Breastfeeding: how do they do it? Infant sucking, swallowing and breathing

To improve breastfeeding management and devise new interventions it is essential that basic knowledge of the suck-swallow-breathe (SSwB) process is expanded. Recent studies have begun to elucidate the SSwB process in term breastfeeding infants highlighting fundamental differences between the coordination of breast and bottle fed infants.

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Key points

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1. Breastfeeding infants use primarily vacuum (negative pressure) to remove milk from the breast.
2. Vacuum is created by downward movement of the anterior portion of the tongue in a motion parallel to the hard palate, expanding the nipple evenly.
3. Infant suck-swallow-breathe ratios are rarely 1:1:1 and are highly variable during breastfeeding.
4. As infants mature vacuum strength reduces, swallowing is followed by expiration more often, oxygen saturation improves and heart rate decreases during breastfeeding.

Coordination of suck, swallowing and breathing during breastfeeding is one of the most intricate processes an infant is required to perform. Efficiency and efficacy of feeding is based on the ability to synchronise all processes while maintaining good cardiovascular stability.[1] Infants are able to suck and swallow, suck and breathe but are unable to breathe and swallow simultaneously. Despite the sophistication of this technique there is poor understanding of the mechanism as most of the research in this area has been performed on bottle fed term and preterm infants.[2,3] Clinical management of sucking problems is largely addressed by advice on improving positioning and attachment of the infant to the breast. This approach, however, has not solved the majority of problems with a significant proportion of women still weaning prematurely due to infant sucking issues.[4]

Sucking dynamics

Suck mechanism

Oral feeding requires good coordination of the suck-swallow-breathe (SSwB) process which is achieved by the finely timed movement of multiple oral structures such as the jaw, hyoid bone, tongue, palate, pharynx and larynx. Sucking patterns can be classified as either nutritive sucking (NS), where milk is actively removed from the breast and there is frequent swallowing and non-nutritive sucking (NNS) where little milk is removed and only occasional swallowing occurs.[5] NNS bursts are shorter and tend to occur towards the end of a breastfeed,[6] whereas NS bursts are longer and occur at the beginning and middle of a breastfeed.[6,7]

The function of the tongue is of major importance during infant sucking; it must remove milk from the breast and safely clear the milk bolus to the pharynx,[8] yet exactly how the tongue functions during sucking is not understood. Two theories describing the sucking mechanism have been debated enthusiastically and originate mainly from clinical observation and examination, cineradiographic images and ultrasound images. One theory suggests a stripping action of the tongue is key to milk removal, which supports compression or positive pressure as the principle mechanism of milk removal.[6,9,10] The alternate theory proposes that the intra-oral vacuum or negative pressure

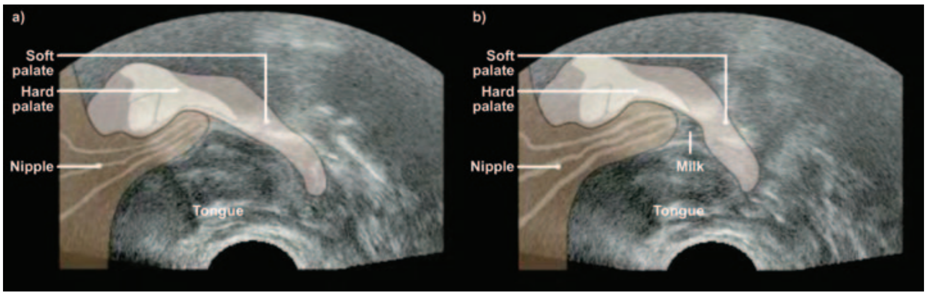

FIGURE 1 Sagittal midline images of an infant's oral cavity during breastfeeding: (a) tongue up (baseline vacuum) (b) tongue down (peak vacuum). Adapted from Medela AG.

generated by the infant during feeding is the primary mechanism of milk removal.[8,11-14]

The stripping action theory asserts that compression of the breast by the infant's lower jaw followed by a peristaltic tongue movement squeezes milk from the nipple.[2,3,10,15] The distal portion of the tongue subsequently lowers, creating a vacuum that draws the nipple back towards the hard soft palate junction and refills the lactiferous sinuses with milk. However this theory has been questioned since ducts at the base of the nipple do not contain significant volumes of milk,[16] and recent studies have confirmed that a peristaltic action of the tongue is not associated with milk removal. Furthermore studies have shown milk removal occurs with the downward movement of the tongue and increasing vacuum rather than compression of the nipple.[8,17]

