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Non-Nutritive Sucking in the Preterm Infant

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Abstract

Objective—To identify the progression of non-nutritive sucking (NNS) across post-menstrual age (PMA) and to investigate the relationship of NNS with medical and social factors and oral feeding.

Study Design—Fifty preterm infants born at ≤32 weeks gestation had NNS assessed weekly starting at 32 weeks PMA with the NTrainer System. Oral feeding was assessed at 38 weeks PMA.

Results—There were increases in NNS bursts per minute ($p = 0.005$), NNS per minute ($p < 0.0001$), NNS per burst ($p < 0.001$), and peak pressure ($p = 0.0003$) with advancing PMA. Level of immaturity and medical complications were related to NNS measures ($p < 0.05$). NNS measures were not related to Neonatal Oral Motor Assessment Scale scores. Smaller weekly change in NNS peak pressure ($p = 0.03$; $\beta = -1.4$) was related to feeding success at 38 weeks PMA.

Conclusion—Infants demonstrated NNS early in gestation. Variability in NNS scores could reflect medical complications and immaturity. More stable sucking pressure across time was related to feeding success at 38 weeks PMA.

Keywords

non-nutritive sucking; preterm; medical factors; oral feeding

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Non-nutritive sucking (NNS) is a foundational skill of infancy that is important for oral feeding and self-regulation. NNS begins long before an infant is born and has been observed as early as 15 weeks after conception, during intrauterine life.[1] By 20 weeks, rhythmical NNS has been reported, with observations of the fetus opening and closing the mouth at regular periods,[1] in a series of organized bursts with pauses between the compressions. The quality of NNS continues to improve throughout gestation, and in an infant at term age, it begins to take on the critical role of allowing the infant to take in nutrition.[2]

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Conflict of Interest
None.

NNS in the neonate is a primitive reflex that is predictable and rhythmical.[3] NNS is an involuntary response elicited when a tactile input is given in or around the mouth,[4] resulting in the infant closing the mouth around the stimulus, developing an intraoral pressure system, and engaging in rhythmical compression and suction on the stimulus.[5] Typical NNS behaviors consist of a burst–pause pattern, in which there are consistent patterns of NNS followed by a rest, followed by a return to the pattern.[6] Typically, nutritive burst–pause patterns involve 4 to 10 sucks per burst, and typical NNS occurs at a rate of two sucks per second, or twice as frequent as nutritive sucking.[7] While NNS is a precursor skill to oral feeding (breast or bottle), oral feeding skills are much more complex. Oral feeding not only necessitates the components of NNS but also requires suck–swallow–breathe coordination to manage a bolus for consumption.[8] While there appears to be a relationship between NNS and oral feeding,[9] NNS ability is not necessarily predictive of feeding success. NNS can be present very early in gestation, before the development of oral feeding skills.[10] Reflexive, involuntary NNS integrates at approximately 3 to 6 months of age.[11]

NNS is a reflexive behavior in the neonatal period, but it can be affected by preterm birth. Preterm infants may not have the muscle strength necessary to successfully suck.[1] Also, it is known that poor NNS can be an indicator of central nervous system problems,[12] and preterm infants have high rates of cerebral injury.[13] However, it is not well understood how arousal and postmenstrual age (PMA) impact NNS performance. Additionally, medical interventions and complications can impact the typical development of oral feeding and NNS in the preterm infant.[14,15] While there is evidence that neural circuits are involved in the expression of NNS, how NNS is elicited can vary based on factors internal and external to the infant. We have limited knowledge of the progression or maturation of NNS in preterm infants, how alterations in NNS may present, and how specific medical factors impact the acquisition of NNS skills.

Previous challenges with the study of NNS are from qualitative assessment of NNS. The NeoSuck Assessment of the NTrainer System (Innara Health, Olathe, KS) can be used to quantify factors related to NNS performance. It allows for the objective and quantifiable measurement of four components of NNS: NNS bursts per minute (number of times the infant engages in a group of sucks prior to a pause in one minute), NNS sucks per minute (number of sucks in one minute), NNS per burst (how many sucks are in each group of sucks before a pause), and NNS peak pressure (the highest pressure [in cm of H_2O] during sucking). A spatiotemporal index has also been reported but is undergoing more validation by Innara Health.

