ORIGINAL RESEARCH

Effects of Maternal Voice Stimulation Combined with Non-Nutritive Sucking on Improving Feeding Intolerance and Promoting Growth and Development in Premature Infants

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ABSTRACT

Aim • This study explores the mechanisms underlying the impact of a combined intervention using maternal voice stimulation (MSS) and non-nutritive sucking (NSS) on feeding intolerance and growth and development in premature infants.

Method • One hundred cases of low birth weight premature infants admitted between August 2021 and December 2022 were randomly assigned into two groups: the combined group and the control group, each consisting of 50 infants. The control group received a non-nutritive sucking intervention, while the combined group received maternal voice stimulation in addition to the sucking intervention. Differences in feeding intolerance, feeding progression, growth and development, feeding performance, and heart rate indices were compared between the groups.

Results • Compared to the control group, the combined group showed significantly reduced incidence of feeding intolerance, feeding transition time, length of hospital stay, and time to regain birth weight, along with lowered heart rate. Additionally, there were significant increases in body mass growth rate, head circumference growth rate, body length growth rate, milk intake ratio, and feeding efficiency in the combined group ($P < .05$).

Conclusion • The application of maternal voice stimulation combined with non-nutritive sucking in premature infants could reduce the risk of feeding intolerance and heart rate levels. Simultaneously, it improved feeding performance and promoted growth and development in premature infants, indicating the clinical value and potential applicability of this combined intervention. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

According to data from the World Health Organization, approximately 15 million premature infants are born globally each year, and about half of them are classified as low birth weight infants. In developed countries, the incidence rate of low birth weight in premature infants is typically around 5% to 10%, while in developing countries, it can be higher, ranging from 15% to 20%.[1] Premature infants with low birth weight often face challenges in oral feeding due to their underdeveloped gestational age, weak sucking strength, and lack of swallowing reflex.[1] Feeding intolerance along with poor growth and development in premature infants have become critical areas of research in recent years. Several feeding strategies, such as gravity feeding and non-nutritive sucking, have shown promising results in improving feeding outcomes. However, individual feeding methods alone may not yield significant improvements, prompting the evaluation of combined methods as the primary approach for feeding interventions.[2]

Previous studies have highlighted the importance of exploring effective feeding interventions for premature infants.[2,3] A randomized controlled trial examining the effects of non-nutritive sucking on feeding outcomes in premature infants found that non-nutritive sucking significantly improved sucking-swallowing-breathing coordination and reduced the duration of tube feeding dependency.[3] Similarly, a prior study found the impact of gravity feeding on feeding tolerance in preterm infants and observed improved gastric emptying and reduced incidence of feeding intolerance.[4] These studies emphasize the need for comprehensive and integrated interventions to enhance feeding outcomes in premature infants. In recent years, maternal sound stimulation (MSS) has emerged as a potential intervention method for improving feeding outcomes in premature infants. MSS has been found to increase gastric hormone secretion, facilitate neurodevelopment, and expedite the maturation of sucking-swallowing-breathing reflexes, thus accelerating the process of oral feeding.[5] While MSS has shown promise in enhancing feeding outcomes, its combined effects with non-nutritive sucking have not been extensively studied, particularly in the context of low birth weight premature infants.[6]

This study aims to address this research gap by introducing an intervention that combines MSS and non-nutritive sucking. The primary objective is to assess the impact of this combined intervention on feeding outcomes in low birth weight premature infants. By exploring the effectiveness of this intervention, the study aims to contribute to the development of more efficient methods for promoting oral feeding in this vulnerable population. The hypothesis is that the combined intervention of MSS and non-nutritive sucking will significantly improve feeding outcomes, including sucking-swallowing-breathing coordination, feeding tolerance, and the duration of tube feeding dependency, in low birth weight premature infants.

MATERIALS AND METHODS

2.1 General Information

A total of 100 cases of low birth weight premature infants, admitted to our department for treatment between August 2021 and December 2022 and meeting the inclusion criteria, were selected for this study. They were randomly divided into two groups: the combined group and the control group, with 50 cases in each group. There were no statistically significant differences in baseline characteristics between the two groups ($P > .05$), as shown in Table 1. The included premature infants had a gestational age between 30 to 35 weeks and a birth weight ranging from 1000 to 2000 grams. Within 24 hours of birth, they were admitted to the hospital for treatment, passed the hearing test bilaterally, were unable to feed orally, required nasogastric feeding, exhibited stable vital signs without abnormalities, had no contraindications for enteral nutrition, and their parents or legal guardians provided informed consent voluntarily. Additionally, the mothers of the premature infants exhibited stable emotions and vital signs. Premature infants capable of oral bottle feeding and with conditions such as neurological disorders, genetic metabolic diseases, congenital gastrointestinal malformations, oral malformations, oral developmental abnormalities, and an Apgar score of 3 or less at one minute after birth were excluded from the study. Maternal exclusion criteria included hoarseness, deaf-mutism, communication disorders, or a history of mental illness.

