as having asphyxia pallida. Of all the asphyxiated infants, he spent the most time asleep. In states Quiet and Active Sleep, he also spent the

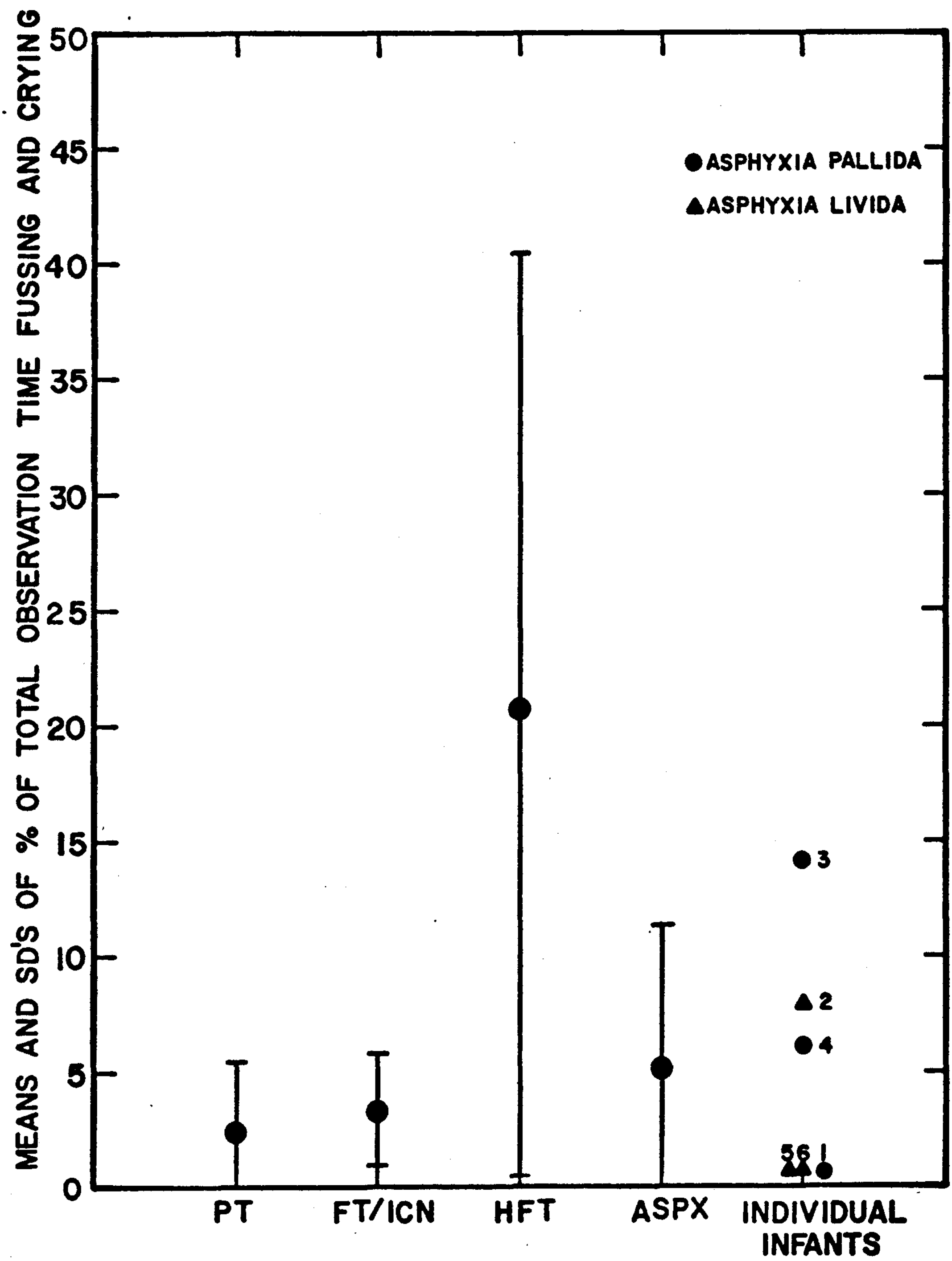

Figure 9. Means and standard deviations for percent of total observation time spent fussing and crying.

highest percent of time (see Figures 2-4). For all of the sleep states this infant was well above the means of each of the four groups. Also, for percent of time spent in each of the awake states Subject#1 was near the bottom of the distributions. In these states again he fell well below the means of all of the groups.

