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Breastfeeding support statement

Through appropriate information, products, and services,
we support breastfeeding for as long as mother and child wish.

In cases where breastfeeding is difficult, for whatever reason,
we offer a full range of products and solutions for healthy child development.

Research Report 2021---05

Sucking research

Aiming for preterm / low birthweight infants
to drink appropriately

The research of Pigeon searching for the development of swallowing and breathing of preterm/low birthweight infants

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Pigeon Research Report
2021-05

Aiming for preterm / low birthweight infants to drink appropriately

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Pigeon is also developing products for low birthweight / preterm infants with premature sucking behavior. In our research and development activities, we are investigating sucking behavior for those infants in cooperation with medical professionals while always asking what functions should be supported and how we can support the functions effectively with our products.

Perspective of Pigeon's research

'Latching on,' 'Tongue movement,' and 'Swallowing' of low birthweight / preterm infants

Pigeon observes 'Latching on,' 'Tongue movement,' and 'Swallowing' as the Three Key Factors of the Sucking behavior.
It is effective to consider each of these three factors carefully when supporting newborns and low birthweight / preterm infants. In particular, low birthweight / preterm infants are often premature in attachment, tongue movement , and swallowing. It is important to understand the developmental status and characteristics of the sucking behavior.

Development of tongue movement in low birthweight / preterm infants

Pigeon has been investigating the sucking behavior to help low birthweight / preterm infants drink appropriately. It is known that low birthweight / preterm infants are premature in the sucking behavior and they are characterized by weak sucking vacuum pressure and an irregular tongue movement. However, how their sucking behavior develops has not been always clarified. Pigeon has addressed these issues, and the results of various collaborative research on the sucking behavior for low birthweight/preterm infants have been published in specialized books and are used in the supporting settings.

- **Development and coordination of tongue movement, swallowing, and breathing of preterm infants**[1)]

  We investigated the development of the sucking behavior by the observation method using a sensor to measure sucking vacuum pressure in the early 2000s when there were not enough objective data to grasp the development of the sucking behavior.
  In this research, 24 healthy preterm infants without complications, etc. (gestational age, 30.0 ± 0.18 weeks [28-31 weeks]) were investigated regarding their tongue movement , swallowing, and timing of breathing during the period from 32 to 36 weeks of postconceptional age (PCA). The sucking vacuum pressure was obtained by measuring the expression pressure and sucking pressure in the oral cavity (Table 1, Table 2).
  According to the measurement results, although the tongue movement was weak and frequently pauses from 32 weeks to 33 weeks' PCA, the sucking pressure, frequency, and duration had developed through 35 weeks' PCA. At 36 weeks' PCA, the sucking pressure was -87.3±2.4 mmHg, which was equivalent to the value (-80mmHg)[2)] of full-term infants at the age of 5 days.
  Also, the pattern of respiration suppression was frequently observed before and after swallowing from 32 to 33 weeks' PCA. However, after 35 weeks' PCA, the rate declined and an increase in the mature pattern of 'inhale-swallow-exhale' was observed instead.
  These observation results suggested that the mature coordinated movement of sucking and breathing during swallowing is established around 35 weeks' PCA.

- **Sucking assessment and neurological prognosis in the neonatal period**[3)]

  It has been clarified that sucking of newborns is an important assessment indicator for subsequent neurological development.
  The sucking behavior was assessed in 4 classes (see the figures below) based on the expression pressure (pressing the nipple with the tongue and palate) and sucking pressure (sucking the nipple) produced in the oral cavity at the time of sucking in 65 newborns with sucking disorder who were born at an average gestational age of 37.8 weeks (35.1- 42.7 weeks). According to the results, there was a correlation with the neurological condition at 18 months of age and the sucking behavior was effective for predicting neurological prognosis (Figure 1).
  Among 4 classes, a serious disorder was observed in all infants at 18 months of age in Class 1 "no sucking pressure and weak expression pressure" group (15 infants) with severe sucking disorder. On the other hand, of 30 infants in Class 4 "sucking pressure within the regular and normal range" group, slight neurodevelopmental delay was observed in 4 infants but other infants were assessed as normal. It has been confirmed that the proportion of neurodevelopmental disorder at 18 months of age tends to be higher if the sucking behavior is regarded as poor from Class 1 to Class 4.
  Based on these results, it is important to detect problems early in the sucking behavior and provide supporting measures in response to the problems for the subsequent development.

