Published in final edited form as:

Adv Neonatal Care. 2004 August ; 4(4): 216–225.

An Integrated Review of the Literature on Demand Feedings for Preterm Infants

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Abstract

In the past 50 years, only 7 studies evaluating demand feedings in preterm infants have been published. The studies employed a variety of research methods including nonexperimental, quasi-experimental, and experimental designs. The earliest demand feeding studies are difficult to interpret due to inadequate sample sizes and incomplete descriptions of methodology. Trials in the 1980s and early 1990s were better described; however, they suffered from designs that produced findings that likely were strongly related to unit, nurse, or infant-specific interactions with the treatment, making it unlikely that findings could be replicated in other settings. The most recent studies are better conceived and described.

Overall, the pattern of findings across the past 50 years indicates that preterm infants who were fed on demand showed some clinical improvement when compared to those infants offered other feeding patterns. Demand-fed infants exhibited more hunger cues and had improved behavior state organization, shorter duration of hospitalization, and gained weight at the same rate or faster than infants not fed on demand. Although each of the studies reviewed had some methodologic weaknesses, the consistency of findings across differing researchers, settings, empirical indicators, and years supports the cautious contention that demand feeding might prove to be the feeding approach of choice for most healthy preterm infants. Further studies in this area are warranted to add to current knowledge regarding the safety and efficacy of feeding various preterm infant populations. Research to address subpopulation differences (i.e., infants with congenital heart disease or orofacial lesions) in timing, method, and approaches to preterm infant feeding care is also needed.

Keywords

preterm infant; premature; feeding; bottle feeding; oral feeding; demand feeding; semidemand feeding; self-regulatory feeding; ad libitum feeding; infant feeding; developmental care; cue-based feedings

The ability to consume enough calories to fuel baseline energy expenditure and to support growth is a common discharge criterion for infants in the newborn intensive care unit (NICU). Attainment of full oral feedings is often the last of the discharge criteria met by the preterm infant, resulting in a population of relatively healthy, growing preterm infants in the NICU awaiting this milestone.^{1,2} This prolonged convalescent stage of hospitalization results in both increased risk to the infant for iatrogenic injury or infection, separation-related effects on the parental relationship, and increased cost to the health care system, simply because the infant is unable to feed orally. The most common reasons for hospital readmission in the 2 weeks after NICU discharge are jaundice and feeding problems.³

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Supported by the National Institute of Nursing Research, F31NR07929. No conflicts of interest disclosed.

Oral feeding practices, including when feedings are started and on what schedule they are then provided, are variable, both within and across NICU settings.¹ A national survey revealed that many NICUs had no consistent criteria for initiation of feeding and no organized protocol for feeding progression.¹ NICUs that reported formal criteria commonly initiate oral feedings based on infant weight and/or postconceptual age (PCA).¹ How feedings are offered once they are started also varies from unit to unit. Some units feed infants on demand, frequently termed *ad libitum*, based on the infants' hunger cues. More commonly, oral feedings are provided on a scheduled basis.¹ This practice is aimed at ensuring adequate caloric intake for growth.

In addition to meeting their nutritional needs, pre-term infants may benefit from an approach to their care that is individualized and developmentally supportive, with uninterrupted periods of sleep, reciprocal interaction, and balanced experience of stimulation and quiet.⁴⁻⁶ Given this combination of needs, it might be clinically advantageous to meet preterm infants' physical needs for calories in a manner that also addresses developmental needs for rest and stimulation. The evidence supporting the relationship between contingent care and development in preterm infants is mounting.⁴⁻⁶ This evidence raises the question of whether scheduled feedings, with their presumed guarantee of adequate nutrition, are better for preterm infants than contingent approaches to feeding such as that offered by demand feeding.

Integrated Review of the Literature

Methods

This integrative review of the literature includes 7 studies undertaken in the last 50 years that were selected for their relevance to inform current practice and future research. The articles were identified via extensive electronic and manual searches of research literature. Once identified, the reference lists for the studies included in this review were considered, and additional studies found and used by other authors in this area were obtained and reviewed for completeness. Literature searches of MEDLINE, CINAHL, and PsycInfo for all indexed years were searched using the keywords: preterm, premature, feeding, bottle feeding, oral feeding, demand feeding, semidemand feeding, self-regulatory feeding, and *ad libitum* feeding. The terms used are delineated in Table 1. Feeding approaches are compared in Table 2.