This high degree of deviation from the state patterns of all other infants in the study may be a result of permanent brain damage suffered by Subject#1. It is logical to hypothesize that his severe degree of asphyxia, pallida, caused lesions in areas of his brain where the reticular formation is located. By assessing his level of brain damage early in his life through examination of his state patterns, immediate action can be taken to deal with Subject#1's handicap.

Subject#3 was diagnosed as having asphyxia pallida because of low Apgar scores of 0/1. Even though she was diagnosed as having this severe form of asphyxia, Subject#3's state patterns do not reflect any deviations from those of her own group or from those of the HFT group. For percent of time spent awake/sleep, she is very close to the mean of the HFT group. For states Quiet and Active Sleep, this infant is slightly above the means of the Asphyxiated and HFT groups (see Figures 2-4). For the state of Alert Inactivity (Figure 5) Subject#3 is again very close to the mean of the HFT group. Some deviations from this normal full-term group do show up in states Alert Activity and Fussing/Crying. In these states, the Subject spent less time than the HFT group; but this may be due to the temporary effects of stress discussed earlier which curtail body movement and depress energy levels.

In the case of Subject#3 it would not have been helpful to label her with a diagnosis of possible brain damage because of Apgar scores which signaled a severe degree of asphyxia. By assessing her state patterns, it can be seen that there is no reason to diagnose any degree of brain damage at this early stage of her life.

Subject#4, the last of the babies diagnosed as having asphyxia pallida, had Apgar scores of 2/3. Of all the time observed (9 hours) this subject spent almost no time asleep (.05%). For almost all of the time she was observed, this infant was found to be awake. Of course, this absence of sleep is very deviant from the means of each of the four groups. As was reported earlier, Subject#4 was diagnosed as having possible cerebral lesions. Given such abnormal state patterns, it is likely that these lesions are in regions of the brain where the reticular formation is located. Early detection of brain damage through EEG readings, and the confirmation of this condition from her state patterns assessment, should allow Subject#4's problems to be more fully understood so that they can be dealt with appropriately.

Of the three infants diagnosed as having asphyxia pallida, two were also labeled as having some level of cerebral dysfunction through assessment of their state patterns. It is believed that evaluation of infant state patterns to diagnose brain damage caused by asphyxia pallida, can be a useful tool for the future medical care of the infant.

Asphyxia Livida

Because of her 5-minute Apgar score of 7, Subject#2 was labeled as having the milder form of asphyxia. In overall percent of time spent awake or asleep, she was very close to the means of the Asphyxiated and HFT groups. Yet in looking at specific sleep states, such as Quiet Sleep this subject spent more time than the average Asphyxiated or HFT infant. However, she was close to the means of the two groups in percent of time spent in Active Sleep (see Figures 3 & 4). The statistical analyses of these data show that the deviations found from the two subpopulations are not significant, and therefore do not signal any abnormalities in sleep states. In the area of awake states, Subject#2 again showed some minor deviations from other group averages. For instance, in the state of Alert Activity she was very close to the mean of the HFT group, which was well below the mean for the rest of the asphyxiated group (see Figure 7). In percent of time spent Fussing/Crying, this infant was near 0. The major reason for this finding could be the lack of available energy due to the temporary effects of her illness.

Because of the data received on Subject#2's state patterns, it is thought that her mild degree of asphyxia did not lead to any cerebral dysfunctions. The effects of asphyxia will probably wear off without causing any permanent damage.

Subject #5 was the second infant in the study to be classified as having asphyxia livida on the basis of a 5 minute Apgar score of 6. For percent of time spent asleep/awake, he is far from the means of the Asphyxiated and HFT groups. His time spent in Quiet Sleep is close to that of HFT group; but percent of time spent in Active Sleep is well below that of all the group averages (see Figures 2-4). His lack of activity during sleep is demonstrated throughout all of the awake states. In Figures 6 and 7, it can be seen that Subject#5 spent very little time in the states of Alert Inactivity, Alert Activity, and Fussing/Crying. This total decrease in energy level is a signal of a high amount of stress, and probable brain damage. It was mentioned earlier, that this Subject had an EEG reading which showed cerebral abnormalities. This reading is substantiated by his abnormal state patterns. His initial Apgar score of 6 at 5 minutes is somewhat misleading, if the extent of his state pattern deviations is examined.