To date, there is limited evidence about the typical acquisition of NNS that takes place from preterm birth to term equivalent age. Such information is critical, as it can aid health care professionals working with this population to understand the sequence of oral motor skill development during hospitalization. It is hypothesized that preterm infants will demonstrate NNS behaviors at 32 weeks PMA but that strength, speed, and complexity will increase across PMA. As with other infant behaviors that are state-dependent, we hypothesize that arousal level will be related to NNS performance. It is also hypothesized that medical factors or interventions, such as length of mechanical ventilation or the presence of cerebral injury, will be associated with a delay in NNS maturation. Finally, it is hypothesized that NNS will

be related to oral feeding outcomes at term equivalent age. Understanding the progression of NNS can inform health care professionals on whether an infant is progressing normally or experiencing alterations in NNS trajectory.

Methods

Procedure

In this prospective cohort study, 50 consecutively admitted very preterm infants born at ≤32 weeks gestation were recruited within 1 week of birth from January 2015 to June 2015. Infants were excluded if there was evidence of a congenital anomaly including syndromes and cardiac defects. The convenience sample was part of another study that aimed to understand progression of oral feeding in preterm infants. The study took place at the St. Louis Children's Hospital neonatal intensive care unit (NICU), an 85-bed level IV NICU, and at the Barnes Jewish Hospital Special Care Nursery, a 20-bed level III special care nursery. At the study sites, infants received standard of care, which often included feeding-related therapies from occupational therapists and speech-language pathologists that were individualized to their needs. Feeding-related therapies were not tracked for the purposes of this study, as this study was observational. The study was approved by the Washington University Human Research Protection Office, and parents signed informed consent. Following enrollment, NNS was assessed one time each week of hospitalization starting at 32 weeks PMA, and oral feeding was assessed at 38 weeks PMA.

Medical and Social Factors

Medical and social factors were extracted from the medical record and included sex, race (Caucasian or non-Caucasian), estimated gestational age (EGA) at birth; days on total parenteral nutrition (TPN), ventilation (whether ventilated and number of days on ventilation), continuous positive airway pressure (CPAP), oxygen through a nasal cannula; presence of necrotizing enterocolitis, cerebral injury, and patent ductus arteriosus (PDA); PMA at discharge; and length of stay. Cerebral injury was identified by routine cranial ultrasound and magnetic resonance imaging (MRI) when available. Cerebral injury was defined as the presence of grade III or IV intraventricular hemorrhage or periventricular leukomalacia. Medical factors were used as independent variables to determine their relationships with NNS.

Non-Nutritive Sucking

NNS measures were obtained from the NEOSuck Assessment of the NTrainer System. The NTrainer System is an FDA class II biofeedback device that includes a wand to which a pacifier is attached. The NTrainer System is connected to an Apple computer. The infant experiences the pacifier placed in the mouth, and the system detects sucking pressure and rhythmicity. The software quantifies NNS into four different measures: NNS bursts per minute, NNS per minute, NNS per burst, and NNS peak pressure. A NNS burst was defined as successive sucks before a pause. For the purposes of this study, an average change per week for each NTrainer System measure was also calculated for each infant based on available measurements.

Prior to the start of the study, all members of the research team took part in a 2-day training session led by Innara Health.

At the time of each assessment, a trained member of the research team obtained measures of NNS using the NTrainer System.[16] The assessment mode, the NEOSuck Assessment, of the NTrainer System was used. The NTrainer System also has an intervention mode in which the system delivers oral tactile sensory stimulation, but this was not used for the purposes of the study. After the infant was weaned to <2 L of oxygen and had reached 32 weeks PMA, NNS assessments commenced and were conducted once per week. Assessments continued each week until discharge or 43 weeks PMA, whichever occurred first.

Infants were seen within half an hour of a scheduled care time or feeding, which typically is every 3 hours at the study sites. The infant was first gently elevated to a 30-degree angle in the bed and turned slightly on his/her side, and the sides of the mouth were stroked with the pacifier to elicit a rooting response. Following these preparatory tasks, arousal was recorded (see the next section). The infant grasped the pacifier with the mouth, or it was gently placed in the mouth, and measurements of NNS occurred over a 5-minute period while the infant was in the crib or an isolette. The same pacifiers were used for assessments that were used through-out hospitalization and included Phillips' Wee-soothie or Soothie pacifiers. The NTrainer System calculated NNS measures, averaged over the 5-minute period.

NNS bursts per minute, NNS per minute, NNS per burst, and NNS peak pressure at each PMA, as well as average change per week (measure minus the previous week's measure averaged over all the weeks that the infant received measurements) for each of the aforementioned measures were used as dependent variables to determine the relationships between PMA, arousal, and medical factors with NNS. These NNS measures were also used as independent variables to determine their relationship with oral feeding out-come, as measured by the Neonatal Oral Motor Assessment Scale (NOMAS) scores and success with >75% of volume of oral intake during a feeding evaluation at 38 weeks PMA.