Studies were excluded if their primary focus of inquiry was not the timing and manner of feeding; specifically, studies were excluded that addressed research questions involving types of formula, cup versus bottle feeding, and bottle versus breastfeeding. Manual searches for the years prior to electronic indexing were conducted using reference lists of indexed articles, identification of specific journals of interest, and the assistance of a reference librarian.

The 7 studies, their authors, major variables, and significant findings are shown in Table 3. The purpose of this article is to review the research on demand feedings in preterm infants and to identify unanswered questions about this potentially important intervention.

Analysis of Literature Findings

Scheduled, Semidemand, and Strict Demand Feeding Comparisons

The first published research study report regarding demand feedings for preterm infants appeared in the literature in 1951 and evaluated 145 preterm infants in 2 settings.⁷ The study was an experimental design and compared 3 feeding regimens: scheduled, semidemand, and strict demand. Outcome variables included infant weight change, length of stay, and the number of bowel movements per day. Although no statistics or *P* values were provided, the report indicates that infants in the strict demand-fed group took larger volumes of formula, gained more weight in a shorter period of time, and were hospitalized for significantly shorter periods of time than infants in either of the other 2 groups. The primary limitation of this study is that

the researchers reported the weight, but failed to report the precise gestational ages of the infants enrolled. Given the inadequate sample description, the infants could have been near-term and very small for gestational age (SGA) or very preterm and appropriate for gestational age (AGA). In reality, the sample is likely a mixed one; because infants were described only by weight at birth and postnatal age in days, there is no way to determine what, if any role this played in the findings.

The lack of foundational research to directly compare scheduled and demand feedings in initially comparable preterm infants prior to this study, as well as several methodological flaws, limit interpretability and usefulness of this study. A major flaw in the study was that the groups were not comparable from the start; infants were recruited and received care in 2 diverse settings and over different periods of time. The scheduled ($n = 47$) and semidemand-fed groups ($n = 51$) were from the premature nursery at the Harriet Lane Home of the Johns Hopkins Hospital, a public hospital serving families of a lower socioeconomic class of all races, and the strict demand feeding group ($n = 47$) were all white infants from families of mid to high socioeconomic status recruited from the Sinai Hospital premature nursery. Once data collection was complete, the researchers stratified the infants into groups for post hoc analysis. The groups were reconfigured based on birth weight: <1000 g ($n = 9$), 1001 to 1500 g ($n = 59$), and 1501 to 2000 g ($n = 77$). The stratified groups were then compared across treatment groups, focusing on the number of days required to reach 2500 g, the desired weight for discharge.

The differences between the groups and the interaction of the treatment with the infants' birth weights is fairly compelling; infants in the strict demand feeding group, no matter what their birth weight, reached the targeted discharge weight much sooner than infants in the scheduled or semidemand-fed groups. For example, infants weighing <1000 g at birth took a mean of 66 days to attain a weight of 2500 grams when demand fed, compared to 74.5 days for the semidemand-fed infants or 99.5 days for the schedule-fed infants. The same trend of requiring fewer days to attain the targeted weight was consistent across all weight groups. Another trend across all weight categories suggested that demand feeding was more effective in reducing the days to attain 2500 g than semidemand; infants fed on semidemand feedings achieved this goal more quickly than those receiving scheduled feedings.

The major weakness of this post hoc analysis is that the groups were very unequal in number; the <1000 g group was particularly small. The inadequate description of the preterm infants studied with respect to PCA and prenatal growth category (i.e., small vs. appropriate vs. large for gestational age) makes these findings difficult to interpret or generalize to modern NICU populations.

Safety of Demand Feedings for Preterm Infants

Another study, conducted in 1952, was an uncontrolled, nonexperimental feeding trial with a nurse-selected sample of 25 preterm infants.⁸ The standard practice in this setting was to offer demand feedings to full-term infants from birth. Preterm infants were transitioned to demand feedings within several days of scheduled discharge. The purpose of the study was to determine if infants could safely be fed on demand earlier than the near-discharge period. The study was designed to assess safety in clinically selected infants in a single institution.

Subjects were selected based on their status as "healthy and vigorous," as assessed by the unit nurses; no specific criteria are provided. There was no random selection, assignment, or control group. As with the previous study, there is no way to ascertain the degree of prematurity of the sample or whether the infants were near-term SGA, or preterm AGA. The outcome variables of interest were daily weight gain and daily caloric intake.

No safety variables were evaluated. Of interest, the reported data suggest that the minimum number of feedings per day for several infants in the study was 3; the maximum amount of time that elapsed between feedings was 15 hours. There were no comments on the presence of a safety threshold in terms of either the number of feedings or the maximum interval between feedings for the study.