Table 1 Maturation in sucking variables from 32 to 36 weeks' PCA

	32 wk	33 wk	34 wk	35 wk	36 wk
Sucking pressure (mmHg)	-16.7 ± 1.4	-31.2 ± 2.0	-51.5 ± 2.4	-70.1 ± 2.4	-87.3 ± 2.4
Sucking frequency (min)	20.1 ± 1.6	33.6 ± 3.3	51.3 ± 2.2	63.6 ± 2.0	73.3 ± 1.6
Sucking duration (s)	0.32 ± 0.01	0.43 ± 0.01	0.57 ± 0.03	0.69 ± 0.02	0.71 ± 0.01
Sucking efficiency (mL/min)	1.1 ± 0.1	2.4 ± 0.2	4.3 ± 0.3	7.3 ± 0.4	10.4 ± 0.3

n=24, values are expressed as mean ± SEM.
There are significant improvements in all sucking variables between weeks(P<.01)except sucking duration between 35 and 36 weeks' PCA.

Table 2 Frequency of each class from 32 to 36 weeks' PCA

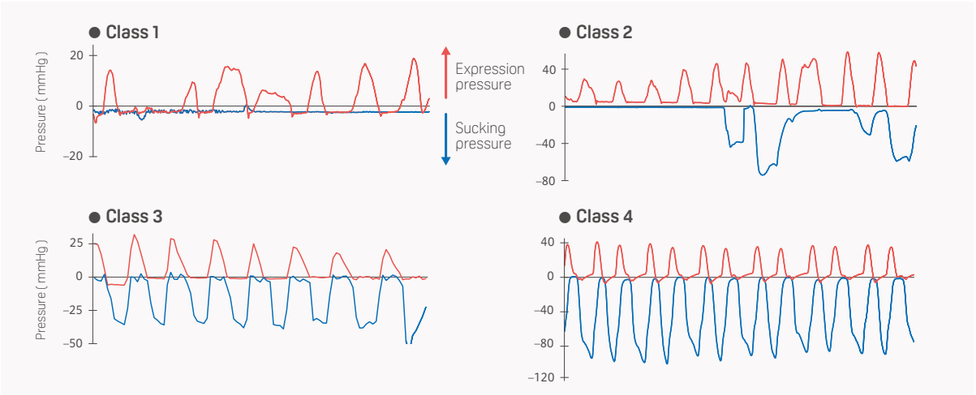
They were classified into 9 classes according to the breathing status before and after swallowing. Values indicate frequency (%).
I : inspiratory airflow, E : expiratory airflow, P : pause, SW : swallowing

		32 wk	33 wk	34 wk	35 wk	36 wk	*P* value
Class 1	I-Sw.-I	8.6	5.9	8.9	6.7	7.3	NS
Class 2	P-Sw.-I	5.8	6.8	6.1	5.4	6.4	NS
Class 3	E-Sw.-I	10.5	16.7	16.1	18.6	18.4	< 0.01
Class 4	I-Sw.-P	3.7	3.4	4.3	3.4	3.2	NS
Class 5	P-Sw.-P	41.3	31.8	20	13.1	11.6	< 0.001
Class 6	E-Sw.-P	3.8	5	4.7	5.3	4	NS
Class 7	I-Sw.-E	14.7	17.2	25.2	29.9	31.3	< 0.001
Class 8	P-Sw.-E	4.1	3.6	3.8	3.9	3.7	NS
Class 9	E-Sw.-E	7.6	9.6	9.8	13.7	13.8	< 0.01

n=24, values are expressed as mean ± SEM.
The frequency of classes 3,7, and 9 significantly increased with maturation. On the other hand, the frequency of class 5 significantly decreased.

