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EARLY VERSUS LATE FEEDING OF PREMATURE INFANTS
EFFECTS ON BLOOD SUGAR AND GROSS MOTOR ACTIVITY

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EFFECTS ON BLOOD SUGAR AND GROSS MOTOR ACTIVITY

by

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Introduction and Review of Literature

The dual problems of what and when to feed the newborn premature infant have been the subject of controversy for many years. The question of what to feed the premature infant has been investigated to at least some extent (17); however, the discussion concerning when premature infants should be fed has proceeded for years based on meager scientific and clinical evidence. Only in the past decade have research efforts been focused specifically on differences produceable in chemical determinations and clinical observations among infants who are fed after varying periods of post-natal fast. The clinical studies have, however, remained at a rather unsophisticated level in differentiating the effects of early versus delayed feeding. The variable most frequently measured is mortality, but there is, in fact, little evidence (69) that this variable has been, or should be, much affected by different feeding schedules. In the present study an attempt has been made to investigate possible differences between early and delayed feeding using what is thought to be a more sensitive measure, gross motor activity. The rationale for this study is based in part on the investigations of carbohydrate metabolism in the newborn which have been reported particularly in the past decade. The literature presented in summary form below will serve as a preface to the present research effort.

Carbohydrates are the prime source of heat production in the fetus and neonate. Needham (54) and Windle (81) have shown that the respiratory quotient of mammalian embryos is close to unity, indicating carbohydrate as the almost exclusive source of energy _in utero_. Studies of newborn infants shortly after birth revealed respiratory quotients between 0.85 and 1.0, being nearer to unity the sooner after birth determinations were made (3, 72). Following the

respiratory quotient through the first few days of life, it was found that the lowest values (range 0.7 - 0.75) were obtained on the third day (16). If subjects were divided into two groups based on premature or full-term birth, it was found that low values of the respiratory quotient were reached on or before the second day by premature infants. The explanation for these findings is not entirely certain since the respiratory quotient reflects changes not only in substances metabolized or inter-converted but also in acid-base balance as it is altered by both metabolic and respiratory activity. One factor, however, which is important from the point of view of a study in infant feeding is that the drop in respiratory quotient indicates that the body's source of energy has shifted from carbohydrate to fat. Furthermore, it appears that premature infants make this transition sooner than do full-term infants.

Carbohydrate is synthesized in fetal liver as well as being stored in the placenta and transported in the maternal blood stream (72). Although human material is scarce, information from the study of human abortuses and animals indicates that glycogen synthesis in the fetal liver increases markedly as term is approached (78). Together with respiratory quotient studies the findings about glycogen synthesis suggest that the shortened gestation of prematures prevents them from accumulating the larger stores of glycogen expected in full-term infants. It should be noted that recent investigations often fail to consider the fact of low carbohydrate stores as important in the discussion of newborn feeding.

The beginnings of investigations of early infant feeding can be traced to the work of van Creveld (77) and Gordon and Levine (31). In 1929 van Creveld reported low blood sugars in premature infants in whom the usual signs of hypoglycemia were not present. The values he reported are of no importance now

since the analytical method used yielded inaccurately high values. In his investigations he fed dextrose to two and three week old prematures and found that this raised their blood sugar levels. This study at least showed that infants need not be forty weeks post-conception to absorb dextrose. A few years later Gordon and Levine (31) published one of a large number of papers on "respiratory metabolism" in the newborn. They found that the drop in respiratory quotient during the first week of life could be prevented by feeding carbohydrates. In their study premature infants fed in the first week of life exhibited a mean respiratory quotient of 0.88, indicating that the infant could not only absorb carbohydrate but also metabolize it.

The effect of this research on the question of early versus delayed feeding apparently was not great. These studies would not in themselves have settled the controversy, yet they did indicate a direction of investigation that should have been followed. Instead the literature on feeding premature infants abounded with warnings of vomiting and diarrhea, aspiration and dehydration. The central issue, the metabolic needs of the premature infant and the consequences of supplying or not supplying these needs, was not directly dealt with for many years. The early literature also suggests a reluctance to experiment with the newborn infant. As it was gradually appreciated that even newborns would survive certain experimental manipulations, direct study of newborn infant feeding began.

Much of the recent interest in early infant feeding is a result of studies of blood sugar levels in the newborn. Sporadic reports had appeared through the years such as van Creveld's, many of them investigating pathological situations. Hartmann and Joudon (36) studied a heterogeneous sample of normal full-term

and premature infants including infants of diabetic mothers and symptomatic hypoglycemic children. Using the analytical technique of Shaffer and Somogyi (67), they concluded that the blood sugar level of newborn infants was in the range of 20 - 60 mg. % over the first three days of life. Miller and Ross (53) observed that the low blood sugar levels measured in infants of diabetic mothers and in asymptomatic premature infants were low.

The work of Norval and her associates (58, 59) was among the first designed specifically to investigate the blood sugar values of normal newborn infants. The micro method of Somogyi (74) using blood obtained by heel stick was employed throughout. The range found during the first six days of life for fifty-one normal full-term infants was from 15-120 mg. % with no clinical signs of hypoglycemia among infants having low values. The mean value for all infants over these six days was 59.4 mg. % ± 1.3 mg. % with no significant differences found among the mean blood sugars on the six different days. Amongst forty-two prematures (birthweight 890 - 2280 grams) including nine who died in the first few days a range of blood sugar from 15 - 117 mg. % was found in the first seven days of life. The mean concentration was 4.7 ± .95 mg. % lower than that of the full-term infants. Here, too, there were no significant differences between days in the mean blood sugar levels. It was noted, however, that on the first day the blood sugar dropped rapidly during the first four hours after birth, slowly reaching a minimum at eight to twelve hours, and then began to rise in spite of the infants' not being fed. No significant correlation was found between birth-weight and blood sugar level whether compared on the first day or over the entire first week of life.

Ward (79) studied twenty-one premature infants (birth-weight less than 2500 grams) during the first two days of life. He found the mean cord blood sugar level to be 66 mg. % (range 40 - 140 mg. %) while the first post-natal sample (taken in the first six hours of life) had a mean value of 45 mg. % (range 16 - 90 mg. %). He took blood samples every six hours during the first forty-eight hours of life and reported finding no significant differences among the mean values in the eight samples. There was no relationship found between blood sugar level and birthweight considering either the cord blood or post-natal blood sugar levels.

Farquhar (26) studied the post-natal blood sugar levels of thirty-two normal, full-term infants using the analytical method of Ramsay (61). Although the absolute values were higher then those of Norval's study, a plot of the data was remarkably similar in showing a rapid fall in blood sugar which leveled off after four hours and rose toward the end of the first day. The investigations of Pedersen (60) and Creery and Parkinson (15) all tended to confirm that among full-term and premature infants there is a marked fall in blood sugar in the first twelve hours of life generally unassociated with signs of hypoglycemia.

Although there was essential agreement about the trends in blood sugar concentration in the first hours or days of life, the absolute values lacked comparability (8, 50). The discrepancies were based on a number of variables including differences in techniques of measurement, exact hourly age when collections were made, birthweight and pre-natal history, and the clinical status of the infants at the time of sampling. Nevertheless, these investigations by the criteria established in individual laboratories all reached the conclusion that in the first hours of life infants, both full-term and premature, go through

a period of "neonatal hyoglycemia".