Infants included in the study were only described by their postnatal age in days at study entry (range 2 to 45; mean [M] = 17 days) and birth (range 1.3 to 2.27 kg) and study entry weights (range 1.55 to 2.21; mean = 1.9 kg) at enrollment; PCA was not reported. The total number of infants enrolled was not provided. The report describes 20 infants who completed the study with adequate caloric intake and weight gain. An additional 5 infants were written up as case studies to explicate the mechanisms and clinical presentation of demand feeding failure.

The researchers concluded that although demand feeding even in very young, small preterm infants was safe and provided some benefit, it also required careful medical supervision, expert nursing care, and a “proper feeding mixture.” The definition of very young, small preterm infants is not explicitly stated; it seems to refer to the smallest of the infants studied, who were <1000 g at birth and only a few postnatal days old. The definition of a proper feeding mixture is also unclear; it appears to refer to the ingredients and proportions of the formula provided, a point of earlier discussion in the research report describing the calorie, fat, and protein content of the infant formula used in the study.

The design of this study resulted in serious limitations in the ability to generalize the findings to other settings. The “adequate, interested” nursing staff was described as having a prominent role in the study and implementation of early demand feedings. Not enough information was given to discern how to measure or determine if a given nurse or group of nurses is adequate or interested enough to make demand feeding feasible in young preterm infants. The total number of infants studied and inclusion or exclusion criteria were not reported. Additionally, the range of study days was highly variable from 8 to 25 days. Despite these limitations, the findings suggest that in a select group of preterm infants, demand feedings resulted in adequate weight gain.

The first randomized controlled trial to formally assess the use of demand feedings in preterm infants was published in 1982.⁹ The sample was recruited from a single NICU and included 37 infants. The mean gestational age and birth weight in the schedule-fed group was 32.9 weeks and 1797.4 g compared to 32.1 weeks and 1743.8 g in the demand-fed group. Outcome variables assessed included weight gain, days to full oral feeding, number and percentage of feedings via gavage, volume ingested by bottle, and length of stay. The researchers hypothesized that preterm infants who were fed on demand would take adequate fluids and nutrition, would have no increased incidence of feeding-related problems, and would feed well enough to be discharged home sooner than infants fed on a schedule.

Demand-fed infants had significantly fewer feedings per day and significantly fewer gavage feedings per day for the entire study and were discharged an average of 6.2 days sooner than the schedule-fed infants. Statistics and *P* values were not provided for any of the findings. The raw mean for weight change in the demand-fed group was 11.2 g/day compared to 14.6 g/day in infants fed on a schedule.

The article does not comment on either the statistical or clinical significance of this difference; therefore, the strength of the relationships cannot be determined. The incomplete description of the study sample makes interpretation of these findings difficult. Descriptive statistics on the sample included birth-weight, gestational age, PCA, and age and weight at the time of entry into the study. No ethnic or gender information on the sample was offered. Although infants

with major neurological and gastrointestinal disorders or acute illnesses were excluded, no analysis or further information about the baseline morbidity in each group was provided.

Self-Regulatory Feedings

The effects of a self-regulatory model to aid the transition from gavage to bottle feeding in preterm infants were tested using a randomized controlled trial.¹⁰ Outcome variables included behavioral state, energy expenditure, and weight gain. The 74 infants in the final sample were randomly assigned to self-regulatory or control groups. Both groups had similar demographics, birth weights, and gestational ages. The mean PCA of the self-regulatory and control groups was the same (30 weeks), as well as lengths (30 cm) and head circumferences (27 cm). However, the self-regulatory group infants were 44 g lighter on average and were receiving more apnea medication (19 vs. 16 in the control group). Conversely, more infants in the control group were receiving oxygen (10 vs. 6 in the self-regulatory group).

Infants were tube fed for 16 consecutive feedings every 3 hours. Thereafter, infants were given 1 oral feeding per day until they were 100% bottle feeding, as defined by 16 complete bottle feedings in a row.

Infants in the self-regulatory group were allowed to bottle feed until they tired; they also received nonnutritive sucking (NNS) for 5 minutes before all feedings, during gavage feedings, and to satiety after all feedings. They were fed using a nipple described in the research report as “firmer and slower.” Infants in the control group were urged to take a complete bottle approximately once each shift and used a nipple described by the researchers as a “faster flow” nipple. No specific information regarding the range or average number of bottles taken per shift or per day in the control group is reported.