The intra-oral vacuum theory, on the other hand, emphasises the creation of a vacuum as the principal mechanism of milk removal in combination with the positive pressure generated within the milk ducts at milk ejection.[8,18] Studies that have simultaneously recorded intra-oral vacuum and ultrasound imaging of the oral cavity have shown that breastfeeding infants attach to the breast by creating a baseline vacuum that stretches the nipple placing it within 5-7mm of the hard-soft palate junction. The tongue is in apposition with the palate and then the infant moves the tongue downwards creating a stronger vacuum. Downward movement of the tongue expands the nipple, which moves a few millimeters closer to the hard-soft palate junction and milk flows into the oral cavity (**FIGURE 1**). The vacuum is then released and, as the tongue rises, the nipple is compressed and the milk is cleared from the oral cavity to the pharyngeal area.

A 3D biophysical model based on 2D mid-sagittal ultrasound images during breastfeeding has provided further support of the intra-oral vacuum theory. The model confirmed a uniform anterior tongue motion, and reported a peristaltic-like posterior tongue movement.[17] In contrast, a study utilising 3D ultrasound to assess infant tongue movement during breastfeeding has suggested that a peristaltic action is prevalent in both the anterior and posterior tongue region.[15] Unfortunately the lack of resolution precluded the ability to image the nipple, nipple ducts and milk flow which, along with an absence of quantitative measurement of tongue movement, has limited the construction of a detailed description of milk removal in this study.[15]

Stage of lactation	Mean vacuums during breastfeeding (mmHg)	
Early lactation (1 day to 1 month of lactation)	Peak:	-93
Established lactation (1-6 months of lactation)	Peak: Baseline:	-122 to -197 -31 to -64
Prior to initial milk ejection (4-5 days of lactation)	Peak:	-93
After initial milk ejection (4-5 days of lactation)	Peak:	-77

TABLE 1 Mean peak (minimum pressure) and baseline (maximum pressure) vacuums during breastfeeding for term infants during early and established lactation. Peak vacuum before milk ejection tends to be stronger than after milk ejection when measured 4-5 days after birth.

While caution should be exercised in extrapolating mechanisms of bottle feeding to breastfeeding, earlier work has shown that milk flow can occur after release of compression of a teat, which coincides with the application of vacuum.[12] Positive pressures are commonly measured within the teat in bottle systems however these are minimal compared to the large negative pressures generated by lowering the tongue and are therefore likely to contribute little to effective milk removal.[11] Furthermore, the application of compression and vacuum alternates such that during breastfeeding milk flow stops as compression is applied, and milk flow begins with the release of compression and coincides with the generation of vacuum.[19] The role of compression is likely to be that of controlling milk flow to accommodate a manageable bolus rather than the removal of milk.

It has also been shown that infants will employ either vacuum or compression to remove milk from a bottle depending on which is the easiest.[20] Indeed, a recent study has confirmed that infants will use vacuum to remove milk from a teat designed to release milk only with the application of vacuum and a tongue movement similar to breastfeeding.[7,8,21,22] It also raises the possibility that some infants may prefer a compression action if exposed to this early in life, thereby hindering the establishment of breastfeeding.

Reported mean vacuums in healthy breastfeeding term infants range from -93 to -197mmHg (**TABLE 1**).[2,8,9,23,24] However, both strong baseline and peak vacuums have been measured in women with nipple pain.[21] Weak vacuums have been associated with compromised milk intake and are often associated with pathologies such as cleft palate and hypotonia.[25] It is likely there are optimal levels of vacuum for milk removal that in part depend on the mother's anatomy and milk supply as well as the infant's oral anatomy.

Nutritive and non-nutritive sucking

NNS has been shown to play an important role in the programming and development of feeding behaviour, particularly in the preterm infant.[26] Despite the importance of NNS and the lack of milk removal, most studies that measure the breastfeed report the entire feed as nutritive.