Infant Arousal

The amount of arousal was recorded immediately after attempting to elicit a rooting response and placing the pacifier in the mouth for the NNS assessment session. Arousal was defined using a 6-point scale (1 = deep sleep; 2 = light sleep; 3 = drowsy; 4 = quiet awake; 5 = active awake; 6 = crying).[17] Scores on this scale were dichotomized into awake and sleep states with states 1 and 2 being considered sleep states, and states 3, 4, 5, and 6 being considered awake states. Drowsy was considered as an awake state for the purposes of this study due to the accompanying motor activity. Arousal was used as an independent variable to determine its relationship with NNS.

Oral Feeding Performance

Oral feeding performance was assessed in two different ways: by using the NOMAS and by determining success with oral feeding at 38 weeks PMA. This timing was adapted when infants were discharged prior to 38 weeks PMA, in which the feeding assessment was conducted within 1 week of discharge. At the study site, infants are not fed unless they rouse and demonstrate signs of feeding readiness. In addition, oral feeding is not initiated until the

medical team deems the infant medically stable, which typically did not occur until infants were on ≤2 L of oxygen. The timing of the feeding assessment was also adapted when infants were not medically stable or mature enough to orally feed at 38 weeks PMA, and then the assessment was conducted when they were ready. During oral feeding assessments, parents fed the infant in the way they preferred (breast or bottle), and infants were bottle-fed when parents were not present. All feeding assessments ended up being during bottle feeding in this study.

At 38 weeks PMA, oral feeding was assessed using the NOMAS by a certified examiner who was blinded to the results of the NTrainer System.[18,19] Using a lateral view of the face to enable a good visualization of the lips, jaw, and nipple, feeding was observed for 2 minutes. Twenty-eight characteristics on the NOMAS were used to define feeding performance as normal, disorganized, or dysfunctional. The NOMAS is currently one of only a few feeding assessments available to determine altered feeding performance in the NICU, but there are mixed reports on its psychometrics.[20] The NOMAS was used as a dependent variable to determine if NNS is related to oral feeding outcome.

At 38 weeks PMA, success with oral feeding was also identified by observing an oral feeding. This time period was selected due to most of the infants being on full oral feeds by 38 weeks PMA. The intent was to determine if early sucking measures may be related to later feeding success. Success with oral feeding was defined as taking >75% of the prescribed volume by breast or bottle. All infants in the sample were on fixed volumes of feedings at fixed time periods, which enabled the research team to calculate if >75% of the prescribed volume was achieved. The prescribed volume of >75% was used as the measure of feeding success to represent that infants met all or most of the prescribed volume. Success in feeding was categorized as "yes" if the infant consumed >75% of the bottle or as "no" if the infant did not consume >75% of the bottle.

Statistical Analysis

Descriptive statistics were used to define the trajectory of NNS scores across time. To account for repeated measures and to determine the impact of PMA on NNS measures, a random coefficient model was used to determine the effect of time on the four NNS measurements, with time (PMA) being the random coefficient. The relationships between medical factors and NNS performance were investigated using regression models and independent samples *t*-tests. Relationships between NNS scores, and early feeding outcomes, NOMAS, and the measure of feeding success at 38 weeks PMA were explored using logistic regression. All analyses were conducted using $\alpha = 0.05$.

Results

In total, 50 infants were enrolled in this study. One infant expired, leaving 49 infants in the cohort. The characteristics of the 49 infantsincluded in thestudyarelisted in Table 1. There were 235 NNS measurements conducted on participants.

The NNS measures (NNS bursts per minute, NNS per minute, NNS per burst, and NNS peak pressure) at each PMA, in addition to the average change from 32 weeks to term, are

described in Table 2. There may be data missing at different time points due to some infants being medically unstable, getting discharged early, or being unavailable.

Relationship between Premenstrual Age and Non-Nutritive Sucking

Relationships between PMA at the time of the assessment and NNS measures are shown in Fig. 1. The random coefficient model revealed increases in NNS bursts per minute (estimate = 0.16; standard error = 0.05; $p = 0.005$), NNS per minute ($\beta = 2.1$; standard error = 0.51; $p < 0.0001$), NNS per burst ($\beta = 0.33$; standard error = 0.10; $p < 0.001$), and peak pressure ($\beta = 0.68$; standard error = 0.18; $p = 0.0003$) with advancing PMA.