Infants in the self-regulatory group had significantly improved measures of behavior state and were more often in regular sleep at feeding end and less frequently in restless states. Infants demonstrated no difference in heart rate during or after feedings. In addition, infants in the self-regulatory group who were <1500 g gained almost 3 times as much weight as infants in the control group (24.4 vs. 8.9 g/day, $F = 13.01$, $P < 0.0003$). Weight gain was similar when the infants were >1500 g (25.8 vs. 28.4 g/day).

These findings must be interpreted with caution. Multiple treatment interference was likely a problem in this study. It would be hard to determine if group differences were related to self-regulation, NNS, or caregiver differences. In addition, little foundation for inclusion of the firmer nipple was provided, and use of the nipple could have had affected feeding performance, which might have masked positive effects of NNS and feeding experience.

Hunger Cues and Demand Feedings

A randomized, controlled trial compared the use of a demand or a scheduled feeding approach in 29 infants ranging in age from 3 to 64 postnatal days ($M = 21$ days). The demand-fed group had a mean birth weight of 1390 g compared to 1565 g in the control group; the gestational age in the demand-fed group was 31.4 weeks and 31.7 weeks in the control group. At study entry, the mean group weights were closer: 1656 g in the schedule-fed group and 1665 g in the demand-fed group.¹¹ Outcome variables were weight gain, length of stay, and the ability to exhibit hunger cues as specific outcome measures. The caloric density of the feedings was identical in both groups.

Research findings were reported without statistics or P values. Infants in the demand feeding group exhibited a greater number of hunger cues (described as statistically significant without reporting statistics) than their schedule-fed counterparts. Although the demand-fed infants, individually and as a group, gained more weight over the 6-day study period, the difference in

their mean weight gain was not statistically significant. Infants fed on demand remained hospitalized an average of 1 day less than the schedule-fed infants; again, this difference was not statistically significant.

The infants fed on a schedule consumed 273 to 313 mL/24 hours compared to demand-fed infants, who took between 251 and 272 mL/24 hours, resulting in increased caloric consumption in the scheduled feeding groups. Despite consuming more calories, the rates of weight gain were equal in both groups. This finding suggests the possibility that the stress of scheduled (noncontingent) feeding may have resulted in the expenditure of the additional calories consumed to manage stress of noncontingent feeding care.

The incomplete description of the study sample makes interpretation of these findings difficult. Descriptive statistics on the sample included postnatal age in days, birth weight, gestational age at birth, and weight at the time of entry into the study. No ethnic or gender information on the sample is provided. Although infants with major neurological and gastrointestinal disorders or acute illnesses were excluded, no analysis or further information about the baseline morbidity in each group is provided.

Ad Libitum Feedings

The potential relationships between feeding patterns and formula caloric density on infant caloric intake and weight change were explored using an experimental, randomized factorial design in 78 AGA preterm infants who were 29 to 31 weeks gestation at birth.¹² Infants were randomized to either an ad libitum or scheduled feeding regimen. They were further randomized to formula caloric density (20 vs. 24 kcal/oz formula).

The ad libitum feeding regimen, without regard to caloric density, had a negative effect on caloric intake. Of the variables examined, only caloric intake had a direct or additive effect on weight change. Over the 5-day study period, infants in the ad libitum group adjusted their intake, regardless of the caloric density received, to come close to achieving the prescribed amount of formula for infants in the scheduled feeding group.

The researchers hypothesized that infants in the ad libitum feeding group gained contingent feeding experience and, thus, were able to self-regulate their intake to match that needed for growth. Although it has long been known that term infants can adjust their intake, even when formulas with various caloric densities are provided, there is no prior evidence to suggest that preterm infants have this capability. These findings suggest that preterm infants may adjust their intake based in calorie content, similar to the way in which term infants do. Further research should address this potentially useful self-regulatory ability relative to the infant or treatment-specific characteristics that predict preterm infant ability to self-regulate nutritional intake.

Limitations of the study include a high loss of subjects. Of the 150 infants consented and entered into the study, 69 were discharged home before the 5-day interval was completed. No differences between the remaining subjects by groups were found. Although no significant pattern of subject loss was determined, this could represent an undetected treatment effect. Analysis and interpretation of findings could also be affected by this high experimental mortality.

Semidemand Feeding Protocol

The use of a semidemand feeding protocol to transition infants from gavage to oral feedings was evaluated in a randomized controlled trial of 81 infants ranging in age from 32 to 34 weeks gestation.¹³ Infants in the control group were fed following the standard practice of gradually increasing scheduled oral feedings. Infants in the semidemand feeding group were assessed

every 3 hours for behavioral signs of hunger. Behavioral signs of hunger were defined as a behavior state assessment at a level of restlessness or wakefulness. If the infants were sleeping at the first assessment, they were left sleeping and reassessed 30 minutes later. If the infants continued to sleep at the second assessment (3.5 hours), the feeding was provided by gavage. The infants were never assessed for hunger more often than every 3 hours.