Figure 1 Pattern classification of the status of expression pressure and sucking pressure during sucking

Class 1 : No sucking pressure, weak expression pressure
Class 2 : Weak sucking pressure and expression pressure randomly appear
Class 3 : Regular but weak sucking pressure
Class 4 : Sucking pressure within a regular and normal range



Aiming for preterm / low birthweight infants to drink appropriately
The research of Pigeon searching for the development of swallowing and breathing of preterm / low birthweight infants

Investigating swallowing and breathing in low birthweight / preterm infants

Low birthweight/preterm infants are prone to aspiration due to their premature sucking behavior and incomplete coordinated movement of sucking and breathing. Pigeon has been examining changes in the respiratory dynamics of NICU infants during the sucking behavior in cooperation with medical professionals. experts.

● Fundamental knowledge of development of swallowing and breathing

In adults, breathing is suspended by swallowing, the rhythm of breathing is reset, and breathing after swallowing is mostly started with exhalation[6]. On the other hand, in swallowing in infancy, it is routinely observed that infants continue sucking without stopping breathing. It is pointed out as a background that the larynx of an infant is positioned high and the distance between palatine uvula and epiglottis is short, which allows an infant to swallow while breathing[4] (Figure 2).

This swallowing specific to infants is called "infant swallowing." It is indicated that unlike adults, infants can swallow without aspiration even without coordination with breathing at the time of the swallowing reflex (Figure3). However, this coordinated movement of swallowing and breathing is not complete. In particular, in low birthweight/preterm infants, the ventilation decreases during sucking and decrease in the percutaneous arterial oxygen saturation (SpO_2) or apnea is observed[5].

The coordinated movement of swallowing and breathing in infancy is one the most important factors not only for achieving safe and sufficient sucking, but also for the healthy development of infants.

● Differences in swallowing between infants and adults

	Infant swallowing	Adult swallowing
Breathing	Synchronize with breathing, but cessation of breathing is short.	Stop breathing.
Lips / jaw	Open the jaw and also the upper and lower lips	Close lips and swallow
Position of the tip of the tongue	Between the alveolar ridge of the lower jaw and nipple	Fixed by pressing against the palate

(excerption of Table 1 Hironaka, 2014)[6]

Figure 2 Comparison of head and neck sagittal section between infant and adult

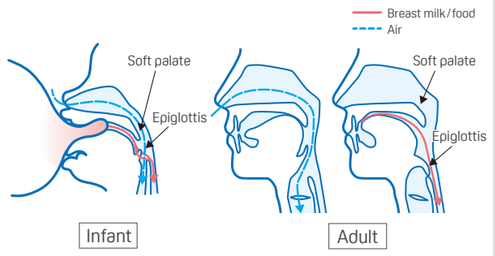


Figure 3 Characteristics of swallowing of newborns[7]

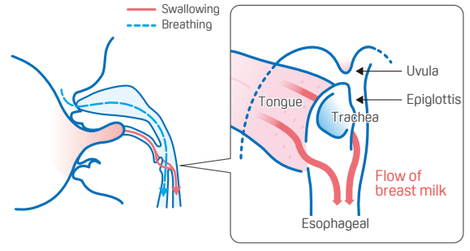
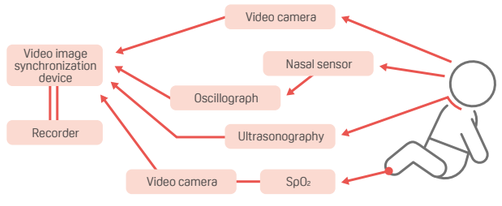


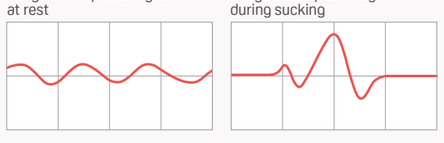
Figure 4 Observation of respiratory dynamics during sucking using a nasal airflow sensor

●Schematic diagram of observation and measurement methods

We synchronized facial lateral images, respiration curve of nasal cavity, and ultrasound images.