Relationships between Infant Arousal and Components of Non-Nutritive Sucking

See Fig. 2 for a boxplot of NNS scores from infants in awake and sleep states. Infants who were asleep demonstrated NNS, but had lower NNS bursts per minute ($p < 0.001$), NNS per minute ($p < 0.001$), and NNS per burst ($p = 0.007$). There was no relationship between arousal and peak pressure.

Social and Medical Factors Related to Non-Nutritive Sucking

At 33 weeks PMA, fewer bursts per minute were observed among infants with a PDA. At 33 weeks PMA, higher NNS peak pressure was observed in infants with higher EGA at birth ($p = 0.001$; $\beta = 2.6$), infants on fewer days of TPN ($p = 0.01$; $\beta = -0.5$), infants on fewer days of oxygen through a nasal cannula ($p = 0.03$; $\beta = -0.2$), infants with shorter length of stay ($p = 0.001$; $\beta = -0.2$), and infants with lower PMA at discharge ($p = 0.01$; $\beta = -1.5$). At 33 weeks PMA, more bursts per minute were related to fewer days on TPN ($p = 0.050$; $\beta = -0.1$,). At 34 weeks PMA, more bursts per minute were related to more days on CPAP ($p = 0.03$; $\beta = 0.2$,). At 36 weeks PMA, more bursts per minute were related to fewer days on ventilation ($p = 0.02$; $\beta = -0.06$,), lower PMA at discharge ($p = 0.01$; $\beta = -0.3$), and shorter length of stay ($p = 0.03$; $\beta = -0.03$). At 37 weeks PMA, higher peak pressure was related to fewer days on TPN ($p = 0.03$; $\beta = -0.2$), fewer days on a ventilator ($p = 0.05$; $\beta = -0.2$), and lower PMA at discharge ($p = 0.03$; $\beta = -0.7$). At 38 weeks PMA, more bursts per minute were related to shorter time on a ventilator ($p = 0.02$; $\beta = -0.06$). There were no other relationships between the four NNS measures at each PMA and medical factors.

More weekly change in the NNS peak pressure measure was observed in infants with cerebral injury ($p = 0.3$; $\beta = 2$]. Higher average weekly change in NNS per minute was related to having a PDA ($p = 0.03$; $\beta = 7.2$). There were no other significant relationships found between social and medical factors and NNS measures. Infants whose NNS measures fell in the upper or lower quartile were also identified to determine if extreme performers had a higher incidence of medical complications, but no relationships were identified.

Relationships between Non-Nutritive Sucking and Feeding Outcome

There were no relationships between any of the NNS measures and NOMAS scores.

Smaller weekly change in NNS per minute ($p = 0.052$; $\beta = -5.8$) had trends toward being related to feeding success at 38 weeks PMA. Smaller weekly change in NNS peak pressure ($p = 0.03$; $\beta = -1.4$) was related to feeding success at 38 weeks PMA.

To further investigate the impact of arousal on NNS performance, analyses were repeated with only the infants who were awake (states 4, 5, and 6) during the assessment, and the findings remained largely unchanged.

Discussion

The key findings of this study were that NNS was present at the beginning of testing, which began at 32 weeks PMA, and that NNS bursts per minute, NNS per minute, NNS per burst, and peak pressure increased as PMA advanced. NNS was present during sleep states, but infants who were asleep demonstrated fewer NNS per burst, fewer NNS per minute, and fewer NNS bursts per minute. EGA at birth, respiratory support, length of time using TPN, and length of stay appear to impact NNS performance. Infants with a PDA had a greater weekly increase in NNS per minute, and infants with a cerebral injury had larger increases in peak pressure. The hypothesis on the relationship between NNS and feeding outcome was not confirmed. NNS measures were not found to be related to NOMAS scores at 38 weeks PMA, but more stable scores across PMA related to feeding success at 38 weeks PMA.