The semidemand regimen shortened time to full oral feeding by 5 days (control group, 10 ± 3.1 days; semidemand-fed group 5 ± 4.2 days), resulting in both a statistically significant ($P < 0.001$) and clinically significant improvement in the length of stay. The semidemand feeding treatment showed no statistically significant change in rate or amount of weight gain compared to the control group. Control group infants gained 26.3 ± 1.3 g/day compared to 23.5 ± 1.4 g/day in the experimental group during the gavage to oral feeding portion of the protocol. Once all feedings were taken orally, the control group infants gained 33.5 ± 2.1 g/day, whereas the experimental group infants gained 31.9 ± 2.1 g/day.

Although this feeding protocol is more contingent than standard NICU feeding care, it is not truly a demand feeding regimen. The scheduled nature of assessments meant that infants in the experimental group received care more like the infants in the control group. The major difference between the nature of feedings in the control group and the experimental group was that the experimental group infants were not awakened for feedings.

Synthesis of the Research Findings

All of the research studies reviewed relative to demand feeding preterm infants prior to the 1990s have methodological limitations that preclude their applicability to current practice. Specifically, a major barrier to applying these findings to current practice is the lack of gestational age estimates in the early studies. In fact, at the time some of these studies were conducted, the most rudimentary tools for estimating gestational age had not been developed.

Although some of the infants described in early reports weighed 750 g at birth and/or at the initiation of feedings, we cannot effectively compare these infants to infants of the same weights in modern NICUs because we have no information about their gestational age, level of acuity, or coexisting morbidities.

Although 2 of the protocols were labeled self-regulatory and semidemand feeding,^{10,13} neither represents a true demand feeding trial. Both studies are perhaps more appropriately viewed as assessments of the contribution of NNS prior to feeding as a means of optimizing behavior state before and during feeding. In addition, the only true demand feeding trial also evaluated different calorie formulas, confounding the findings with differences in nutritional intake.¹² This study, coupled with work by others, strongly suggests that ad libitum feeding is not only likely to be safe, but it may represent a therapeutic benefit to preterm infants.^{12,13}

Objective outcome variables to directly assess specific aspects of safety, such as screening for hypoglycemia with blood sugar measurements, were not performed in any of the studies. It is equally important to note that the control condition, scheduled feeding, has also never been systematically subjected to safety testing with outcomes such as serum blood sugar.

All of the research reviewed in this article, including studies conducted more than 50 years ago, were conducted in clinical practice settings, where infants were carefully observed by skilled personnel. More recent studies were conducted under the auspices of institutional review boards (IRBs), requiring prompt and systematic reporting of any adverse events. No safety issues were reported in any of the studies. Future feeding studies need to consider outcome variables that directly document safety, as a safe fasting interval has not been determined for infants fed either on schedule or demand.

Each method, therefore, should be considered on its merits as interventions. There are no data to support the improved safety of demand feeding as opposed to scheduled feeding. The only study where true demand feeding has been tested (i.e., unlimited length of time between feedings) was conducted over 50 years ago and missing data, discussed previously, make the findings difficult to interpret and less useful.⁷

Implications for Clinical Practice

Nurses in NICUs are in a unique position to affect feeding care of preterm infants. The evidence for feeding practices in preterm infants is limited; the number of studies is small, and the sample sizes, methodology, and ability to generalize are weak. Implementation of clinical care based on the existing knowledge requires formal planning and careful consideration.

Demand feeding should only be considered for growing preterm infants who would have been eligible for inclusion in the reported research; specifically, infants without congenital heart disease, orofacial lesions, gastrointestinal lesions, or significant intraventricular hemorrhage (grade III or IV) may be eligible. Demand feeding for these infants could start with initial feeding opportunities and continue until successful full oral feeding was established. Demand feeding would, temporarily or indefinitely, cease in the instance of clinical changes, such as initiation of a septic workup, or signs that the infant was too tired to orally feed. Safety measures would likely include one or all of the following:

- A limit on the interval between feedings (i.e., 4 hours)
- Calculation of daily fluid minimum and caloric intake goals
- Routine assessment of growth
- Assessment of blood glucose levels with any clinical suspicion, or at the extended time limits of demand feeding

Demand feeding protocols should be designed by interdisciplinary team members and attempted only in settings where unit administration and expert nurses are committed to the initial extra effort involved in developing and using a formal demand or ad libitum feeding protocol. The extra effort required to develop and implement such a plan would require administrators and clinicians to believe that some substantial benefit to the infant exists. When considering the effort involved in attempting and evaluating demand feeding safety, it is important to note that scheduled feeding, the standard in many nurseries, has no more evidence to support it as a safe and effective means of providing feedings.