Table 1. Comparison of Baseline Characteristics of the Two Study Groups [$\bar{x} \pm s$ (n, %)]

Parameters		Control group ($n = 50$)	Combined group ($n = 50$)	t/χ^2	P value
Gender	Male	23 (46.00)	24 (48.00)	0.040	.841
	Female	27 (54.00)	26 (52.00)		
Gestational Age at Birth (weeks)		30.11 ± 1.32	30.28 ± 1.30	0.649	.518
Birth Weight (kg)		1.67 ± 0.23	1.68 ± 0.23	0.217	.828
Head Circumference at Birth (cm)		30.76 ± 1.96	30.77 ± 1.81	0.027	.979
Birth Length (cm)		42.16 ± 3.23	42.54 ± 2.11	0.696	.488
Mode of Delivery	Cesarean Section	39 (78.00)	38 (76.00)	0.056	.812
	Vaginal Delivery	11 (22.00)	12 (24.00)		

Methods

Intervention Methods. Control group Intervention: Premature infants in the control group received non-nutritive sucking intervention according to the following procedure: every 2 to 3 hours, a gravity-assisted nasogastric feeding was administered, and a rubber nipple was provided to the infant for approximately 5 minutes before and after each feeding session.

Combined Group Intervention: In addition to the intervention received by the control group, premature infants in the combined group were exposed to maternal voice stimulation. The procedure involved the researcher entering the obstetrics ward within 24 hours of the infant's admission, explaining the study's purpose and methods to the infant's mother, obtaining her support and consent, and recording the mother's voice using the same model of voice recorder. The mothers were instructed to maintain a relaxed and gentle tone while recording nursery rhymes, stories, or softly speaking to the infant for several minutes. The recordings were named with the infant's hospital identification number. To prevent cross-infection, the used voice recorder underwent surface disinfection with 75% alcohol before each playback. The pre-recorded maternal voice was played in the incubator, maintaining the volume at 45-50 dB, three times a day (morning, noon, and evening) for 20 minutes per session, and continued until the infant's discharge.

Laboratory Index Measurement. A multifunctional electrocardiogram monitor was used to record the infants' heart rate 5 minutes before intervention, 1 hour post-intervention, and 2 hours post-intervention. Measurements started 5 minutes prior to each time point, and the average heart rate was calculated for analysis.

Outcome Measures

The study employed various outcome measures to assess the effects of the combined intervention of non-nutritive sucking (NNS) and maternal sound stimulation (MSS) as multisensory stimulation on premature infants. These measures included the incidence of feeding intolerance, feeding progression indicators, growth and development indicators, feeding efficiency, milk intake ratio, and heart rate.

Feeding Intolerance Incidence: Feeding intolerance was defined based on specific criteria. The criteria for defining feeding intolerance included the following indicators: vomiting ≥ 3 times/day, no increase or a decrease in milk intake lasting for more than 3 days, gastric residual volume exceeding 1/3 of the previous feeding volume, abdominal distension with a 24-hour increase in abdominal girth > 1.5 cm, and the presence of coffee-ground-like material in the stomach or positive occult blood in stools.

The occurrence of any of these indicators was considered as feeding intolerance. A comparison was made between the combined intervention group and the control group to determine the incidence of feeding intolerance in each group.

Feeding Progression Indicators: Feeding progression indicators were used to assess the progress of oral feeding in premature infants. These indicators included the duration of gastric tube placement, feeding transition time, and duration to achieve full enteral nutrition.

The duration of gastric tube placement referred to the time from the initiation of gastric tube placement until its removal, allowing for complete oral feeding. Shorter durations indicated faster progress in transitioning to oral feeding. The feeding transition time was the duration from the commencement of oral feeding until complete oral feeding was achieved. The duration to achieve full enteral nutrition referred to the time required for the infant to gradually cease nasal feeding and reach the caloric intake of 130-135 kcal/(kg/d), as per the infant's requirement. Faster progress in these indicators indicated improved feeding progression.

Growth and Development Indicators: Growth and development indicators were used to evaluate the physical growth and development of premature infants. These indicators included measurements of length, weight, and head circumference at birth and 4 weeks post-birth.