Previous literature supports the findings that NNS is present from very early in gestation.[21] Infants in utero can be observed making sucking movements or sucking on the thumb starting at 15 weeks after conception.[1] In this study, NNS was present at 32 weeks PMA despite the challenges that accompany preterm birth. However, the organization of NNS (NNS per burst, NNS per minute, NNS per burst, and NNS peak pressure) increased with advancing PMA. This equated to increasing from a mean of 5 NNS per burst, 21 NNS per minute, 3 bursts per minute, and a peak pressure of 17 cmH_2O at 32 weeks PMA, to 12 NNS per burst, 51 NNS per minute, 3 bursts per minute, and a peak pressure of 28 cmH_2O at 43 weeks PMA. At 38 weeks PMA, there was an average 32 ± 21 NNS per minute, and there were 6 ± 3 NNS per burst. This is consistent with other studies reporting that NNS occurs at a rate of two sucks per second and that there are 4 to 10 sucks per burst.[7] This also parallels other studies on nutritive sucking which has been shown to advance from an immature pattern to a rhythmic pattern[22,23] with nutritive sucking activity and frequency increasing with advancing PMA.[6] This highlights that although sucking may be present early in gestation, early oral movements may not be reflective of advanced sucking patterns that are observed later in gestation or among full-term infants.

Infants demonstrated NNS while asleep, but the quality of NNS was different among infants in a sleep state. This is consistent with other reports that infant behavior is state-dependent.[24] The presentation of neonatal reflexes and feeding performance are tied into the infant's ability to achieve and maintain an awake state. Our findings were consistent with other literature tying performance to arousal level,[24] as NNS bursts per minute, NNS per minute, and NNS per burst were altered in infants who were in sleep states. Peak pressure, however, was not different among infants in a sleep or an awake state. While feeding skills can be tied into the ability to maintain an awake state,[8] NNS appears to be a primitive reflexive response that can be present in both sleep and awake states. However, the consistency of the strength of NNS among infants in a sleep or an awake state can potentially be dangerous when infants are bottle-fed in sleep states, as they may demonstrate adequate intraoral pressure to express milk without the complexity of oral motor responses to manage a bolus. Therefore,

our findings support current recommendations to ensure an awake state during the complex task of oral feeding.

Previous work has demonstrated that struggles with early feeding skills are related to medical complications and interventions during NICU hospitalization.[14] Others have found that respiratory compromise can impact NNS.[25] Our findings were consistent with these findings in that infants who had increased length of time on a mechanical ventilator or other respiratory supports had reduced NNS performance. Infants born at lower EGA, with longer length of stay, and with more use of TPN also had poorer NNS performance. The reasons for these findings could be increased medical compromise or alterations in development. Alternatively, the reason could be decreased opportunities for oral motor experiences due to medical interventions that are sustaining life, which result in decreased NNS experiences. Our findings also demonstrated that infants with PDA had larger weekly increases in NNS per minute. Infants with PDA may demonstrate physiological instability and alterations in function early in gestation, resulting in larger increases as PMA advances. Finally, infants with cerebral injury demonstrated larger increases in peak pressure, which could relate to the tonal abnormalities, which can include the jaw and tongue in this population.[26]

Previous research has documented that NNS skills do not necessarily translate to success with oral feeding.[8] This is consistent with our findings that demonstrated no relationships with NNS performance on the NOMAS or feeding success at 38 weeks PMA. Although NNS is a prerequisite skill for oral feeding, oral feeding is much more complicated and requires appropriate timing of sucking, swallowing, and breathing. While NNS measures at a single time point did not relate to feeding success, smaller weekly changes in NNS peak pressure, or more stability of scores across time, were related to feeding success at 38 weeks PMA. Others have reported decreased variability of the NNS pattern with increased maturity,[6] making stable measures of NNS a potentially important marker. This may lend support for routine measurements across time, with stable scores being a potential predictor of feeding success. More research on the utility of weekly change scores is warranted.

Understanding the progression of NNS skills and the impact of medical factors on NNS maturation is clinically important, because NNS is an innate skill of infancy that is present long before birth. NNS appears to progress as pre-term infants grow outside the womb, but large changes in scores, specifically in peak pressure, may be markers for potential challenges. Monitoring weekly change in NNS measures warrants more investigation to determine its utility in predicting feeding success at 38 weeks PMA, a time during which oral feeding is often expected in preterm infants. It is also important to understand that medical factors can impact the progression of NNS. Infants with medical factors, such as PDA and cerebral injury, may demonstrate larger increases across time in NNS measures as their condition stabilizes. This study complements other studies that have found that infants with a diagnosis of moderate-to-severe respiratory distress syndrome and those who receive more supplemental oxygen struggle more with NNS. In addition, these infants transition more slowly to full oral feeds when compared with infants who received less oxygen support.[9,25]