The final subject (Subject#6) was also diagnosed as having asphyxia livida, because of a 5-minute Apgar score of 6. For overall amount of time spent asleep/awake, Subject#6 was far from the means of the Asphyxiated and HFT groups. The percents of time spent in individual states give a mixed picture of this infant's state patterns. For example, in percent of time spent in Quiet Sleep, she is well above the means for the HFT and Asphyxiated groups; but for Active Sleep, she is very close to both group means (see Figures 3 & 4). Also, for time spent in Alert Inactivity (Figure 5), she fell between the means of the HFT and Asphyxiated infants; in the Fussing/Crying states, she is below the means of both groups. These mixed results, indicating an unstable set of state patterns, are deviant. From the assessment of her state patterns alone, it is difficult to label this child as brain damaged or as normal. An EEG reading did reveal the possibility of widespread cerebral damage. If both of these measures are taken into account, an accurate assessment for Subject#6 would state that she does have some degree of cerebral dysfunction.

Of the three infants diagnosed as having asphyxia livida, there is substantial evidence that two do have some degree of brain damage. The evaluation of these infants state patterns was useful in the final assessment of their cerebral conditions.

DISCUSSION

The present study was designed to examine the effects of asphyxia neonatorum on infant state patterns. A group of six asphyxiated infants (3 with asphyxia pallida and 3 with asphyxia livida) were recruited and their state patterns were observed during each week of their stay at the Evanston Hospital. In addition, the state patterns from three groups of non-asphyxiated infants were examined (i.e., preterm, full-term with perinatal illness, and healthy full-term). The state patterns of the asphyxiated group were compared and contrasted to those of the other groups. Each of the planned comparisons isolated a specific set of variables which allowed certain conclusions to be drawn about the relationship between the sleep/waking cycles of the asphyxiated and the non-asphyxiated infants.

The data from this experiment have produced a number of interesting results. First, for percent of total time awake/asleep, the asphyxiated group spent almost identical amounts of time as the HFT group; and both of these two group spent much less time asleep when compared to the other sick groups (PT and FT/ICN). For individual sleep states, the asphyxiated babies averaged the most total observation time of all the groups in Active Sleep. The asphyxiated group spent the least amount of total observation time of all the groups in REM Sleep; and the infants with asphyxia were intermediate in between the groups in amount of time spent in Quiet Sleep. For awake states, the asphyxiated group spent more total observation time than any other group in the states of Drowsy and Alert Activity. In the state of Alert Inactivity, the HFT and asphyxiated groups spent similar amounts of total observation time, which was more than the PT and FT/ICN groups. The three groups of sick infants (PT, FT/ICN, and ASPX) spent much less total observation time crying and fussing, when compared to the HFT group.

HFT vs. Asphyxiated Infants

Similarities. In percent of total time spent awake/asleep, the asphyxiated infants were similar to the healthy full-term infants. Thus, in these infants asphyxia does not affect the overall amount of time spent awake/asleep in newborns. In amount of time spent in Active Sleep, again HFT and ASPX groups were similar. Also, for percent of sleep time spent in the states of Active Sleep and REM Sleep, the HFT and ASPX groups were almost equal. On the basis of these data, it was concluded that asphyxia neonatorum does not have an effect on the amounts of overall time spent in Active Sleep and on the percent of sleep time spent in REM and Active Sleep. Amounts of time spent in one more state, Alert Inactivity, were also similar for the HFT and ASPX groups. Thus, asphyxia may not affect the length of time an infant spends in this state.

Differences. Although not statistically significant, the HFT and ASPX groups differed in the amounts of sleep time spent in Quiet

Sleep (HFT = 58%, ASPX = 66%), the amounts of overall time spent in REM sleep (HFT = 22%, ASPX = 15%), and the amounts of overall time spent in the state of Drowsy (HFT = 6%, ASPX = 12%). These findings will be discussed in further detail later.

Statistically significant differences were found between the two groups (HFT and ASPX) in the amounts of awake time spent in the states of Drowsy, Alert Activity, and Fussing/Crying; and in the overall amounts of time spent in Alert Activity and Fussing/Crying. These data will be further analyzed in the next section to rule out the effects of illness unrelated to asphyxia.