NNS is characterised by shorter suck bursts,[2,5] a higher suck frequency[2,3,5] and shorter suck duration[2,5] compared to NS. During breastfeeding sucking pressure is significantly higher during NNS (the period prior to the first milk ejection) compared to NS in 4-5 day old infants (**TABLE 1**).[2] However others have measured NNS bursts throughout the breastfeed and have shown NNS suck bursts were shorter but not always stronger than NS.[7]

Similarly differences in tongue movement between NS and NNS exist, in that there is less anterior and mid-tongue movement during NNS compared to NS. These findings have been confirmed with ultrasound imaging of a pacifier (NNS) versus a bottle (NS).[27] Lowering the tongue more during NS may simply be a consequence of accommodating the milk bolus within the oral cavity.[28]

Changes in sucking over time

The initiation of lactation can be divided into two stages: secretory differentiation where the lactocytes lining the alveoli of the breast are differentiated and there is minimal secretion of colostrum; followed by secretory activation, which marks the onset of copious, milk production that occurs 30-45 hours after birth. Despite a dearth of longitudinal breastfeeding studies it is assumed that sucking 'matures' over time and that major changes occur around secretory activation (lactogenesis stage II). Despite these clinical assumptions there is no evidence that sucking dynamics, in terms of generation of vacuum and tongue movement, differ in the early days post-partum compared to established lactation.[28] The only exception is that infants lower their tongue more after day 3 (average timing of secretory activation, **TABLE 2**). This change may be due to a combination of increased milk flow associated with increased milk supply and/or the ability of the infant to generate greater vacuums (**TABLE 1**).

In older infants there has been no change in vacuum when measured at one, three and six months during both bottle and breastfeeding.[24] In fact the only detectable difference was an increase in the number and duration of sucks, along with greater feeding efficacy. This study did not account for either NNS at the breast or the complete absence of NNS at the bottle. When NS and NNS are considered separately it has been shown that breastfeeding vacuums actually decrease (weaken) from one month to 2-4 months of age along with a reduction in pause durations and increase in suck burst durations (**TABLE 2**).[7] Changes in efficacy of feeding over time are therefore unlikely to be as a result of changing tongue dynamics but rather increased coordination of SSwB and improved cardiorespiratory stability.

Swallowing and respiration during feeding

The process of swallowing

Safe swallowing is crucial for successful coordination of the SSwB reflex in breastfeeding infants. The process of swallowing moves the bolus into the digestive system, while preventing it from entering the airway. Swallowing begins in the oral cavity with the removal of milk from the breast and propulsion of the bolus towards the back of the cavity.[29] During each suck cycle the upward movement of the anterior tongue assists in stemming milk flow while the peristaltic action of the posterior tongue propels the bolus under the soft palate towards the pharynx.[8] Milk accumulates in the pharynx and with sufficient volume a swallow is triggered. The soft palate elevates preventing the bolus from entering the nasopharynx.[29] The vocal cords move together closing over the trachea and the hyoid moves upwards and forwards and the larynx elevates at the same time. Respiration ceases briefly during the swallow.[30] Tilting of the epiglottis over the larynx may also occur, although this is less consistent in infants compared to children and adults.[30] Pharyngeal peristalsis and changing pressure gradients in the pharynx assist movement of the bolus and relaxation of the cricopharyngeus muscle allows the oesophagus to open and, subsequently, the bolus to enter. Contraction of the cricopharyngeus prevents reterograde movement of the bolus while oesophageal peristalsis propels the bolus towards the stomach.[29]

During sucking and breathing air does not enter the digestive system. Relaxation of the soft palate and vocal cords allow air entering the nose to move towards the lungs. Contraction of the cricopharyngeus prevents air entering the oesophagus. Infants must cease breathing for approximately half a second to swallow[31] (**FIGURE 2**). Respiratory rates during breastfeeding range from 40 to 65 breaths/minute[7] and reduce due to increased swallowing during NS compared to NNS.

In term infants, swallowing interrupts both the inspiratory and expiratory phases of respiration. Dominant inspiration-swallow-expiration patterns have been shown in several studies of term bottle feeding infants.[32,33] Few studies have investigated breastfeeding despite the vast differences in milk delivery. High milk flow rates, the size of the teat flow hole and teat compressibility are likely to influence the variation in swallowing and breathing observed during bottle feeding. It is possible that there may not be an optimal phase to swallow and that a coordinated infant is able to swallow on any phase of respiration to maintain cardiorespiratory stability.