Limitations

The limitations of this study included it being an observational study in which no intervention was administered. Infants were not stimulated to an awake state, but, instead, observations were made about what state the infant was in. Additionally, there was no control group of healthy, full-term infants to compare with the preterm infant population. This study was an exploratory study that involved a small sample size that could reduce power to detect relationships, leading to a type II error. There were early and later time points that had little representation of the whole sample, as some infants were too medically compromised to undergo early testing and many infants were already discharged and could not undergo testing at and beyond term. The sample size was also not adequate to conduct further subanalyses on different medical conditions. Future work can better define sucking performance among different groups of infants, for example, those with and without cerebral injury, using appropriately powered samples. There was a high variability within the sample due to the intensive medical courses and interventions within the population. There was also significant variability in the NNS measures in the sample. Finally, shorter intervals than once per week for NNS measurements may have elucidated more developmental trends of NNS. Future studies should aim to capture additional objective measures concurrent with NNS measures, such as level of arousal, environmental factors, and medical interventions. Other studies have documented the impact of respiratory distress on NNS,[25,27] and this as a potential confound in this small sample is probable. Multiple people administered the NNS assessment to the infant, possibly introducing variability. This exploratory study employed multiple statistical comparisons, which increase the risk of type I error, but the findings set the stage for future studies. This study did not control for feeding-related therapies, different methods of oral feeding, or stimulation, and other environmental sensory exposures that could have influenced outcome. This is the first study to use a weekly change in NNS measure, and the use of this measure necessitates further validation. One of the aims of this study was to track the development of NNS parameters over time. However, medical interventions appear to impact NNS parameters, and due to the medically complex sample, typical trajectory of NNS could not be achieved.

Conclusion

NNS exists early in gestation, but its strength and speed continue to advance across PMA in preterm infants. NNS takes place even while infants sleep, but its complexity in awake states is different. It remains unclear how the complexity of the NNS response relates to the timing of oral feeding success. While NNS is innate, it can be altered by medical complications and interventions. NNS was not related to NOMAS scores in this study of preterm infants; however, smaller changes in NNS peak pressure across PMA did appear to predict success with oral feeding at 38 weeks PMA. Objective measurements that allow us to further understand NNS, such as those obtained from the NTrainer System, are an important advancement in neonatal assessment. However, more research that expands upon these observational findings is needed to aid our understanding of how early behavioral feeding responses translate to feeding success and how the environment and early therapy interventions may impact NNS and feeding behaviors.

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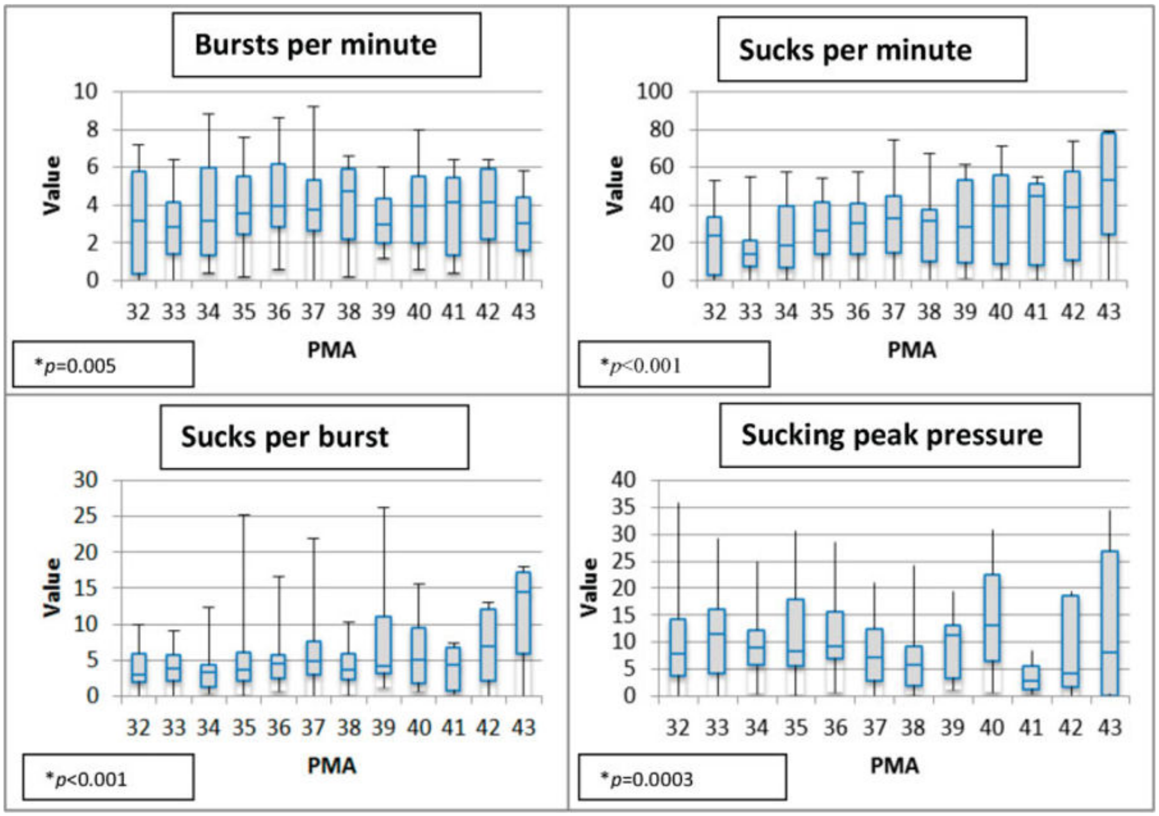