Comparisons were made between the combined intervention group and the control group to assess the differences in length, weight, and head circumference at these time points. Higher values indicated better growth and development in these aspects. Additionally, the recovery time to birth weight was measured, which corresponded to the time taken from the physiological weight reduction phase after birth until the infant's weight returned to its birth weight.

Feeding Performance Indicators: Feeding performance indicators were utilized to evaluate the effectiveness of the intervention on feeding performance in premature infants. These indicators included feeding efficiency and milk intake ratio.

Feeding efficiency represented the average milk intake per minute during feeding. Higher values indicated more efficient feeding. The milk intake ratio indicated the ratio of the amount of orally consumed milk to the prescribed milk intake. Comparisons were made between the combined intervention group and the control group to assess the differences in feeding efficiency and milk intake ratio at various time points, including 5 minutes before the intervention, 1 day, and 3 days post-intervention.

Heart Rate: Heart rate measurements were included as an indicator of physiological response to the combined intervention. Heart rates were measured before the intervention, as well as 1 hour and 2 hours post-intervention.

Comparisons were made between the combined intervention group and the control group to evaluate the effects of the intervention on heart rate. Lower heart rates after the intervention indicated a reduction in physiological stress and a more relaxed state in the infants.

Statistical Methods

SPSS 26.0 was used for data processing in this study. Normality tests were performed on continuous data, represented as ($\bar{x} \pm s$). The *t* test was used for comparisons. Count data were expressed as percentages and analyzed using the χ^2 test. Multiple group data were analyzed using the F-test. Sphericity tests (Mauchly) were employed for comparisons between different time points within groups. A significance level of $P < .05$ indicated statistical differences.

RESULTS

Comparison of Feeding Intolerance Incidence

The incidence of feeding intolerance was significantly lower in the combined group compared to the control group, with statistically significant differences ($P < .05$). See Table 2.

Comparison of Feeding Progression

The duration of gastric tube placement and time to achieve full enteral nutrition in the combined group did not exhibit a statistically significant difference from the control group ($P > .05$). However, the combined group demonstrated a shorter feeding transition time and length of hospital stay compared to the control group, with statistically significant differences ($P < .05$), as shown in Table 3.

Comparison of Growth and Development Indicators Differences

The combined group exhibited a significantly shorter duration to regain birth weight than the control group. Additionally, infants in the combined group showed longer body length and head circumference four weeks after birth, with higher weight compared to the control group, all displaying statistically significant differences ($P < .05$), as seen in Table 4.

Comparison of Feeding Performance Discrepancies at Different Time Intervals

Both groups demonstrated a significant increase in milk intake ratio and feeding efficiency, with a more pronounced

Table 2. Comparison of Feeding Intolerance Incidence Between Control and Combined Groups (n, %)

Group	Vomiting	Abdominal distension	Gastric retention	Coffee-ground content in the stomach	Total
Control group ($n = 50$)	6 (12.00)	7 (14.00)	3 (6.00)	9 (18.00)	25 (50.00)
Combined group ($n = 50$)	3 (6.00)	5 (10.00)	3 (6.00)	3 (6.00)	14 (28.00)
χ^2					5.086
P value					.024

Table 3. Comparison of Feeding Progression Differences

Group	Duration of gastric tube placement (days)	Transition time to full enteral feeding (days)	Duration of achieving adequate enteral nutrition (days)	Length of hospital stay (days)
Combined group ($n = 50$)	19.01 ± 11.67	3.12 ± 1.59	19.94 ± 1.15	27.09 ± 14.16
Control group ($n = 50$)	23.50 ± 13.04	5.35 ± 2.70	20.30 ± 2.33	32.74 ± 13.32
t	1.814	5.032	0.980	2.055
P value	.073	<.001	.330	.043

Table 4. Comparison of Growth and Development Indicators Differences

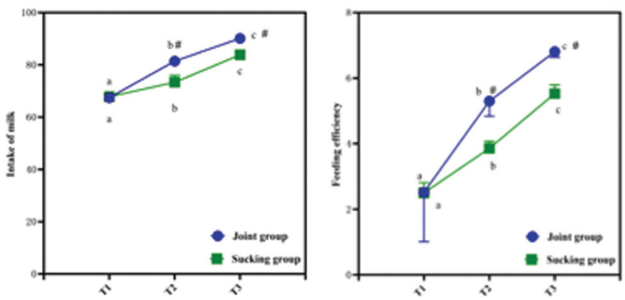
Group	Time to regain birth weight (days)	Weight (grams)	Head circumference (cm)	Body length (cm)
Combined group ($n = 50$)	19.79 ± 1.61	0.37 ± 0.11	2.01 ± 0.60	2.34 ± 0.64
Control group ($n = 50$)	28.90 ± 1.18	0.27 ± 0.14	1.56 ± 1.42	1.98 ± 0.67
t	-32.271	3.972	2.064	2.747
P value	<.001	<.001	.041	.007