Maturation of swallowing and breathing

There is evidence that swallowing and breathing patterns change as an infant ages. During both bottle and breast-

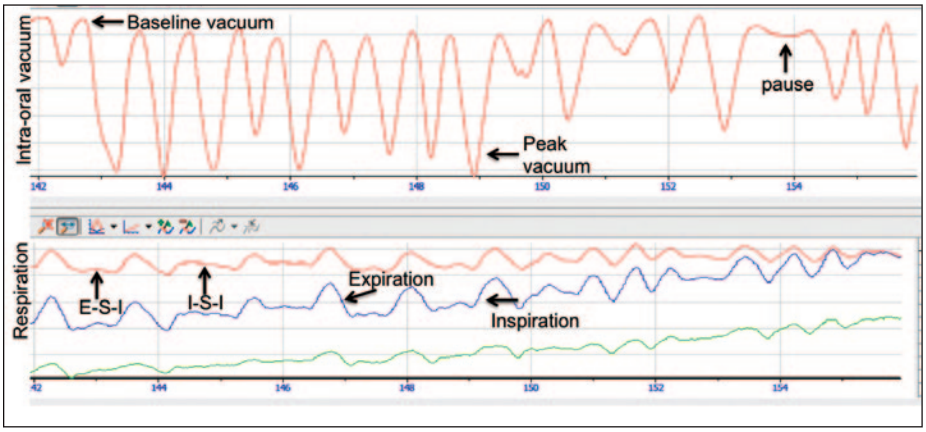

FIGURE 2 Simultaneous recording of infant intra-oral vacuum and respiration (respiratory inductive plethysmography, RIP) during a breastfeed. The intra-oral vacuum shows a variable baseline vacuum (latch vacuum) and a peak vacuum (sucking vacuum). The respiratory trace measures respiration as inspiratory effort and expiratory effort and absence of the signal indicates a swallow. The respiratory phase of swallowing can be identified: E-S-I = expiration-suck-inspiration; I-S-I = inspiration-suck-inspiration.

	Baseline vacuum	Peak vacuum	Suck burst duration	Pause duration	Nipple position (NHSPJ-D)	Anterior tongue movement	Mid tongue movement
Change	Weaken	Weaken	Increase	Decrease	No change	No change	Increase
Time frame	1 to 2-4 months				Day 3 to 4 weeks		

TABLE 2 Changes in infant sucking parameters over time. Key: NHSPJ-D = nipple hard-soft palate junction distance.

feeding, Kelly et al[34] found the majority of swallows occurred after expiration in the first 12 months postpartum. Clear maturation effects were shown, where swallows changed from predominantly mid-expiration in the first few days postpartum to both mid-expiration and inspiration-expiration by one week of life, and persisted for six months, after which the majority of swallows were followed by expiration (**TABLE 2**). Between nine and 12 months an inspiration-expiration pattern was dominant. These changes in timing of swallowing across the first six months were thought to be due to increasing peripheral and central nervous system maturity along with oral anatomical changes including descent of the larynx allowing transition from nasal to oral respiration.[34]

Increased feeding efficiency can also be explained by increased swallowing rates as the infant matures. Swallows and breaths increase per suck burst from one to 2-4 months postpartum, in term breastfeeding infants suck bursts become longer.[7] However swallowing rates do not appear to increase across the first month postpartum in term infants.[35] This suggests the first month postpartum may be a critical period for feeding development and this coincides with development of cerebral and brainstem pathways involved in sucking, swallowing and breathing.[36]

Suck-swallow-breathe coordination

Coordination of the SSwB is innately programmed and is essential to efficient and effective feeding.[37] A SSwB ratio of 1:1:1 to 2:1:1 has long been considered optimal;[38] however to expect a regular ratio during a breastfeed is not logical given rapid increases and decreases in milk flow within a milk ejection and that multiple milk ejections occur during a breastfeed.[39] Values for SSwB ratios differ widely in the literature (**TABLE 3**). Suck-swallow ratios can change within a breastfeed from 1:1 to 2:1-3:1 later in the feed[6] whereas during bottle feeding ratios tend to be more consistent at 1:1.[35]

Breastfeeding infants do not appear to have consistent SSwB ratios within a breastfeed with high variability documented and ratios ranging from 1:1:1 to 12:1:4 during NS and 2:0:1 to 23:1:23 during NNS.[7] Similar variation of suck:breathe, breathe:swallow and suck:swallow ratios, suck and respiratory rates have also been shown with differences between NS and NNS. Given changes in milk flow rates during milk ejection,[39] as well as the different patterns of milk ejection between mothers, these findings are not unexpected and underscore the infants ability to adapt during breastfeeding.