More recently Baens, <u>et al</u>. (1), have presented a study of the blood sugar levels of one hundred and nine premature infants (birthweight 735-2190 grams). They noted studies showing increased glycolysis in newborn erythrocytes (77, 84) as well as reports of very low and absent blood sugar levels in newborn prematures where the collection and processing of blood were probably not optimal (84). Blood in Baens' <u>et al</u>. study was taken by heel stick and precipitated in $Ba(OH)_2$ and $ZnSO_4$ within two minutes of sampling, thus eliminating artifacts due to a number of variables. The samples were analyzed by both the Somogyi-Nelson (26, 56) and the newer glucose-oxidase methods (51). The mean glucose measurements were lower than the mean "true sugar" levels by 3.5 mg. %, a statistically significant finding. By the glucose oxidase method the mean value from birth to three hours of age was 41 ± 11.4 mg. % at seven to twelve hours of age and then slowly declined to reach a minimum on the third and fourth days of 39 ± 12.8 mg. %. This finding is at variance with previously cited studies. The explanation for the probably misleading results of Baens' <u>et al</u>. study is that there was no uniform feeding schedule for all their subjects. Only infants of birthweight under 1250 grams were not fed on the first day of life. Those infants over 1250 grams were fed, but it was not reported at what hour of life feeding was begun in these heavier prematures. From the previuosly mentioned studies of carbohydrate metabolism in the newborn there is every reason to suspect that feeding on the first day would raise the blood sugar. The studies reporting a fall in blood sugar in the first day of life were performed on fasting infants and probably offer a more accurate representation of the blood sugar variations in that period.

The findings during the first week of life in the study of Baens et al., are interesting and important. As in other reports there was no significant correlation between birthweight and blood sugar on the first day; however, when the values for the first week of life were pooled, it was found that infants weighing less than 1500 grams or between 1500 and 2000 grams at birth had significantly lower mean blood glucose levels than those weighing over 2000 grams (40 mg. % and 43 mg. % versus 48 mg. % respectively). The difference between the under 1500 gram and the 1500 - 2000 gram groups was not significant. Again, however, there is a question as to what extent the one or two day fast of the smallest babies resulted in artifactiously low blood glucose levels which reduced their over-all weekly value. Another significant variable in their study was race. Non-white infants had higher mean glucose levels in the first week than did white infants. The reason for this finding is not certain but may be related to the frequent observation that non-white infants appear more mature than their birthweights indicate (69).

Concurrent with the studies documenting the existence of neonatal hypoglycemia there have been an equally large number of investigations performed to explain its occurrence. The focus of these research efforts has been on endocrinologic regulation and the liver.

Van Creveld (77) extrapolating from the concentration of glycogen in various newborn mammalian livers assumed that the newborn premature had sufficient glycogen, and concluded that an "immature" liver was failing to regulate the newborn's blood sugar. There is evidence from more recent animal studies to support this point of view such as those showing diminished glucose-6-phosphatase activity in fetal guinea pig liver (46, 57). Windle's (81) studies

of fetal glycogen storage in the last trimester of pregnancy have been variously interpreted to mean that newborn prematures do or do not have adequate glycogen stores (26, 79). Autopsy studies on previously distressed infants have shown severe depletion of liver glycogen, but they have not defined the cause-effect relationship (36, 79). Knowledge of the newborn infant's glycogen stores is incomplete, much of it having been inferred from indirect studies (such as reported below) which have used various glycogenolytic stimuli.

The mechanisms of neonatal hypoglycemia have been investigated mostly in terms of hormonal regulation. Hartmann (35) and Hartmann and Joudon (36) have written on the concept of "relative hyperinsulinism" in the newborn. Histological and chemical evidence of true excess insulin production has been found only in off-spring of diabetic mothers (11, 60, 72). Among normal newborns it has been found that a given dose of insulin produces a more profound and prolonged hypoglycemia response than it does after the first week or two of life. This research is of interest when considered with the activity of the hyperglycemic regulatory mechanisms in the pituitary-adrenal system. Desmond (19) administered epinephrine to premature infants and found that the hyperglycemic response to a given dose of epinephrine varied with the age of the infant. There was a 41 ± 18 mg. % rise at one to three days of age as compared with a 57 ± 16 mg. % rise at four to ten days of age. Also the latency of the response to epinephrine decreased with increasing age. The findings of these two groups of investigators tended to support poor regulation by glycogenolytic mechanisms as the basis for neonatal hypoglycemia.

Cornblath, et al. (8) measured the difference in sugar concentration between capillary and venous blood samples to evaluate the effect of epinephrine. They found that the newborn responded like an adult, exhibiting elevation of blood sugar level and decrease of peripheral utilization as evidenced by a diminuation in the capillary-venous blood sugar difference. Administration of glucagon produced a significantly smaller glycemic response in premature as compared with full-term infants even when the former received larger doses (9). As glucagon is known to have its primary effect on activation of liver phosphorylase, this was taken as evidence for the "immaturity" of the premature's liver; however, the possibility of increased peripheral utilization could not be discounted.

Investigations have also proceeded from the opposite direction to determine the efficiency of mechanisms for clearing glucose from the blood. Desmond (19) and Read (62) had reported that newborns responded to an exogenous glucose load like adults, but recent research by Bowie, et al. (4) has indicated this to be only in part true. In a careful study of intravenous glucose tolerance tests in full-term, newborn infants they found that the rate of removal in the first hour of testing was slow. The blood sugar in the second hour then exhibited a precipitous drop with no decrease in rate as the fasting level was approached. The infants then went through a phase of marked hypoglycemia (i.e., as compared with the pre-testing level) before returning to the fasting level. A "normal" curve of glucose disappearance was found in newborns given extra insulin with the glucose and in three day old infants given glucose alone.

Shortly after the study of Bowie, et al., appeared, Cornblath, et al. (12) reported finding a similar response to the glucose tolerance test among newborn

premature infants. There was an initial slow clearance followed later by a failure to decrease clearance rate at two hours when fasting level was approached. Premature infants three to seven days of age had faster initial clearance rates and better control of blood sugar level than did infants under three days of age. Tolbutamide tolerance tests were administered to premature infants of different ages. Newborns less than one day old did not respond with a statistically significant decrease in blood sugar level whereas one week old infants did. This finding indicates that neonatal hypoglycemia is not the result of hypersensitivity to insulin as suggested by Hartmann (36).

The various studies summarized here indicate that the newborn premature probably possesses the necessary mechanisms and possibly possesses enough glycogen for carbohydrate homeostasis, but no definite statement about the cause of neonatal hypoglycemia can be made. Some more quantitative estimation of glycogen stores and peripheral glucose consumption must be made. At the same time the regulatory systems involving gluconeogenesis, glycogen synthesis, and glycogenolysis which operate in varying degrees of speed and efficiency must be further studied.

The relationship between studies of carbohydrate metabolism in newborn infants and the feeding practices of the average hospital nursery have only recently been appreciated. For a long time the establishment of feeding schedules, particularly for premature infants, was based on the belief that a post-partum fasting period was needed to allow the respiratory and gastrointestinal systems to adjust to the *ex utero* environment such that they would function harmoniously when feeding was begun. These precautions which sought to prevent aspiration pneumonia and other catastrophes like vomiting, diarrhea,

over-hydration, and edema were well-intentioned but short-sighted in their failure to grasp the core of the problem. The decision whether or not to feed early must be based primarily on the possible need in the newborn period of supplementary nutrition for optimum function. To emphasize a point, it is not merely increased infant survival that is sought but rather the maintenance of an optimum state of health.

Starvation experiments (30, 33, 65, 83) in laboratory animals employing survival data as the dependent variable are species specific and probably should not be directly applied to the problem of management of premature infants. Yet, the antagonists in the argument over early versus delayed feeding, Ylppö (83) and Smith (71), have used different sets of animal data to support their respective positions. Studies in human premature infants have also focused on the effects on mortality. Most investigators, including Ylppö (83), have been unable to demonstrate differences in mortality in human infants as a result of varying the period of post-partum fasting. Gleiss (29) was virtually alone in his finding that premature infants fed from twelve to twenty-four hours after birth had a significantly lower mortality than those infants not fed until thirty-six hours of age.

The work of McCance and Widdowson (49) and of Hansen and Smith (34) and the failure of experiments in early feeding to alter mortality have been used by exponents of delayed feeding to support both the beneficial effects on water and electrolyte balance and the harmlessness of fasting in the first one to three days of life (71). However, mortality is too crude a measure to evaluate the effects of early feeding. Recognizing this, some investigators have looked at other frequently present variables, acidosis and the syndrome of

respiratory distress (48). Bauman (2) has stated that early feeding of glucose and saline has no specific effect on the variables of dyspnea and mortality whereas Usher (75, 76) using intravenous administration of glucose and sodium bicarbonate for therapeutic purposes has obtained a profound beneficial effect. The data are relatively new and not yet conclusive; however, many institutions are now investigating this problem.