Table 5. Comparison of Feeding Performance Discrepancies at Different Time Intervals

Group	Time points	Milk intake (%)	Feeding efficiency (ml/min)
Combined group (n = 50)	Pre-intervention 5 minutes	67.45 ± 1.51	2.52 ± 0.30
	Post-intervention 1 day	81.44 ± 1.66	5.30 ± 0.46
	Post-intervention 3 days	90.16 ± 1.12	6.81 ± 0.17
F		322.32	233.43
P value		<.001	<.001
Control group (n = 50)	Pre-intervention 5 minutes	67.86 ± 1.88	2.50 ± 0.31
	Post-intervention 1 day	73.36 ± 2.61[a]	3.86 ± 0.22[a]
	Post-intervention 3 days	83.83 ± 1.21[a]	5.53 ± 0.26[a]
F		261.43	265.45
P value		<.001	<.001

[a]Denote comparison with the combined group at the same time point, $P < .05$.

Figure 1. Feeding Performance at Different Time Intervals



Note: a, b, c denotes differences compared to other time points with $P < .05$; # denotes comparison with the control group with $P < .05$.

Table 6. Comparison of Heart Rate Changes at Different Time Points

Group	Time points	Heart rate
Combined group (n = 50)	Pre-intervention 5 minutes	130 ± 20
	Post-intervention 1 hour	117 ± 15
	Post-intervention 2 hours	110 ± 16
F		1.996
P value		.049
Control group (n = 50)	Pre-intervention 5 minutes	130 ± 21
	Post-intervention 1 hour	123 ± 15[a]
	Post-intervention 2 hours	116 ± 14[a]
F		2.000
P value		.048

[a]Denote comparison with the Combined group at the same time point, $P < .05$.

increase observed in the combined group. These differences were statistically significant ($P < .05$). Refer to Table 5 and Figure 1.

Comparison of Heart Rate Changes at Different Time Points

Both groups exhibited a significant decrease in heart rate, with a more substantial reduction observed in the combined group. These differences were statistically significant ($P < .05$). See Table 6.

DISCUSSION

The results of the study indicate that the combined intervention of non-nutritive sucking (NNS) and multisensory stimulation has several positive effects on premature infants, including a reduction in feeding intolerance, improved feeding progression, enhanced growth and development, and better feeding performance. In this section, we will discuss these results in detail and analyze the underlying mechanisms and reasons for these observed effects.

Feeding Intolerance

The study showed that the combined intervention group had a lower incidence of feeding intolerance compared to the control group. Feeding intolerance in premature infants is often caused by factors such as small gastric capacity and weak intestinal motility. These factors can lead to symptoms like abdominal distension and vomiting, which pose risks to the infant's nutrition and overall health.

The NNS intervention in this study effectively stimulated and strengthened muscle groups involved in feeding, such as the masticatory muscles, tongue, and pharynx. This stimulation promoted saliva secretion and enhanced digestive enzyme secretion, thereby improving digestive and absorptive functions. As a result, the symptoms of feeding intolerance, such as abdominal distension and vomiting, were alleviated.[3,4]

Additionally, the MSS intervention played a role in reducing feeding intolerance by improving the postnatal sound environment for premature infants. Prolonged exposure to a noisy environment can have adverse effects on brain development and the sympathetic nervous system, indirectly affecting gastrointestinal functions. The implementation of MSS intervention effectively reduced noise levels and provided a comfortable auditory setting for the infants, thereby mitigating the adverse effects on brain development and the sympathetic nervous system. This, in turn, improved gastrointestinal functions and reduced the risk of feeding intolerance.[7]

Feeding Progression

The combined intervention group of premature infants demonstrated improved feeding progression compared to the control group. Several indicators of feeding progression, including gastric tube placement duration, time to transition to full enteral nutrition, duration of achieving adequate enteral nutrition, and hospital stay length, favored the combined intervention group.

The NNS intervention played a crucial role in enhancing feeding progression. Non-nutritive sucking stimulates sensory responses in areas like the cheeks, oral cavity, and tongue, facilitating the sucking reflex and aiding in feeding progression. The stimulation of these sensory areas promotes sucking awareness in premature infants, leading to increased sucking frequency and milk intake per feeding session.[8] This improvement in feeding performance contributes to a faster transition to full enteral nutrition and shorter hospital stay durations.