Fig. 1.

Non-nutritive sucking performance measures across postmenstrual age (PMA). *Values of *p* are from investigations into relationships between PMA and the sucking measure using a random coefficient model. Peak pressure value is in centimeter of water (cmH_20).

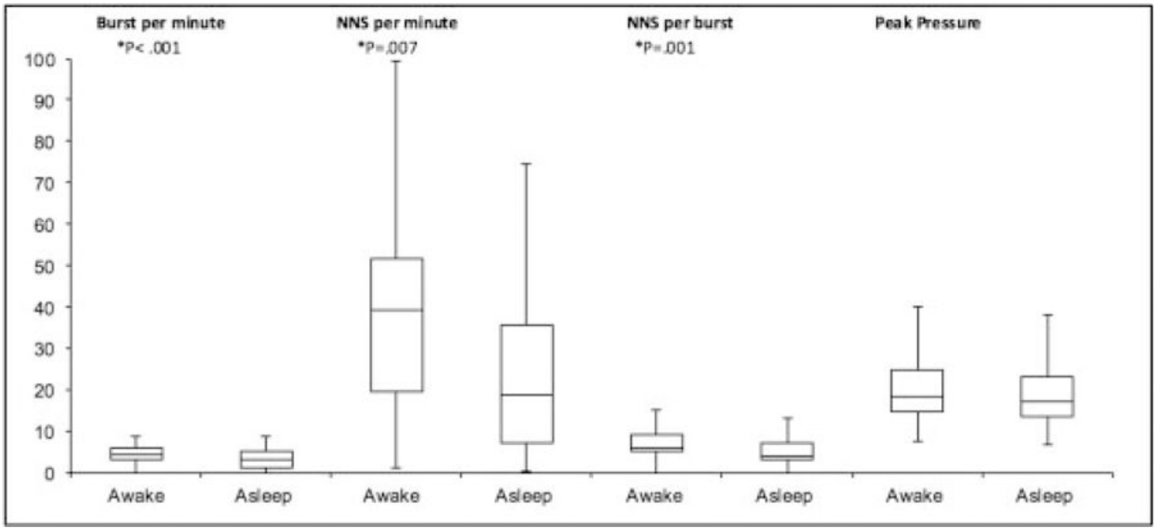

Fig. 2.

Non-nutritive sucking performance and arousal. NNS, non-nutritive sucking. *Values of *p* are reported for significant investigations into differences among NNS measures in awake and sleep states using independent samples *t*-test.

Table 1

Sample descriptives

Medical factors, *N* = 49	**Mean ± SD or median [IQR] or *n* (%)**
Gender (female)	24 (48)
Race (non-Caucasian)	20 (41)
EGA at birth (wk)	27.5 ± 2.6
Days on TPN	11 [6–18.5]
Mechanically ventilated (yes)	37 (76)
Days on mechanical vent	2 [0.5–16.5]
Days on CPAP	5 [0–14]
Days on a nasal cannula	24 [6–40]
Presence of NEC	6 (12)
Presence of cerebral injury	8 (16)
Presence of PDA	13 (27)
PMA at discharge (wk)	40.3 ± 4.6
Length of stay (d)	83.7 ± 40.1

Abbreviations: CPAP, continuous positive airway pressure; EGA, estimated gestational age; IQR, interquartile range; NEC, necrotizing enterocolitis; PDA, patent ductus arteriosus; PMA, postmenstrual age; SD, standard deviation; TPN, total parenteral nutrition.