Research employing more refined techniques is needed to investigate early versus delayed feeding in terms of the following issues: 1) all newborn infants undergo a period of relative hypoglycemia commencing a few hours after birth; 2) premature infants are subject to a more profound and longer lasting hypoglycemia than are full-term infants; 3) premature infants are by virtue of their prematurity not "normal" and thus investigations on, and treatment of, full-term infants are not necessarily applicable; 4) premature infants in addition to having a mortality greater than full-term infants suffer a greater number of non-lethal insults many of which involve the central nervous system and not all of which can be accounted for by birth injury, anoxia, hyperbilirubinemia, etc. (20, 21, 23, 25); and 5) the usual lack of clinical manifestations in neonatal hypoglycemia does not preclude its being injurious since so-called symptomatic hypoglycemia, itself an ill-defined entity, is not always responsive to glucose administration and may have other mechanisms involved in its pathogenesis (45).

Ylppö has said: "I am of the opinion that we must try to arrange to feed the premature infant immediately after birth, as far as possible in conformity with nature and the conditions of the fetal period". The birth of an infant prematurely does not necessarily signify the same ability to exist <u>ex utero</u>

as for a full-term infant. If as can be inferred from Kety's (44) work the brain accounts for utilization of so large a proportion of the basal metabolic output (48% in a five year old versus 20% in an adult) and the brain is proportionately in the infant six times that of an adult (63), then whatever restriction exists in the premature infant's ability to maintain an adequate glucose supply may affect central nervous system functioning. Cornblath, et al. (12), on the basis of crude calculations estimated the premature infant's liver to be capable of supplying from 70% to 150% of the brain's glucose requirements compared with figures of 300% to 400% in an adult. These figures are even more impressive when one considers the additional demands for energy at birth resulting from drops in body temperature, increased muscular activity either alone or associated with respiratory distress, acidosis, fat metabolism, etc. Cornblath, et al. (12) found that blood sugar levels between 20 mg. % and 30 mg. % appeared in only 28% of asymptomatic prematures whereas it appeared in 42% of prematures who were stressed by one or another illness.

The accuracy of the above calculations is not crucial. What is important is their implication that hypoglycemia in newborn premature infants (and perhaps the full-term as well) may not be the benign, so-called "normal", process which has been ascribed to it for many years. The issue, therefore, of early versus delayed feeding should not be viewed merely in terms of weight changes or mortality but more directly in terms of the possible subtle effects which blood sugar variations in the immediate post-partum period might have, for example on central nervous system function.

The present research was undertaken to determine whether elevation of

blood sugar level in newborn prematures by immediate post-partum feeding would produce measurable and consistent changes in gross motor activity, a parameter presumably more sensitive to such alterations than mortality, weight gain, or the like.

Materials and Methods

Prematurity is defined by birthweight less than 2500 grams (69). It has been shown by a number of investigators, as already discussed, that amongst premature infants there is no direct relationship between birthweight and blood sugar level in the first few hours or days of life. It seemed logical, however, that if maintenance of blood sugar level were related to glycogen stores and/or development of hormonal regulatory mechanisms, then the chances of producing some measurable differences through early feeding would be more likely amongst small premature infants. After the present research was underway, the report by Baens', et al., (1) discussed previously, offered support for this rationale.

The subjects used for this study were infants born at the Yale-New Haven Hospital with birthweight under 1800 grams. They were collected randomly during the following periods: November, 1962-August, 1963; June-August, 1964; and April-June, 1965. A total of thirty-five infants were studied during the first forty-eight hours of life. Most infants were normal except for their prematurity. Five had the respiratory distress syndrome, and eight had mothers with premature rupture of the membranes with suspected or proved infection. By chance no infants with blood-type incompatibilities were in the study. Two sets of twins whose birthweights were within the defined limits were in the study; but two sets of twins of dissimilar size, one over and one under 1800 grams, were excluded. It was decided originally to omit those with gross congenital abnormalities diagnosable from birth, such as: microcephaly, meningocoele, encephalocoele, omphalocoele, esophageal atresia, and cyanotic heart disease. Since the research began, three of the subjects have been diagnosed as having the following congenital malformations: one hydrocephalic, one branchial cleft cyst, and one horseshoe kidney. None of the

thirty-five infants had any minor detectable deformities such as hare-lip, cleft palate, polydactyly, etc. Four infants originally accepted in the study did not survive the forty-eight hours necessary for observation, all having died with the respiratory distress syndrome. Brief follow-up inquiries in the first few months of life indicated that all of the final sample of thirty-five were living; however, the follow-up did not determine the appearance of specific abnormalities or the speed of growth and development. The sample then is of a group of very small, mostly normal and unstressed premature infants with no detected physical abnormalities at the time of study.

At birth the infants were randomly assigned to one of two groups: the first received no feedings for the first twenty-four hours of life while the second was fed glucose for the corresponding period. The amount fed was 3 cc/kg. of 20% dextrose every two hours. Anticipating the probable inability for all newborn prematures to suck adequately, it was decided to feed all the infants in the "fed group" by gavage tube. A separate tube was used for each bi-hourly feeding. Recognizing as well the differential tolerance to large volumes of fluid, a concentrated dextrose solution was used rather than the 5% or 10% solution with which feedings in the nursery are usually initiated. The caloric value of the feedings was approximately three-fifths of the newborn's estimated basal requirement of 50 cal/kg/day (69). The amount administered is about what the brain itself might use (12). After twenty-four hours all infants were put on feeding schedules determined by the house staff. This consisted of Enfamil^R or Similac^R every three or four hours. The "non-fed" group at twenty-four hours started usually with two 10% glucose feedings before receiving milk formula.

Blood samples for sugar determination were taken at birth and at twelve,

twenty-four, and forty-eight hours of age. In practice the blood sample at birth was taken anywhere from several minutes to not more than three hours after birth with an average sampling time at approximately forty-five minutes. Samples were obtained by heel puncture and put immediately into $Ba(OH)_2$; they were then refrigerated until all four samples were collected. They were analyzed by the Somogyi-Nelson technique (56, 74). Controlled studies by the laboratory which did these determinations had shown previously that this method handling samples did not alter the values from those obtained if blood were precipitated in both $Ba(OH)_2$ and $ZnSO_4$ and analyzed without the forty-eight hour delay.

The variable measured to assess the effect of early feeding was gross motor activity, quantified by a technique developed in the Department of Psychology of Yale University by Professor William Kessen (42, 43). Preceding each of the four heel sticks, the infants were photographed in their Isolettes^R with a Bolex^R 16 mm movie camera mounted on a rig under which their incubators could be rolled. The film used was Kodak Tri-X^R negative at a speed of twelve frames per second. Indirect lighting was provided by two 500 watt lamps mounted on the camera rig and pointed at the ceiling. Each of the four observations consisted of two twenty-five second filming segments separated by a five minute rest interval. Prior to each segment the experimenter picked up the subject through the portholes of the incubator and elicited a Moro reflex by the head-drop technique. The infant was then placed on his back and the twenty-five second filming segment begun. Each subject thus had two pre-stimulated twenty-five second film observations at birth and at twelve, twenty-four, and forty-eight hours. The filming was followed by the heel puncture for blood

samples. For the "fed" group (given glucose every two hours) the observations were done one to one and one-half hours after a feeding. The same interval for the forty-eight hour observation in both groups was used. The twenty-four hour observation in the "non'fed" group was done prior to their first feeding.

The analysis of the motion pictures was done on a Vanguard^R motion analyzer. A frame of film is projected onto a screen where cross-hairs are centered on the hands and feet. Abscissa and ordinate readings for the location of the four limbs are given by the machine. In subsequent frames the same spots on the four limbs are relocated and the difference in the abscissae and ordinates between that and a preceding frame can be easily converted by Pythagorean theorem into linear displacement. The arithmetic was done by computer from cards punched with the co-ordinates.