QUESTIONS FOR FUTURE RESEARCH

When considered individually, all of the studies reviewed here have 1, or in some cases several, methodological flaws. When considered as a group, the flaws do not outweigh the evidence produced to support both the safety and efficacy of demand feedings for at least some preterm infants. Neither the weight of the research evidence from the studies conducted in this area nor this literature review are likely to change practice in the area of preterm infant feeding. Such a change would and should require a more substantial evidentiary basis than that provided by the literature currently available. Again, it is worth noting that the “standard” to which demand feeding is compared, that of scheduled feeding, has no such evidentiary basis.

To demonstrate any existing relationship between demand feeding and infant well-being, more infant-sensitive outcomes must be included in future demand feeding trials, such as the combination of these variables:

- Weight gain

- Behavior state
- Feeding performance
- Hypoglycemia
- Time to transition to full bottle feeding
- Length of stay

Further studies in this area are warranted to add to current knowledge regarding the safety and efficacy of feeding various preterm infant populations. Specifically, replicable well-controlled experimental trials to directly compare scheduled, semidemand, and strict demand feeding in representative NICU samples across various settings should be conducted. Care should be taken to provide clear descriptions of the infant populations studied, as well as inclusion and exclusion criteria, both for ease of current interpretation and for use by future scholars and researchers. More research on the safety and efficacy of demand feeding protocols is also needed. Although it would appear that demand feedings offer a more contingent approach to feeding, neither the short-nor long-term benefits of demand feeding have been fully explicated. Of particular interest is research that investigates the underlying biobehavioral mechanisms by which demand feeding might work to produce more rapid feeding progression.

Further research is also needed to identify the gestational age and other relevant characteristics of pre-term infants who might best be able to learn, over a several-day period, how to self-regulate oral intake to support a change to demand feeding. Another area worthy of research attention is the identification of interventions to enhance recognition, by nurses and parents, of early hunger cues and interventions that reinforce preterm infants' behavioral expressions of hunger. Once identified, these interventions should be studied to specify the theoretical means by which they are effective. This would result in better understanding of the mechanisms and might suggest additional interventions for effectiveness testing.

Conclusion

In summary, the number of studies in the area of best feeding schedules for preterm infants is small. Moreover, half of the studies reviewed in this article were conducted more than 50 years ago and likely reflect a substantially different population of preterm infants when compared to the current NICU populations. Even in light of the limitations discussed, the consistency of findings across differing researchers, settings, empirical indicators, and years supports the cautious contention that demand feeding might prove to be the feeding approach of choice for most healthy preterm infants. Further well-conceived research in this area is clearly required to improve care to and the feeding outcomes of these fragile infants.

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Table 1Definition of Key Infant Feeding Terms^{9,11–13}

Term	Definition
Ad libitum feeding ¹²	Feeding is begun on infant cues of hunger and ended on infant cues of satisfaction of hunger, regardless of the time or volume taken.
Demand feeding ¹¹	Feeding is begun on infant cues of hunger and ended when total ordered feeding volume has been taken.
Scheduled feeding ⁹	Feedings are begun on a timed or scheduled basis without regard to infant status. Infants are awakened from sleep to feed.
Semidemand or modified ad libitum ¹³	Feeding is begun and ended on specified infant cues of hunger and volume of feeding is prescribed by providers, not determined by the infant. Hunger is assessed on a scheduled basis (i.e. every 3 hours). If the infant is sleeping, reassessment is done once more, 30 minutes later. If the infant remains asleep at that time, feeding is provided by gavage. If the infant displays hunger cues at either assessment, feeding is provided and ended when total volume is taken.