	Respiratory phase of swallow	SSwB ratio	Mean oxygen saturation (%)	Mean heart rate (beats/min)
Early lactation (<1 month)	First week E-Sw-E >1 week E-Sw-E and I-Sw-E	SSw increases during a feed from 1:1 to 1:3	97-98%	162
Established lactation (1-6 months)	E-Sw-E and I-Sw-E	3.8:1:2.2 (1:1:1 to 9:1:4)	99%	155-160

TABLE 3 The difference in suck-swallow-breathe parameters from early to established lactation for term breastfeeding infants. Key: E-Sw-E = expiration-swallow-expiration, I-Sw-E = inspiration-swallow-expiration, SSwB = suck:swallow:breathe, SSw = suck:swallow ratio.

It is possible that the infant adapts over time to the mothers innate milk ejection pattern. The timing, number and pattern of milk ejection during breast expression is consistent within mothers over the first 12 months of lactation.[39] Bottle feeding, in contrast, generally provides a continuous flow of milk explaining the consistent SSwB patterns that are likely to depend on the dimensions of the teat hole and venting of the bottle. Thus flows that are too high may result in disorganisation of sucking and periods of oxygen desaturation.[3,40,41]

Maturation of suck-swallow-breathe coordination

SSwB ratios have been shown to change with infant age and development. Term bottle-feeding infants improve their efficiency over time by reducing their 1:1 suck-swallow ratios such that the proportion of 1:1 decreases from day 3 (78.8%) to one month (57.5%) when 2:1, 3:1 and higher ratios were more prevalent.[42] Since milk intake increases dramatically after secretory activation one would expect sucking patterns and SSwB patterns to change accordingly. During established lactation however, breathe:swallow ratios, and suck:breathe ratios do not differ from <1 month to 2-4 months postpartum, indicating early development of coordination (**TABLE 2**).[7] The only change observed was an increase in the number of sucks, swallows and breaths during NS due to sustained suck bursts.

Oxygen saturation and heart rate

Physiological stability

Physiological stability during feeding is essential for good SSwB coordination. Oxygen saturation has been shown repeatedly to be higher during breastfeeding than bottle feeding.[3,40,43] This is attributed to decreased ventilation and more frequent and random swallowing during bottle feeding.[40] Increased heart rate during NS has been observed during both breastfeeding and bottle feeding compared to NNS.[7,44]

Maturation of physiological stability

Some aspects of cardiorespiratory stability improve over time. Heart rate tends to be lowest in newborn infants and peaks at six weeks of age. NS heart rate is increased and variability decreased compared to NNS. The physical demand of sucking and subsequently less vagal input explains these changes. Furthermore, lower heart rates at six months also suggests sucking is less demanding as the infant ages. More recently it was found that heart rate decreased from one month to 2-4 months of age during both NS and NNS (**TABLE 3**), further supporting the notion of maturation over time.

Summary

Accumulating evidence supports the application of vacuum as a critical factor for successful removal of milk by the breastfeeding infant. Breastfeeding suck dynamics are consistent during initiation and in established lactation with clear differences between NS and NNS. Similarly vacuum, suck rates and burst durations are different for NNS and as a result the clinician should expect a large range of sucking patterns within a breastfeed.

SSwB patterns also vary within a breastfeed suggesting that good coordination allows adaptation to rapid changes in milk flow due to milk ejection. Thus breastfed infants rarely suck, swallow and breathe in a regular manner and it is feasible that the inability to vary SSwB coordination may potentially impede adaptation to the mother's changing milk flow and thereby reduce the volume of milk ingested and/or extend feeding times. Good coordination of infants is evident in the early postpartum period, however changes in oxygenation, heart rate, feed duration and vacuum represent a level of neurological maturation and conditioning across lactation.