As described by Kessen, et al. (42), frames at five second intervals were chosen; therefore, on a twenty-five second strip of film the co-ordinates for six frames (0, 5, 10, 15, 20, and 25 seconds) were determined and the linear displacement of the limbs for five separate five-second intervals was calculated. A mean movement value for each five second interval was then obtained by averaging the linear displacements of the four different limbs. Finally a Movement Index of gross motor activity was computed which represented the average of the five mean movement values.

Preliminary calculations on the first ten or twelve subjects indicated unduly great variations in the first, the 0-5 second, interval. This was, and would be, due to the experimenter's uncontrollable lack of uniformity in handling the infants and stimulating the Moro reflex. It was also found that when excessive

movement did occur in the first interval, it diminished quickly and was not seen in the second or subsequent intervals. It was decided then to ignore the 0 - 5 second interval in calculations for the rest of the study. The 20 - 25 second interval was found to be a uniformly inactive one; it was dropped along with the first interval. Therefore, the Movement Index as calculated in this study represents the average linear motion of the four limbs for a period 5 - 20 seconds following elicitation of a Moro reflex.

Results

Before the data were assembled, it was necessary to eliminate two subjects. One subject had only three motion picture observations; the fourth was inadvertently lost during processing. One subject in the "non-fed" group was fed prior to the twenty-four hour observation. The thirty-three subjects left were divided seventeen -sixteen between the "non-fed" and "fed" groups respectively. By chance the groups were balanced for sex except for an extra female in the "non-fed" group. One of the nine females was chosen at random and discarded; thus, leaving a sample of thirty-two for analysis with sixteen infants, eight male and eight female, in each group.

The mean values of gross motor activity and blood sugar for the two groups are shown in figures 1 and 2. The mean blood sugars at birth and at twelve, twenty-four, and forty-eight hours of age for the "fed" group were 40.2, 59.4, 59.3, and 50.1 mg. % while for the "non-fed" group they were 40.6, 37.6, 37.2, and 52.9 mg. % respectively. An over-all analysis of variance of the two curves shows them to be significantly different at the 0.05 level of confidence. The analysis further reveals no significant difference between observations irrespective of the two groups and no significant interaction between the "fed - non-fed" and time dimensions (see table 1).

	df	F	P
between groups	1	4.77	<.05
between observations	3	1.37	not significant
groups x observations	3	2.82	not significant

Table 1: Summary of the analysis of variance of blood sugar values for all observations (see Appendix IV).

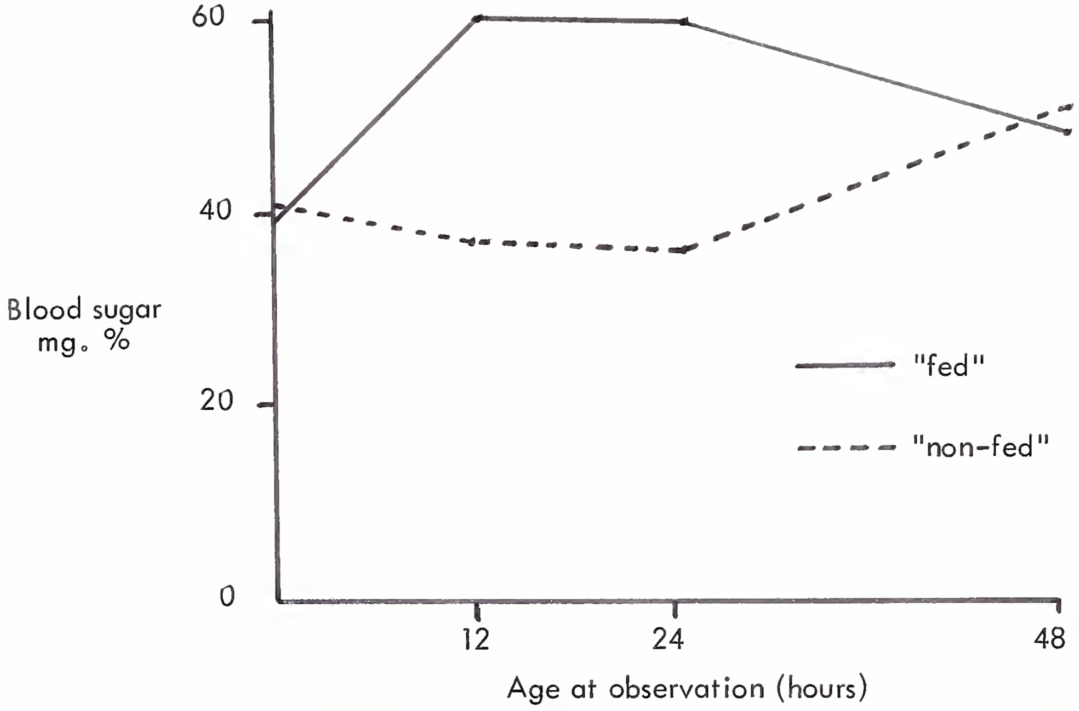

Figure 1: Graph of the mean blood sugar values for the two experimental groups at each of the four observations (see text for specific values).

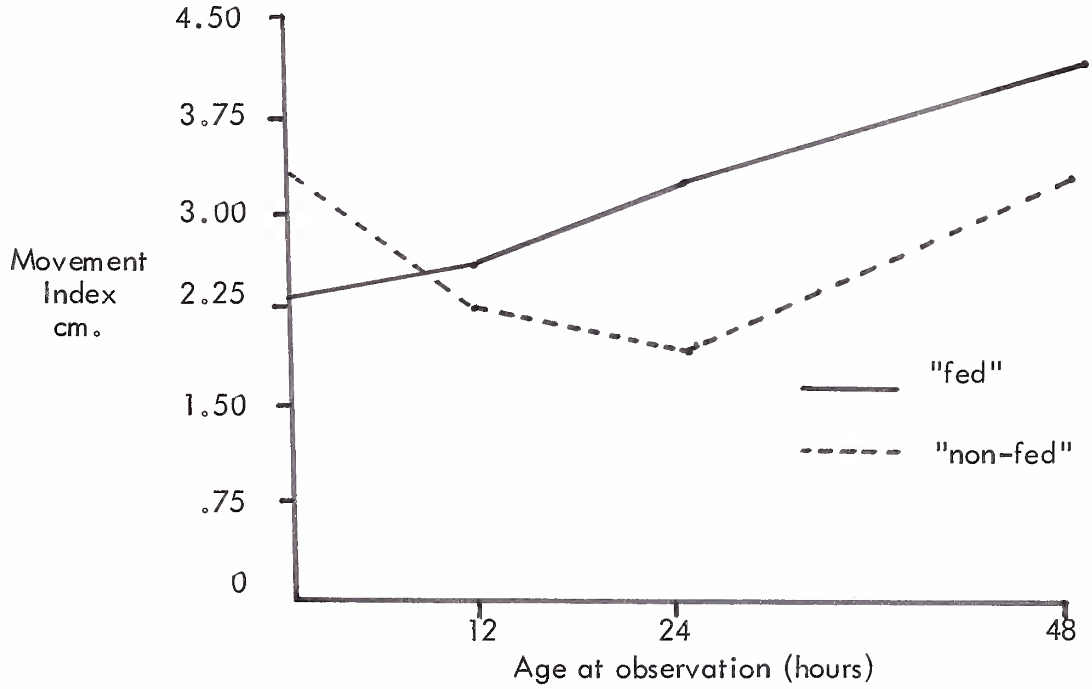

Figure 2: Graph of the mean movement indices for the two experimental groups at each of the four observations (see text for specific values).

The mean movement values at birth and at twelve, twenty-four, and forty-eight hours for the "fed" group was 2.32, 2.51, 3.15, and 3.92 cm. while that for the "non-fed" group was 3.42, 2.21, 2.01, and 3.12 cm. respectively. An analysis of variance was done comparing the groups, the periods of observation and the two segments which made up each observation. In this analysis only the observations at birth and at twelve and twenth-four hours were included. This restricted the comparison of data to only those times when the two groups were distinguished on the basis of being, or not being, fed. To include the forty-eight hour observation when both groups had been fed for twenty-four hours would partially eliminate the effects of feeding versus fasting.