Table 2
Comparison of Characteristics of Feeding Regimens^{11–13}

Terminology	Feeding Volume	Feeding Initiated	Feeding Ended
Ad libitum feeding ¹²	Determined by infant	Infant cue	Infant cue
Demand feeding ¹¹	Ordered by provider	Infant cue	Total feeding volume taken
Semidemand or modified ad libitum feeding ¹³	Ordered by provider	Time and infant cue	Total feeding volume taken

Table 3

Studies of Demand Feeding⁷⁻¹³

Study/ Year	Design, Sample, and Target Population	Interventions and Outcome Variables	Findings	Critique and Synthesis
Hardy JB, Goldstein EO ⁷ 1951	Design: Quasiexperimental Sample: N = 145; 2 settings; strict demand-fed infants were all white infants from mid to high SES families, whereas other groups included infants of all races from lower SES families Target population: Preterm infants weighing between 932 to 1733 g, no specified inclusion or exclusion criteria	Interventions: <ul style="list-style-type: none"> • Demand vs. scheduled feedings • Various caloric density formulas Outcome variables: <ul style="list-style-type: none"> • Weight gain • LOS • Number of BM 	Post Hoc Analysis: Stratified by wt <ul style="list-style-type: none"> • <1000 g • 1001-1500 g • 1501-2000 g <p>Across all weight groups, infants fed both higher calorie formula and fed on demand had an increased average daily weight gain and reduced LOS. In <1000- g group, demand feeding shortened time to discharge by 33.5 days when comparing schedule feeding and by 8.5 days when comparing semidemand feeding</p>	<ul style="list-style-type: none"> • No <i>P</i> values or statistics provided • Modern preterm infants may not be comparable • PCA not reported • Intervention assignment setting- based • Socioeconomic differences in settings. Findings might have been affected by historical threats not accounted for in the design.
Horton FH, Lubchenko LO, Gordon HH ⁸ 1952	Design: Uncontrolled, not experimental Sample: N = 25 (20 successfully completed; 5 feeding failures reported) 1 setting (more) Target population: Preterm infants from 1300 to 2270 g at birth, no specified inclusion or exclusion criteria	Interventions: <ul style="list-style-type: none"> • Demand feeding • Formula caloric Outcome variables: <ul style="list-style-type: none"> • Weight gain • Feeding intervals in hours 	<ul style="list-style-type: none"> • No difference in weight gain • Longer interval between feedings and demand • feedings 	<ul style="list-style-type: none"> • No <i>P</i> values or statistics reported • No report of BW or PCA • Described only by postnatal age in days and postnatal weight at study start • Demand feeding failures not reported • Did 80 start and only 20 successfully complete the study? • 5 feeding failures reported; denominator unclear • No <i>P</i> values or statistics provided
Collinge JM, Bradley K, Perks C, Renzy A, Topping P. ⁹ 1982	Design: Experimental Sample: N = 36, single setting Target population: ≤2500 g preterm infants AGA, able to coordinate suck- swallow and breath, taking all nutrition orally while maintaining normoglycemia, no major neurologic or GI anomalies	Intervention: Demand feeding Outcome variables: <ul style="list-style-type: none"> • Weight gain • Days to full oral feeding • Number and % of feeds via gavage • Volume taken by bottle • LOS 	Demand-fed infants <ul style="list-style-type: none"> • Significantly increased percentage of volume taken by bottle • Took significantly more by bottle than infants fed on schedule • Showed significantly shorter number of days from study admission until feeding well enough for discharge 	<ul style="list-style-type: none"> • Report of birth weight and PCA estimate made for sample • Sample derived from potential of 46; parents of 8 infants refused consent; 1 physician refused infant inclusion; 1 infant removed from scheduled feeding group due to continued need for gavage feedings after 14 days on study; was then offered demand feedings and within 4 days no longer required gavage feedings • If modern NICU population is similar

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Anderson GC ¹⁰ 1990	Design: Randomized controlled trial Sample: n = 74 Target population: <2400 g and 34 weeks PCA at birth, AGA, free of anomalies that would interfere with feeding	Intervention: Self-regulatory with prefeed non-nutritive sucking Outcome variables: Behavior state, heart rate, and weight gain	Self-regulatory infants <ul style="list-style-type: none"> Had more regular sleep at the end of the interfeeding interval ($P < 0.03$) Infants <1500 g at birth Gained almost 3× weight ($P < 0.0003$) Infants >1500 g at birth No weight gain outcomes benefits observed. Actual P value not reported 	<p>to infants studied here, study strongly suggests demand feeding is safe and may provide significant benefit in terms of shortened LOS</p> <ul style="list-style-type: none"> Sample is not well enough described to make this recommendation Multiple treatment interference likely No foundation or explanation for inclusion of the firmer nipple as a variable Self-selection of nurses for self-regulatory group might have contributed more variability than the experimental condition itself and was unaccounted for in design Infants weighing <1500 g are most likely to benefit most from self-regulatory feeding No P values or statistics provided
Saunders RB, Friedman CB, Stramoski PR. ¹¹ 1991	Design: Experimental, random assignment to groups Sample: n = 29 Target population: <37 weeks PCA at birth, AGA, no major neurologic or GI anomalies, no acute illnesses, weight <1550 g at study initiation, taking all nutrition orally, no fluid restriction, blood sugar screen >40 mg/ dL, able to coordinate suck- swallow and breath sequence	Intervention <ul style="list-style-type: none"> Demand feeding Outcome variables <ul style="list-style-type: none"> weight gain LOS exhibition of hunger cues 	<p>Pattern of weight gain across 6 days similar for 2 groups</p> <ul style="list-style-type: none"> Demand-fed group gained more weight; difference not significant LOS Demand-fed infants 1 day shorter Difference not statistically significant <p>Hunger cues</p> <ul style="list-style-type: none"> Demand-fed group exhibited statistically significantly more hunger cues 	<ul style="list-style-type: none"> No morbidity assessment or information about group differences offered Gender and ethnicity information not provided Schedule-fed infants consumed more calories but did not gain more weight or gain weight faster than demand-fed infants Suggests possibility that stress of being fed via an externally directed rhythm costs a significant portion of the calories consumed. No exploration or follow-up made relative to this potentially important finding Synthesis that demand feeding is weight and safety