Intraoral ultrasound image (sagittal echo image)
Measuring nasal airflow intraoral ultrasonography and measuring method of nasal airflow



● Coordinated movement of swallowing and breathing and burden on breathing

<Measuring respiratory dynamics during sucking>

In the research in 2006[8], we conducted observational research on breathing conditions of 3 infants during sucking using a nasal airflow sensor.

The results showed that the respiratory curve at rest repeatedly exhibited slow-up (exhale) and slow -down (inhale), and not steep. On the other hand, exhale and inhale during sucking exhibited a changing pattern that showed a steep-up (like a spike)(exhale) and speed-down (inhale), and it presented a period of suspension of airflow (approx. 500-600 msec) before and after the pattern. The results also showed that exhale and inhale of infants during swallowing were comprised of several patterns (Figure 4).

<Summarizing the relationship between the type of respiratory dynamics during sucking and respiratory suppression >

In the research using the same method in 2007[9], the breathing rate per minute at the time of suspension of swallowing was higher than that at rest in all 13 infants in NICU. This suggested that the sucking behavior suppressed breathing.

Respiratory dynamics during sucking can be divided into 3 types according to the airflow pattern during the burst. Type A shows disappearance of airflow, type B shows continuous airflow but a different airflow pattern from that at rest, and type C shows an irregular airflow pattern.

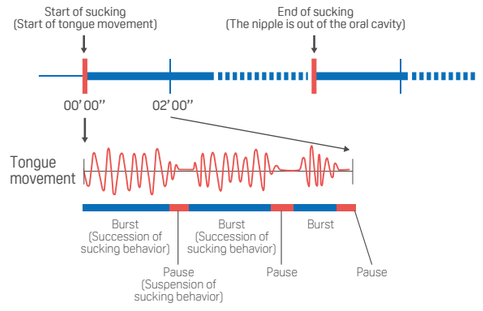
Infants classified as type A have a significantly shorter gestational age than those classified as type B. This suggests that the coordinated movement of premature breathing and swallowing may lead to respiratory suppression (Figure 5).

<Confirming the relationship between swallowing and burden on breathing according to milk flow>

The research from 2008 to 2009[10][11] revealed that nasopharyngeal closure that occurred in association with elevation of the soft palate/palatine uvula during swallowing and airflow was transiently suspended (within 500 msec). The research also revealed that at the time of sucking without swallowing, milk was drawn by sucking and retained around the intraoral epiglottis vallecula without suspension of airflow and breathing continued.

The respiratory dynamics during sucking was compared using two types of artificial nipples with different milk hole sizes. The results showed that more milk was retained in the oral cavity when an artificial nipple with a larger milk hole was used and the frequency of swallowing per sucking was higher than the frequency with an artificial nipple with a smaller milk hole. These results suggest that the use of an artificial nipple for a large amount of milk is likely to cause respiratory suppression due to increased swallowing frequency and put a burden on breathing of newborns and low birthweight infants (Figure 6).

Figure 5 Relationship between the type of respiratory dynamics during sucking and respiratory suppression

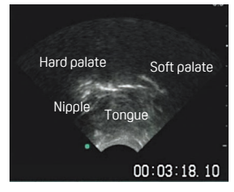


Respiratory dynamics (nasal cavity)		
Pattern	Burst	Pause
A	Off	On
B	Off	
C	On and Off	

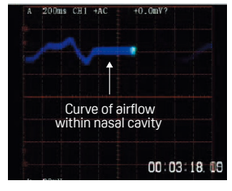
Pattern A: Exhale and inhale disappeared during the burst, and the movement of airflow caused by exhale and inhale was observed only during the pause.
Pattern B: The movement of airflow caused by exhale and inhale was observed during both the burst and pause.
Pattern C: The movement of airflow caused by exhale and inhale was intermittently observed during the burst while continuous airflow was observed during the pause.