This analysis of variance revealed no significant differences between the two groups ("fed" versus "non-fed") or between the three observations (birth, twelve, and twenty-four hours). These findings are readily apparent from an inspection of the graph in figure 2. A significant finding was the interaction term between groups and observations (see Table 2).

	df	F	P
groups	1	1	not significant
observations	2	2.08	not significant
groups x observations	2	3.21	$<.05$
segments	1	1.95	not significant
segments x observations	2	3.89	$<.05$
groups x segments	1	1	not significant
gr. x segs. x obs.	2	1	not significant

Table 2: Summary of analysis of variance for gross motor activity for observations at birth, twelve, and twenty-four hours (see Appendix V).

An unexpected finding was a significant interaction between the two segments of each observation and the time of the observation. The mean movement indices for each segment of the observations is given in Table 3. The second segment of observations one and three is less than the first while the reverse is true for the second observation in which the second segment is greater than the first. The interaction term, segments x observations, indicates this pattern to be statistically significant.

	Fed		Non-Fed	
	A	B	A	B
birth	3.04	1.59	3.65	3.19
24 hr.	2.08	2.93	1.92	2.50
48 hr.	3.52	2.77	2.59	1.43

Table 3: Mean movement indices for each segment of the three film observations in the "fed" and "non-fed" groups.

Because a significant interaction was found between feeding and movement over the twenty-four hour experimental period, a correlation was sought between movement and blood sugar level. Scatter plots and chi-square analyses were done between movement and blood sugar at birth and at twenty-four hours (see Figures 3 and 4; Tables 4 and 5). Median scores for movement and blood sugar were

		Blood Sugar	
		high	low
Movement	high	8	8
	low	8	8

Table 4: Chi-square table showing division of subjects at birth for movement and blood sugar using the median score of each (3.70 cm. and 34 mg. % respectively) for the separation.

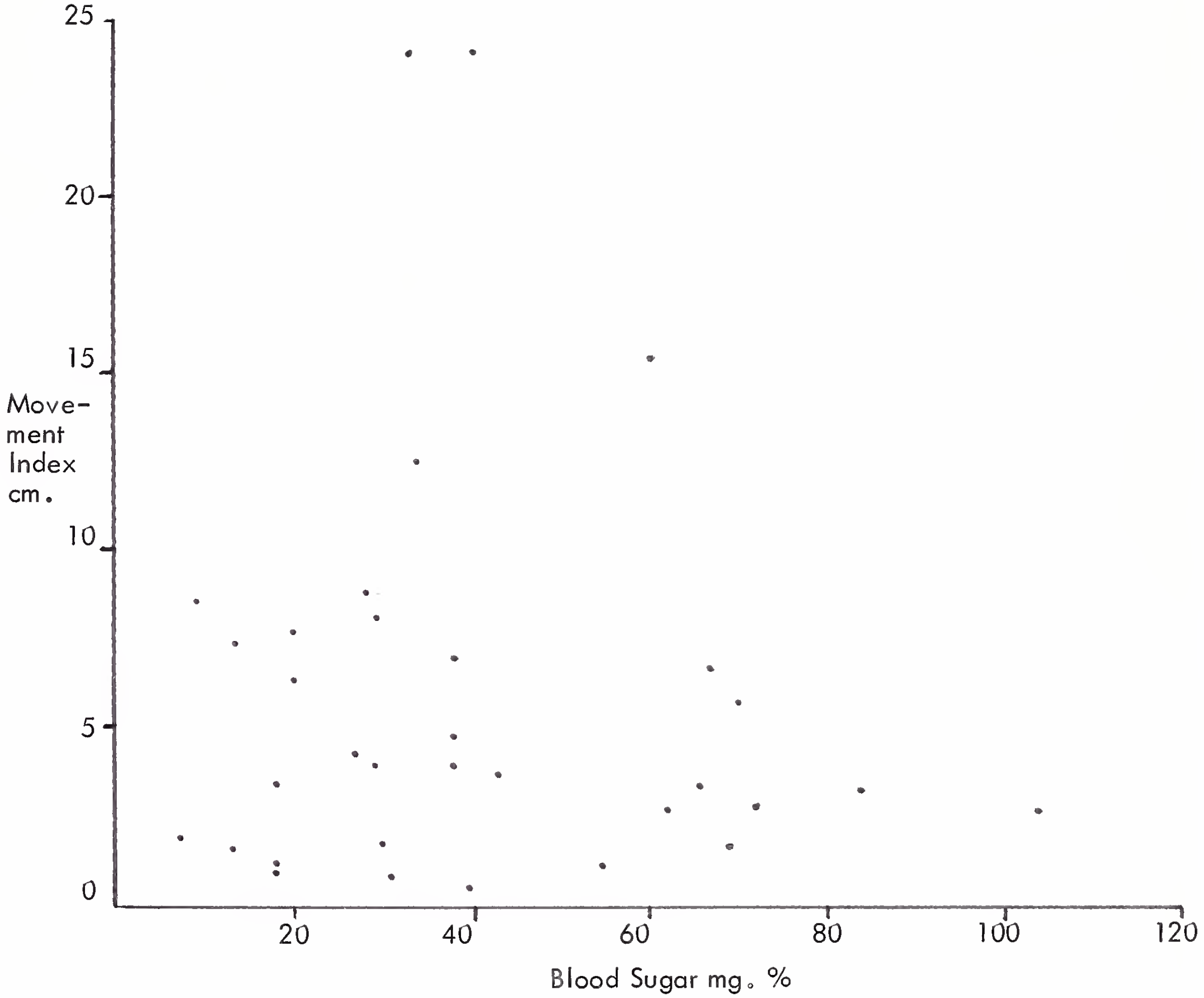

Figure 3: Scatter plot of movement and blood sugar data at birth for all 32 subjects.