Table 2

Non-nutritive sucking descriptives of the sample at each PMA

PMA	NNS measure	*N*	Min	Max	Median	IQR	Mean	SD
32	Burst per minute	23	0.0	7.2	3.2	5.8	3.3	2.5
32	NNS per minute	23	1.2	54.4	25.4	30.6	21.4	16.8
32	NNS per burst	23	0.0	10	3	4	4.5	2.8
32	NNS peak pressure	23	6.7	42.7	14.6	10.5	17	8.8
33	Burst per minute	28	0.0	6.4	2.9	2.7	3	1.8
33	NNS per minute	28	0.4	55.2	14.9	12	18.1	14.1
33	NNS per burst	28	0.0	9	4	3.5	4	2.2
33	NNS peak pressure	28	5.7	34.9	17.3	11.9	16.8	7.5
34	Burst per minute	31	0.4	8.8	3.2	4.6	3.9	2.5
34	NNS per minute	31	3	59.8	21.4	32.8	26.1	17.3
34	NNS per burst	31	2	14	5	3	5.3	3.2
34	NNS peak pressure	31	8.6	33.2	17.2	6.6	18	5.6
35	Burst per minute	32	0.2	7.6	3.6	3.1	4	1.9
35	NNS per minute	32	2.4	56.6	28.9	27.4	28.8	15.9
35	NNS per burst	32	2	27	5.5	4	6.7	4.6
35	NNS peak pressure	32	7.5	37.9	15.8	12.4	18.5	8.3
36	Burst per minute	30	0.6	8.6	4	3.3	4.5	2.2
36	NNS per minute	30	3.2	59.8	33.2	26.9	31.9	16.9
36	NNS per burst	30	2	18	6	3.3	6.5	3.8
36	NNS peak pressure	30	8.6	36.5	17.5	8.6	19.8	7.1
37	Burst per minute	24	0.0	9.2	3.8	2.7	4	2.4
37	NNS per minute	24	0.2	74.4	33.5	30.1	31	21.5
37	NNS per burst	24	0.0	22	5	4.75	6.3	5.2
37	NNS peak pressure	24	12.3	33.4	19.6	9.6	20.1	6
38	Burst per minute	20	0.2	6.6	4.8	3.8	4.2	2.1
38	NNS per minute	20	1.8	69.2	33.3	27.3	32	21.2
38	NNS per burst	20	2	12	5.5	3.5	6	2.9

PMA	NNS measure	*N*	Min	Max	Median	IQR	Mean	SD
38	NNS peak pressure	20	13.5	37.5	19.2	7.4	20.6	6.9
39	Burst per minute	15	1.2	6	3	2.4	3.3	1.6
39	NNS per minute	15	5	65.4	32.8	43.4	32.4	22.1
39	NNS per burst	15	2	27	5	8	8.5	7.2
39	NNS peak pressure	15	12.1	30.4	22.3	9.8	20.2	5.8
40	Burst per minute	16	0.6	8	4	3.6	4	2.1
40	NNS per minute	16	1.6	72.4	40.9	47.2	35.9	23
40	NNS per burst	16	2	17	6.5	7.8	7.3	4.8
40	NNS peak pressure	16	7.8	38.1	20.5	16.1	21.6	9.08
41	Burst per minute	5	0.4	6.4	4.2	4.1	3.6	2.3
41	NNS per minute	5	6	60.8	50.6	43.5	38.6	23.6
41	NNS per burst	5	7	14	11	6	10.6	3.1
41	NNS peak pressure	5	18.3	26.3	20.8	4.4	21.3	3
42	Burst per minute	6	0.0	6.4	4.2	3.7	3.9	2.3
42	NNS per minute	6	1	74.6	40.4	46.8	37.7	26.3
42	NNS per burst	6	0.0	13	7	10	7	5.2
42	NNS peak pressure	6	13.1	32.6	17.5	17	21.3	8.6
43	Burst per minute	6	0.0	5.8	3.1	2.8	3	2
43	NNS per minute	6	1.2	80.2	55.1	53.7	51	30.7
43	NNS per burst	6	0.0	18	14.5	11.3	12	6.9
43	NNS peak pressure	6	15	49.6	23.2	26.4	27.7	14.6
Overall change								
	Burst per minute	45	−1.2	3.8	2.2	−0.3	0.3	0.8
	NNS per minute	45	−19.4	49.2	0.1	−5.9	2.9	10
	NNS per burst	45	−1.6	4	0.2	−1	0.3	1
	NNS peak pressure	45	−4.5	7.8	0.3	−1.2	0.5	2.2

Abbreviations: IQR, interquartile range; NNS, non-nutritive sucking; PMA, postmenstrual age; SD, standard deviation.