Figure 6 Relationship between swallowing and burden on breathing according to milk flow

Ultrasound image

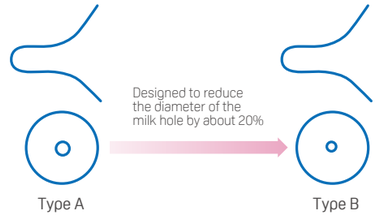


Oscilloscope image



● Two types of artificial nipples used in the research

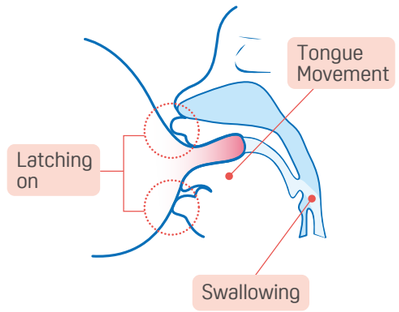
Types A and B have the same appearance and material with different diameters of the milk holes on the tips.



Supporting low birthweight/ preterm infants based on the Three Key Factors of Sucking

Pigeon calls important factors for the sucking behavior clarified through a long period of research the "Three Key Factors of Sucking" and puts them in the center of research and development. The Three Key Factors of Sucking are comprised of the following three behaviors : (1) "Latching on", the function of latching on to the nipple and sealing out of the areas from the areola to the nipple with the lips and tongue of infants; (2) "Tongue movement", the tongue's wave-like motion to draw milk; (3) "Swallowing", the function to transfer milks down to esophagus (Figure 7).
It is effective to consider these Three Key Factors when supporting sucking of low birthweight/ preterm infants. In low birthweight/preterm infants, premature latching on, tongue movement, and swallowing are gradually developed into a mature and coordinated sucking behavior. During this period, it is important to carefully observe each function of the Three Key Factors of Sucking, investigate where and what kind of problems exist, and provide necessary support. Various backgrounds cause poor sucking , for example, poor attachment , weak sucking power, or inability of a coordinated movement of swallowing and breathing that causes choking.
We pursue the theory of the sucking behavior and determine the required product functions to provide our products mainly based on the Three Key Factors of Sucking. And this is Pigeon's approach to sucking research.

Figure 7 Three main factors that compose sucking behavior (Three Key Factors)



'Latching on,' 'Tongue movement,' and 'Swallowing' of low birthweight / preterm infants

	Appropriate movement	Conditions in low birthweight / preterm infants
Latching on The function of latching on to the nipple and sealing out of the areas from the areola to the nipple with the lips and tongue of infants	● Both upper and lower lips turn outward and attach to the areola. ● The lips firmly hold the areola to prevent leaking of milk and sucking of air.	● The upper lip folded inward, then not to fit tightly. ● Sometimes, infant does not open the lips. ● Lips latch on the tip, then the milk becomes leakage. ● When not fit tightly, there is risk to swallow the air.
Tongue movement The tongue's wave-like motion to draw milk	● Wave-like motion of the tongue ● Wave-like motion with a cycle of a suck of about 800msec. lasting for 10 to 15 minutes. ● The tongue motion makes vacuum pressure in the intraoral cavity.	● Tongue motion is like stop-and-go, frequently pauses. ● 10 minutes sucking may burden the body, resulting fatigue and sleep before drink up. ● Weak suction power not rhythmic.
Swallowing The function to transfer milks down to esophagus	● Coordination between respiration and swallowing (stable SpO_2, percutaneous oxygen saturation) ● Smooth swallowing without choking	● Premature of the coordination between respiration and swallowing (Unstable SpO_2, percutaneous oxygen saturation) ● easy to get choked (with SpO_2 down)

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