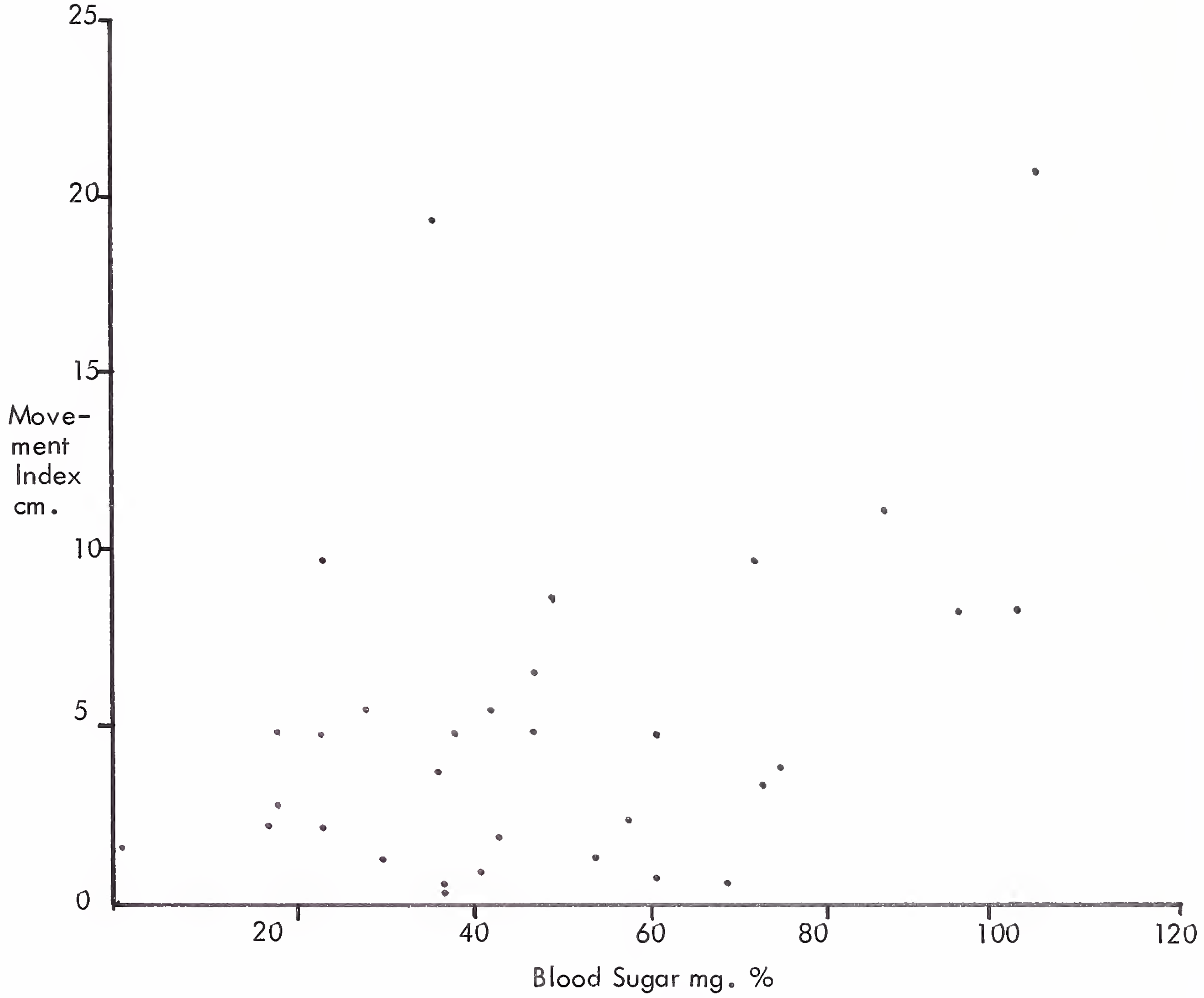

Figure 4: Scatter plot of movement and blood sugar data at 24 hours for all 32 subjects.

used to distinguish "high" and "low" movement indices and blood sugar levels. At birth the subjects divided equally amongst the four cells, precluding a significant correlation. At the twenty-four hour observation similar results were obtained. It was concluded that no correlation between blood sugar and gross motor activity would be found in this data.

		Blood Sugar	
		high	low
Movement	high	9	7
	low	7	9

Table 5: Chi-square table showing division of subjects at twenty-four hours for movement and blood sugar using median score of each (4.0 cm. and 43 mg. % respectively) for the separation.

Birthweight is an important variable in the study of premature infants; therefore, it was analyzed to assess possible relationships to blood sugar and gross motor activity. Chi-square analysis revealed no relationship between weight and blood sugar at birth (see Table 6). As there were no provisions for later weighings and because of the feeding variation, subsequent comparisons of weight and blood sugar were not made.

		Blood Sugar	
		high	low
Movement	high	8	8
	low	8	8

Table 6: Chi-square table showing division of subjects at birth for weight and blood sugar using median score of each (1600 grams and 34 mg. % respectively)for the separation.

When birthweight was compared with gross motor activity at birth an almost significant relationship was found (see Table 7). Birthweight was therefore compared with over-all motor activity through the first forty-eight hours of life. In this analysis birthweight was considered for its projective value in relation to gross motor activity. A "t-test" revealed that over the entire period of study infants who weighed more than 1600 grams at birth (the medial birthweight in this sample) were more active than those under 1600 grams irrespective of the feeding variable ($t^2 = 8.33$ $p < .01$; see Appendix VI).

		Movement	
		high	low
weight	high	11	5
	low	5	11

$X^2 = 3.125$ $.05 < p < .10$

Table 7: Chi-square table showing division of subjects at birth for weight and gross motor activity using median score of each (1600 grams and 3.70 cm. respectively) for the separation

Race and sex were also analyzed. Sex was evenly divided in the sample with sixteen males and sixteen females. Racial representation was unbalance with regard to the general population, but was not unusual for a sample of premature infants. There were thirteen non-white (twelve Negro and one Puerto Rican) and nineteen white babies. No relationship was found between movement and the sex or race of the infants (see Appendix VI) either at birth or over the entire forty-eight hours of observation.

Blood sugar was analyzed with respect to race and sex; however, since there were variations in feeding and only sex was balanced between groups,

comparison of blood sugar and race was done only at birth. There were no significant differences of blood sugar by sex either at birth or over forty-eight hours. It was found that non-white babies tended to have higher blood sugar levels at birth than white babies ($t^2 = 4.10 > .05$; see Appendix VI). Baens, *et al.* (1), have reported a significant racial difference when comparing blood sugars over the first week of life.

As indicated previously the criteria used in selecting babies for this study were such as to exclude those with gross congenital abnormalities. All but one of the subjects were delivered vaginally. None of the subjects received blood transfusions. The five infants with the respiratory distress syndrome who were included in this study were thought to have only a mild-to-moderate stage of the disease. Four of these five cases occurred in the "non-fed" group and only one in the "fed" group. No consistent finding with regard to blood sugar level or movement indices can be seen among them. Clinically significant premature rupture of the membranes (i.e., greater than twelve hours) occurred in four of the "fed" and four of the "non-fed" subjects. These infants tended to have low Apgar scores at birth and tended to remain longer in the premature nursery (see Appendix I). There were, however, no consistent variations in this group of eight subjects with respect to blood sugar or gross motor activity.

Discussion

The primary hypothesis of this study was that small premature infants fed immediately from birth would exhibit increased gross motor activity compared to a similar group not fed after birth for a corresponding period of time. This specific prediction was not verified most likely because at the outset the two groups were not homogeneous with respect to the dependent variable, gross motor activity. The interaction between feeding and observation time was significant, indicating that the effect of feeding over time was to reverse the difference in movement indices exhibited at birth by the two groups. This finding is statistically as powerful as a direct significant difference between the two groups if they had similar movement indices at birth. It, however, is not quite so esthetically pleasing and calls for an explanation of the lack of homogeneity between groups.

As indicated above certain variables were either balanced between the two groups (e.g., sex) or exhibited no statistical significance when the entire sample was pooled (e.g., ract). However, birthweight did show an apparent significant relationship to gross motor activity, and a retrospective analysis of the two groups revealed they were not homogeneous with respect to birthweight. The average weight of the "fed" group at birth was 1515 grams while that for the "non-fed" group was 1628 grams. The median birthweight for the entire sample (upon which the birthweight-activity analysis was based) was 1600 grams; therefore, at birth the "fed" and "non-fed" infants were simultaneously members of "high" and "low" weight groups. Beside the more general problems of sample size and randomization, this birthweight discrepancy appears as the most reasonable explanation for the differences in gross motor activity at birth. The important point, however, is that the birthweight-activity relationship which

approached significance at birth and which was significant over the forty-eight hours of the study was overridden by the feeding process in the first twenty-four hours.

The other significant findings in this study related to the maintenance of blood sugar levels by oral glucose feedings. The graph in Figure 1 shows the average values for the two groups; the individual values can be found in Appendix II. The blood sugar values at birth are in agreement with those reported in the literature (1, 10, 79). In the "non-fed" group there is a drop in blood sugar which persists until feeding is begun at twenty-four hours. This finding does not agree with all investigations, but the discrepancy as discussed in the Introduction probably resides with variations in subjects used (premature and full-term infants), feeding schedules, and sampling times in these other studies (1, 58, 59, 79). The best information available, including the present study, indicates that the blood sugar amongst premature infants approximates 40 mg. % at birth, falls to about 35 mg. % at eight to twelve hours post-partum and then begins a very slow rise, or remains steady, until such time as feeding is instituted or the sluggish homeostatic mechanisms of blood regulation begin to function effectively (8, 10, 19, 35).

The graph in Figure 1 and the statistical analysis of the blood sugar data reveal that oral administration of 20% glucose solution was successful in maintaining a high blood sugar level at a time when without such feeding it would have been much lower. Simply, this demonstrates that infants are capable of absorbing glucose into their blood stream and that oral glucose feeding is an effective way of raising the blood sugar.