Furthermore, the mid-pregnancy development of the cochlear nerve in premature infants makes them particularly responsive to auditory stimulation. The MSS intervention provided positive auditory stimulation, which aided in optimal comfort and nervous system development. The combination of auditory stimulation with non-nutritive sucking enhanced the effectiveness of the intervention in promoting oral feeding. This combined intervention approach facilitated feeding progression and aided in the recovery of premature infants.[8,9]

Growth and Development

The combined intervention of NNS and MSS demonstrated positive effects on the growth and development of premature infants. The combined group exhibited quicker recovery to birth weight, increased body mass, and better head circumference and body length growth rates compared to the control group.

The NNS intervention played a significant role in improving growth and development outcomes. It improved behavioral status and oxygenation responses in premature infants, leading to enhanced growth and development. NSS intervention facilitated nutrient absorption, improved sleep quality, and indirectly reduced energy expenditure. This resulted in adequate energy and nutrition provision for growth and development in premature infants.[10]

Moreover, the MSS intervention contributed to growth and development by creating a peaceful growth environment. Gentle sound stimulation provided by the intervention promoted feeding and sucking behavior in premature infants. It also improved sleep quality, positively influencing neurological and behavioral development. The combination of NNS and MSS interventions fostered optimal relaxation and focused attention during feeding, thereby enhancing sucking efficiency and milk intake. These factors collectively contributed to improved growth and development outcomes.[11-13]

Feeding Performance

The combined intervention of NNS and MSS showed positive effects on feeding performance in premature infants. The combined group exhibited higher feeding efficiency and milk intake ratios compared to the control group.

Non-nutritive sucking intervention played a crucial role in enhancing feeding performance. It stimulated feeding actions and fostered sucking awareness in premature infants. This led to increased sucking frequency and milk intake per feeding session, thereby improving feeding efficiency.[14] Additionally, the MSS intervention aided premature infants in achieving optimal relaxation and improving sleep quality. This positive influence on neurological and behavioral development encouraged infants to focus on feeding actions, reducing pauses, and enhancing sucking efficiency and milk intake during the initial feeding period. The combination of NNS and MSS interventions reinforced sucking behavior and continuity, ultimately improving feeding performance.[15]

It is important to acknowledge the limitations of the study. Firstly, the study design was a single-center randomized controlled trial, which may limit the generalizability of the findings to other healthcare settings or populations. Additionally, the sample size in the study might be relatively small, which could affect the statistical power and precision of the results. Moreover, the study focused on a specific intervention combining NSS with MSS, and it is possible that other interventions or factors not considered in the study could also influence feeding tolerance and growth in premature infants. Lastly, the study duration might not have been sufficient to capture long-term effects and outcomes beyond the hospital stay. Future research avenues could include investigating the long-term effects of the combined intervention on neurodevelopmental outcomes, exploring the optimal timing and duration of the intervention, and evaluating its effectiveness in diverse populations and healthcare settings. Additionally, further studies could explore the underlying mechanisms of how non-nutritive sucking and MSS intervention impact physiological and behavioral responses in premature infants.

The findings of this study have important clinical implications for healthcare practitioners in neonatal care settings. Implementing a combined intervention of NSS and MSS can be considered as a potential strategy to improve feeding tolerance, feeding progression, and growth in premature infants. Healthcare practitioners can incorporate non-nutritive sucking as a routine intervention during feeding sessions, stimulating feeding reflexes and enhancing oral feeding skills. Additionally, providing a calm and quiet auditory environment through MSS intervention can reduce stress responses and optimize growth and development in premature infants.

Healthcare practitioners should also consider the individual needs and characteristics of each premature infant when applying the intervention. Monitoring feeding tolerance, growth parameters, and physiological responses can help tailor the intervention to specific infants and track their progress. Collaborative efforts among healthcare professionals, including neonatologists, nurses, and speech therapists, can further optimize the implementation of the combined intervention and provide comprehensive care for premature infants.

CONCLUSION

In conclusion, the combined intervention of non-nutritive sucking and multisensory stimulation has shown significant benefits for premature infants. It reduces feeding intolerance, enhances feeding progression, promotes growth and development, and improves feeding performance. The mechanisms underlying these effects involve the stimulation of muscle groups involved in feeding, improvement of digestive and absorptive functions, creation of a comfortable auditory environment, and facilitation of sensory responses and sucking awareness. Non-nutritive sucking intervention promotes saliva secretion and digestive enzyme secretion, while multisensory stimulation intervention reduces noise levels and creates a peaceful auditory setting. These interventions work synergistically to improve feeding outcomes and overall well-being in premature infants.

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AUTHOR DISCLOSURE STATEMENT

The authors declare that they have no competing interests.

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