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Pridham K, Kosorok MR, Greer F, Carey P, Kayata S, Sondel S. 12 1999	<p>Design: Randomized, controlled trial</p> <p>Sample: n = 78</p> <p>Target population: PTI <35 weeks PCA and AGA at birth who were not transferred out of the nursery prior to discharge home, full oral feeding achieved by 40 weeks PCA, without significant congenital or medical conditions that would interfere with feeding</p>	<p>Intervention</p> <ul style="list-style-type: none"> Ad libitum v scheduled, then further randomized to 20 vs. 24- calorie formula <p>Outcome variables</p> <ul style="list-style-type: none"> Dietary intake Volume kcal/kg/day grams of protein/kg/ day Change in weight (g/kg/ day) for each study day 	<p>No significant effect on weight change from</p> <ul style="list-style-type: none"> Feeding regimen Caloric density Interaction of regimen and caloric density <p>BPD infants had</p> <ul style="list-style-type: none"> Lower weight gain in grams/ kg/day Finding only marginally significant Support Waterlow's claim preterm infants' appetite and feeding behavior could not guide feeding practice Over all 5 study days ad libitum feeding regimen infants took in <AAP recommended 120kcal/kg As ad libitum feeding regimen infants progressed over 5 day study period median caloric intake approached prescribed amount Support nipple- feeding experience may affect how ad libitum regimen preterm infants 	<p>neutral while providing a benefit in terms of the infants, ability to communicate via hunger cues</p> <ul style="list-style-type: none"> Cautious use of demand feeding in structured setting of NICU within a feeding protocol might benefit the highest risk SGA, low-birth-weight infants and assist them in interaction ability with caregivers High experimental mortality with no data to support that infants lost were not different with respect to gender and ethnicity No discussion of efforts to detect a meaningful pattern to subject loss Infants self-selected by having to have taken 80% of feedings by bottle prior to inclusion in the study Synthesis with previous research suggests ad libitum feeding is safe, may support self- regulation and learning in preterm infants Infants already taking 80% of feedings by bottle could reasonably be tried on ad libitum feedings Possible clinically useful suggestion is infants allowed to feed ad libitum within a structured feeding protocol and were not consuming adequate calories by feeding protocol day 5, would require additional assessment for unidentified sources of feeding problems

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McCain, Gartside PS, Greenberg JM, Lott JW ¹³ 2001	Design: Randomized, control trial Sample: n = 81 Target population: PTI	Intervention <ul style="list-style-type: none"> Semidemand feeding protocol Outcome variables <ul style="list-style-type: none"> Time to full oral feeding Weight gain 	regulate dietary intake and consequently grow Note: Whole model <i>P</i> values and quadratic effects were provided, no values relative to specific findings. •Semidemand-fed infants shortened time to oral feedings by 5 days (<i>P</i> < 0.001)	<ul style="list-style-type: none"> Scheduled nature of assessments for hunger used in study detracts from demand or contingent nature of intention of demand feeding Coupled with previous research this study suggests feeding infants when they display hunger cues is safe and shortens time to full oral feeding without negative effect on weight gain

Abbreviations: SES, socioeconomic status; LOS, length of stay; BM, bowel movement; PCA, postconceptual age; BW, birth weight; AGA, appropriate for gestational age; GI, gastrointestinal; NICU, neonatal intensive care unit; SGA, small for gestational age; BPD, bronchopulmonary dysplasia; AAP, American Academy of Pediatrics.