This finding raises more questions than it answers. Basically, what does a given level of blood sugar mean? As mentioned in the introduction, so-called "symptomatic hypoglycemia" is a rare occurrence. Various investigators mentioned above have set 30 mg. % as the lower limit of normal for blood sugar in the neonatal period. Yet, they like this author have seen blood sugars below 30 mg. % amongst many infants without clinical signs of hypoglycemia. When such signs have occurred in association with hypoglycemia, oral glucose therapy has been consistently reported as ineffective whereas intravenous administration together with glucagon or adrenal steroids is generally successful (13, 55). This suggests that hypoglycemia with symptoms may be a more complex entity than is presently thought, unrelated to ordinary "neonatal hypoglycemia".

If the "normally" low blood sugar level of the newborn is not an indicator of "poor health" then one must ask what advantage might an elevated level have. To answer this question one must decide on some measurement that distinguishes "good" and "poor" health. As noted above, mortality data have rarely been successful in making such a distinction in studies of early versus delayed feeding.

From published investigations and from personal observation it seems a reasonable generalization that "active infants are healthy infants". Studies of laboratory animals have led to similar conclusions (47). The intuitive association of movement and health is probably verified by the significant relationship between gross motor activity and birthweight, for it is well established that birthweight has a positive correlation with many health criteria including decreased mortality (69). Thus, the old clinical impression can be offered

more forcefully that gross motor activity is a measure within certain limits of the health of the newborn premature infant.

Glucose feedings in the first twenty-four hours of life did cause a significant increase in gross motor activity compared with fasting during the same period. This seemed almost sufficient evidence that such feedings were beneficial, but to define this in more definite terms it was logical to relate increased activity to increased blood sugar levels. However, no correlation between activity and blood sugar either at birth or at twenty-four hours was demonstrable. In retrospect the lack of strict observation timing, the stimulus variations both between and during observations, and the intrinsic variability of the blood sugar indicate previous undue optimism that the design of this experiment would have found a significant activity-blood sugar relationship, if indeed one existed. Another consideration, probably more important, is that like low blood sugar and symptomatic hypoglycemia, there is no simple relationship between high blood sugar and increased activity. Although feeding is a common factor producing changes in both blood sugar and gross motor activity, the two need not be affected in the same direction simultaneously. In fact the mechanism by which feeding worked to increase gross motor activity is not at all clear. The mechanism might have been a direct one, providing fuel for the musculoskeletal system. It may have been a source of energy to aid, for example, the phosphorylase enzymes in metabolizing fuel already in the body. It may have worked to counteract the acidosis (related in part to excessive fat catabolism) generally present in premature infants. These are only a few and all-too-simple suggestions for the effect of feeding on activity. Without a knowledge of the exact metabolic effect of exogenous glucose, it is impossible in a behavioral

study such as this to draw conclusions other than those based on the observed data. Thus, an effect of feeding on gross motor activity and blood sugar can be seen, but no relationship is exhibited between the two variables, nor is there an obvious reason for one to be, or not to be, present.

Mention should be made briefly about the race and sex variables. Traditionally it has been stated that Negro and female prematures tend to do better than white and male infants. One explanation for the race difference is that Negro babies tend normally to be smaller than white babies, and thus a population of prematures chosen by weight will tend to include an excess of smaller, more mature Negro babies. No reasonable explanation is available for the difference between the sexes. In the present study no significant differences were found except for a trend among Negro babies to have higher blood sugar levels at birth. Together with previously cited studies of newborn blood sugar levels (1) this tends to support the view that for a given weight at birth Negro infants tend to be more mature than white infants.

This study has generated enthusiasm about the value of early infant feeding at the Yale-New Haven Hospital. This is a result not only of the research findings but also of the spontaneous observations of the personnel in the premature nursery whose unanimous opinion was that early-fed infants tolerated milk feedings after the first twenty-four hours of life better and took them more quickly than did the "non-fed" infants. They felt also that the early-fed infants would have accepted larger volumes of milk if offered, but unfortunately this possibility was not foreseen and nursery procedures do not allow for demand feeding in the twenty-four to forty-eight hour period. Thus, it was not possible to quantify the staff's opinion.

More recently an article has appeared from England purporting to demonstrate a significant detrimental effect of early feeding. Wharton and Bower (80) fed premature infants relatively large volumes of undiluted breast or diluted evaporated milk through indwelling naso-gastric catheters. The milk volumes used were those reported in another study where more favorable results were obtained (70). Wharton and Bower (80) reported a significantly higher mortality among the early-fed group with the occurrence of possibly fatal aspiration in 40% of the early-fed infants who died.

Among the thirty-two infants in the present study including the four who died before the forty-eight hours of observation (two of whom were fed) there was not one known instance of aspiration. The differences between this study and that of Wharton and Bower were the type of food given, the amount, and the technique of administration. The nursing personnel in the Yale-New Haven premature nursery who are well trained and interested used separate gavage tubes for each feeding which may be safer than the indwelling catheters of the English report. The smaller amounts of glucose given were more likely to be tolerated than larger volumes of milk, both in terms of initial mechanical and subsequent absorptive factors. The choice of food must be made carefully. Reaction to the decades-long practice of fasting premature infants must not result in over-enthusiasm to "fatten" them up. Newer practices should not be instituted in a haphazard manner that mirrors the unscientific aura of old beliefs.

The present study has sought to investigate a few basic factors related to early feeding and infant health. These are by no means the only measures

which can or might be made, but they hopefully indicate a direction to be followed. There is a need to devise new measures of infant health, particularly of the neuro-muscular apparatus. Only on the basis of more subtle evaluations can such problems as early infant feeding be adequately investigated.

Summary

A motion picture technique to quantify gross motor activity of newborn infants was used to study the relation between feeding and activity of premature infants. Thirty-two premature infants free of obvious illness (birthweights under 1800 gm.) were assigned randomly at birth to one of two groups: Group A was fed 20% dextrose (3 cc/kg.) by gavage every two hours for the first 24 hours of life while Group B received no feedings in the same period. After 24 hours all infants were put on milk formulas. At birth and at 12, 24, and 48 hours gross motor activity and blood sugars were measured. The average blood sugar levels for the four respective observations were as follows: Group A (40.2, 59.4, 59.3, 50.1 mg. %), Group B (40.6, 37.6, 37.2, 52.9 mg. %). The difference between the two curves is statistically significant. The gross movement indices which represent average linear displacement of the four limbs were as follows: Group A (2.32, 2.51, 3.15, 3.92 cm.), Group B (3.42, 2.21, 2.01, 3.12 cm.). An analysis of variance showed the interaction of feeding and time to be significant in the first 24 hours of life. The initial discrepancy of movement was a result of birthweight differences (Group A: 1515 gm. vs. Group B: 1628 gm.); a positive correlation having been found between gross motor activity and birthweight. There were no instances of aspiration during early feeding. These studies indicate that neonatal hypoglycemia can be prevented by oral feeding without apparent danger to the infant. One effect of early carbohydrate feeding is enhanced gross motor activity in the first day of life.