FT/ICN vs. Asphyxiated Infants

Similarities. The FT/ICN and ASPX groups were similar in amounts of awake time spent in Alert Activity. Since these two groups are similar and differ from the HFT infants, it is proposed that the illness factor played a part in the amount of awake time spent in Alert Activity. The direct effects of asphyxia or its sequalae could have caused the newborns who suffereed from asphyxia neonatorum to spend less of their time awake, moving and crying. This is probably due to the physical discomfort created by any illness in general and a decreased amount of energy brought upon by the illness factor. In addition, both the FT/ICN and ASPX group spent similar (and little) amounts of total observation time crying which are much less than the amount of the HFT group. Again, this could be due to the illness factor causing a decrease in energy which would normally be used for crying.

Differences. No statistically significant differences were found between the two groups (FT/ICN and ASPX). However, some slight differences have been observed which are worth mentioning and discussing. Infants in the asphyxiated group spent much less total observation time in the state of REM Sleep (15%), when compared to the FT/ICN group (24%). The asphyxiated group spent more total observation time in the state of Drowsy (12%), than did the FT/ICN infants (6.5%). Also, the infants who suffered from asphyxia neonatorum spent much more total observation time in Alert Activity (4%) compared to the FT/ICN groups (1%). Finally, the ASPX group spent less total observation time (12%) than the FT/ICN group (23%) in the amount of awake time spent crying. These differences will be further discussed later in this paper.

PT vs. Asphyxiated Infants

Similarities. For the amount of total observation time spent in REM Sleep the PT and ASPX groups were similar, spending much less time in this state than the remaining two full-term groups (HFT and FT/ICN). The decrease in amount of total observation time spent in the state of REM Sleep may be due to a dysmaturity (asphxiated group)/prematurity (PT group) factor. Asphyxia neonatorum may influence sleep/waking cycles causing a decrease in the amount of REM Sleep, similar to that seen in premature infants.

Differences. A significant difference was found between the PT and ASPX groups in the amount of total observation time spent in the Drowsy state. Differences (not statistically significant) were also found between the two groups in amount of overall total observation time spent in Alert Activity (PT = 1%; ASPX = 4%) and amount of awake time spent fussing and crying (PT = 17%; ASPX = 12%).

HFT, FT/ICN, and PT vs. Asphyxiated Infants--The Effects of Asphyxia Itself

By analyzing the data in the preceding stepwise fashion it can be seen that the results from three states (i.e., Drowsy, Alert Activity, percentage of awake time spent in Fussing/Crying) cannot be explained by the factors of illness or prematurity/dysmaturity. Also the asphyxiated group differs from the healthy full-term group in these states. Therefore it can be concluded that asphyxiated group's deviance from the non-asphyxiated groups is unusual and may be due to the effects of asphyxia itself.

A planned comparison of HFT, FT/ICN, and PT vs. ASPX groups showed significant differences or near significant differences ($p<.07$, Drowsy State), and important trends for these states (see Results). Thus, these data have been confirmed in two separate fashions. In addition, the planned comparison (HFT, FT/ICN, and PT vs. ASPX) showed a near significant difference ($p< .056$) for amount of time spent in Alert Inactivity.

In summary, the infants who suffered from asphyxia neonatorum spent more time than the non-asphyxiated infants in the states of Drowsy, Alert Activity, and Alert Inactivity. Also, percent of awake time spent in the Fussing/Crying state by the ASPX group came in between the amounts of the non-asphyxiated groups (much more than HFT and much less than PT and FT/ICN). It can be hypothesized that these differences may not be attributed to an illness in general or dysmaturity factor. It appears that asphyxia neonatorum and its sequalae are the major contributors to these patterns.

It is believed that even though the asphyxiated infants spent an extremely high amount of time in the awake states of Drowsy, Alert Activity, and Alert Inactivity, the time that they actually spent in the processing of sensory information was abnormally low. When comparing the awake states of the asphyxiated group to those of the HFT infants, the observers noticed a difference in appearance between the two groups. Usually, the HFT infants were observed as being awake and alert. The asphyxiated infants merely had their eyes open; the "sense of alertness" was not often present.

Conclusions

Earlier in this paper, it was mentioned that asphyxia neonatorum has been found to cause lesions in areas of the brain containing the reticular formation, which is partially responsible for regulating sleep/waking patterns in humans (Sechzer, 1973; Jouvet, 1967). Therefore, it can be hypothesized that infants who have suffered from asphyxia neonatorum may have brain damage which can be confirmed by their abnormal state patterns. Assessment of state patterns can be an important tool in the evaluation of the cerebral condition of the asphyxiated infant.

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APPROVAL SHEET

The thesis submitted by RICHARD J. SOSNOWSKI has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts, Developmental Psychology.

May 11, 1983
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