Appendix I

A profile of the subjects including Apgar score at one and five minutes, length of stay in the nursery, and miscellaneous clinical data (RDS=Respiratory Distress Syndrome, PRM=Premature Rupture of the Membranes)

Fed Group

Subject	Sex	Weight	Apgar	Nursery Stay	Clinical data
1	f	1605	7-8	31	-
2	f	1160	5-8	66	PRM
3	f	1540	6-9	24	C-section
4	f	1360	2-5	55	PRM
5	m	1350	9-10	60	-
6	f	1605	7-10	33	-
7	m	1680	8-10	34	-
8	m	1360	3-6	59	mild RDS
9	f	1515	9-10	52	-
10	m	1660	7-8	32	-
11	f	1225	4-6	67	PRM
12	m	1780	5-6	24	-
13	m	1170	1-5	48	hydrocephalic
14	m	1775	9-10	25	-
15	m	1800	4-6	24	-
16	f	1665	6-8	26	PRM

Non-Fed Group

17	m	1300	6-8	40	-
18	f	1475	5-7	56	mild RDS
19	m	1555	6-8	49	mild RDS
20	f	1880	7-9	24	infected delivery
21	m	1580	6-8	38	branchial cyst
22	m	1520	8-8	41	mild RDS
23	f	1650	4-8	23	-
24	f	1825	9-10	31	-
25	m	1595	----	28	-
26	m	1400	8-10	56	mild RDS
27	f	1700	3-7	36	amnionitis
28	f	1685	7-9	29	-
29	f	1790	8-8	26	horseshoe kidney
30	f	1735	6-9	32	PRM
31	m	1575	----	--	-
32	m	1785	6-8	24	PRM

Appendix II

Blood Sugar Date for Each Subject

Fed Group

Subject	Birth	12 hours	24 hours	48 hours
1	13	60	75	86
2	31	48	30	25
3	84	88	58	54
4	69	59	23	8
5	18	18	41	46
6	39	66	18	46
7	55	67	61	28
8	50	78	61	33
9	43	51	43	50
10	39	62	42	40
11	39	96	73	78
12	9	49	87	84
13	72	7	102	31
14	34	63	36	57
15	20	106	95	37
16	28	33	104	99
Mean	40.2	59.4	59.3	50.1

Non-Fed Group

17	18	14	38	0
18	41	13	37	36
19	19	24	37	70
20	104	29	36	28
21	30	37	47	49
22	29	8	18	73
23	67	11	17	38
24	29	51	47	70
25	62	59	69	37
26	20	17	0	60
27	7	42	23	54
28	66	70	72	80
29	27	77	28	30
30	60	46	23	67
31	40	53	49	78
32	31	51	54	77
Mean	40.6	37.6	37.2	52.9

Appendix III

Individual Subject Movement Indices for Each Segment of the Four Observations

Fed Group

	birth		12 hrs.		24 hrs.		48 hrs.	
Subject	A	B	A	B	A	B	A	B
1	.25	1.26	1.34	4.54	1.85	2.02	.34	.34
2	.34	.42	1.26	1.01	.42	.76	1.51	1.76
3	2.02	1.34	.17	4.20	.59	1.60	.25	2.86
4	.25	1.34	2.35	2.60	3.11	1.51	1.85	2.44
5	.92	.17	.67	.76	.67	.17	.17	.08
6	3.95	.67	2.77	2.44	3.02	1.60	2.27	2.69
7	.76	.25	3.19	3.44	2.77	1.76	4.12	4.12
8	5.46	.25	.17	1.51	.17	.50	.67	.59
9	.50	3.11	1.18	.17	1.68	.17	1.76	3.28
10	3.53	3.44	3.19	1.51	3.28	2.10	2.02	1.85
11	1.18	2.60	.17	.17	.08	3.14	.76	.17
12	7.90	.59	.59	3.78	4.87	6.13	7.07	7.07
13	2.02	.67	.67	2.60	1.18	7.06	.76	.50
14	5.38	7.06	4.62	7.39	11.36	7.56	15.62	14.26
15	6.64	1.01	.74	2.11	3.97	4.09	14.63	2.11
16	7.48	1.26	10.25	8.65	16.97	4.20	14.53	12.85
Mean	3.04	1.59	2.08	2.93	3.52	2.77	4.27	3.56
Mean of Means	2.32		2.51		3.15		3.92	

Non-Fed Group

	birth		12 hrs.		24 hrs.		48 hrs.	
Subject	A	B	A	B	A	B	A	B
17	1.68	1.76	4.54	2.02	3.70	1.01	1.76	.50
18	.17	.25	.50	.92	.25	.17	3.53	1.51
19	.92	.17	.17	.25	.17	.25	.17	.17
20	1.26	1.34	1.43	.34	3.44	.25	2.35	2.52
21	.76	.76	1.26	2.27	2.44	4.12	.76	2.52
22	1.93	2.02	.59	1.01	2.52	.25	3.02	1.26
23	3.36	2.86	2.10	3.11	.50	1.85	.37	.25
24	3.70	4.37	4.28	2.69	2.60	2.18	2.23	2.73
25	2.18	.42	1.26	.17	.25	.17	1.34	.17
26	2.27	4.03	.50	.25	1.51	.08	1.18	.25
27	1.01	.92	3.70	.25	1.93	.17	1.76	.59
28	2.69	.76	2.48	2.23	5.70	3.97	1.12	.99
29	2.02	2.18	.92	1.76	4.12	1.18	3.78	3.44
30	7.39	8.06	2.86	6.89	4.70	4.96	.84	6.80
31	11.34	12.85	.67	.84	6.97	1.60	11.17	12.01
32	15.71	8.32	3.44	15.04	.59	.59	12.03	16.62
Mean	3.65	3.19	1.92	2.50	2.59	1.43	2.96	3.27
Mean of Means	3.42		2.21		2.01		3.12	

Appendix IV

Analysis of Variance for Blood Sugar Data

(Form used is that described by Winer (82))

	Sum of Squares	df	MS	F	p
Between Subjects	24113.94	31	-	-	-
A	3310.95	1	3310.95	4.77	<.05
S.w.G.	20802.99	30	693.43		
Within Subjects	54179.97	96	-	-	-
B	2175.50	3	725.17	1.37	NS
A x B	4467.25	3	1489.09	2.82	NS
B x S.w.G.	47537.22	90	528.19		

Legend:

df - degrees of freedom
MS - mean square
F - F number
p - confidence limit
A - variable representing the two experimental groups
B - variable representing the four observations
S.w.G. - subject within group variations

Appendix V

Analysis of Variance for Movement Data

(Form used is that described by Winer (82))

	Sum of Squares	df	MS	F	p
Between Subjects	802.51	31	-	-	-
A	1.	1	-	-	-
S.w.G.	801.93	30	26.73		
Within Subjects	845.01	159	-	-	-
B	8.34	2	4.17	2.09	NS
A x B	42.60	2	21.30	3.21	<.05
B x S.w.Gb.	398.67	60	6.64		
C	7.90	1	7.90	1.95	NS
A x C	1.00	1	-	-	-
C x S.w.Gc.	121.85	30	4.06		
B x C	30.18	2	15.09	3.89	<.05
A x B x C	4.92	2	2.46	1.00	NS
B x C x S.w.Gbc.	232.64	60	3.88		

Legend:

df - degrees of freedom
MS - mean square
F - F number
p - confidence limits
A - variable representing the two experimental groups
B - variable representing the four observations
C - variable representing the two segments in each observation
S.w.G. - subjects within group variation
S.w.Gb. - subjects within group variation (evaluated by the four observations)
S.w.Gc. - subjects within group variation (evaluated by the two segments
S.w.Gbc. - subjects within group variation (the over-all variation)

Appendix VI

Analysis of Race, Sex and Birthweight Differences in Relation to Movement by Means of the t-test

$$t^2 = \frac{n_1 n_2 \left(\frac{\Sigma x_1}{n_1} - \frac{\Sigma x_2}{n_2}\right)^2}{\Sigma x_1^2 + \Sigma x_2^2 - \left(\frac{(\Sigma x)^2}{n_1} + \frac{(\Sigma x)^2}{n_2}\right)} \cdot \frac{n_1 + n_2 - 2}{n_1 + n_2}$$

Legend:

n - the number of subjects in each group (i.e., white and non-white, or male and female, etc.)
x - the movement indices of each subject in the groups being analyzed

Movement x Race:
at birth - $t^2 < 1$, not significant
through 48 hours - $t^2 < 1$, not significant

Movement x Sex:
at birth - $t^2 < 1$, not significant
through 48 hours - $t^2 < 1$, not significant

Movement x Birthweight
at birth - $t^2 = 2.45$, $p > .05$
through 48 hours - $t^2 = 8.33$, $p < .01$

Analysis of Race and Sex Differences in Relation to Blood Sugar at Birth by Means of the t-test

Blood Sugar x Race: $t^2 = 4.10$, $p > .05$ (t^2 of 4.15 is significant at the .05 level)

Blood Sugar x Sex: $t^2 = 2.65$, $p > .05$

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