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References

1. **McClellan H.L., Hartmann P.E.** Evolution of lactation: nutrition v. protection with special reference to five mammalian species. *Nutr Res Rev* 2008;21:97.
2. **Mizuno K., Ueda A.** Changes in sucking performance from non-nutritive sucking to nutritive sucking during breast- and bottle-Feeding. *Pediatr Res* 2006;59:728-31.
3. **Mathew O.O.P., Bhatia J.J.** Sucking and breathing patterns during breast and bottle-feeding in term neonates. Effects of nutrient delivery and composition. *Arch Dis Child* 1989;143:588-92.
4. **McClellan H.L., Hepworth A.R., Garbin C.P. et al.** Nipple pain during breastfeeding with or without visible trauma. *J Hum Lact* 2012;28:511-21.
5. **Wolff P.H.** The serial organization of sucking in the young infant. *Pediatrics* 1968;42:943.
6. **Weber J., Woolridge M., Baum J.** An ultrasonographic study of the organisation of sucking and swallowing by newborn infants. *Dev Med Child Neurol* 1986;28:19-24.
7. **Sakalidis V.S., McClellan H.L., Hepworth A.R. et al.** Oxygen saturation and suck-swallow-breathe coordination of term infants during breastfeeding and feeding from a teat releasing milk only with vacuum. *Int J Pediatr* 2012;2012:130769.
8. **Geddes D.T., Kent J.C., Mitoulas L.R., Hartmann P.E.** Tongue movement and intra-oral vacuum in breast-feeding infants. *Early Hum Dev* 2008;84:471-77.
9. **Ardran G., Kemp F., Lind J.** A cineradiographic study of breastfeeding. *Br J Radiol* 1958;31:156-62.
10. **Woolridge M.** The anatomy of infant sucking. *Midwifery* 1986;2:164-71.
11. **Colley J.R.T., Creamer B.** Sucking and swallowing in infants. *Br Med J* 1958;2:422-23.
12. **Soentgen M.L., Pierce L., Brenman H.S.** Mouthing activities in the human neonatal sucking act. *Arch Oral Biol* 1969;14:1159-67.
13. **Waller H.** The force exerted by the baby. In: *Clinical Studies in Lactation*. William Heinemann Ltd; 1936
14. **Hytten F.E.** Observations on the vitality of the newborn. *Arch Dis Child* 1951;26:477.
15. **Burton P., Deng J., McDonald D., Fewtrell M.S.** Real-time 3D ultrasound imaging of infant tongue movements during breast-feeding. *Early Hum Dev* 2013;89:635-41.
16. **Ramsay D.T., Kent J.C., Hartmann R.A., Hartmann P.E.** Anatomy of the lactating human breast redefined with ultrasound imaging. *J Anat* 2005; 206:525-34.
17. **Elad D., Kozlovsky P., Blum O. et al.** Biomechanics of milk extraction during breast-feeding. *PNAS* 2014; 111:5230-35.
18. **Colley J.R., Creamer B.** Sucking and swallowing in infants. *Br Med J* 1958;2:422-23.
19. **Geddes D.T., Sakalidis V.S., Hepworth A.R. et al.** Tongue movement and intra-oral vacuum of term infants during breastfeeding and feeding from an experimental teat that released milk under vacuum only. *Early Hum Dev* 2012;88:443-49.
20. **Sameroff A.J.** The components of sucking in the human newborn. *J Exp Child Psychol* 1968;6:607-23.
21. **McClellan H., Geddes D., Kent J. et al.** Infants of mothers with persistent nipple pain exert strong sucking vaccums. *Acta Paediatr* 2008;97:1205-09.
22. **McClellan H., Sakalidis V., Hepworth A. et al.** Validation of nipple diameter and tongue movement measurements with B-mode ultrasound during breastfeeding. *Ultrasound Med Biol* 2010;36: 1797-807.
23. **Prieto C.R., Cardenas H., Salvatierra A.M. et al.** Sucking pressure and its relationship to milk transfer during breastfeeding in humans. *Reproduction* 1996;108:69-74.
24. **Taki M., Mizuno K., Murase M. et al.** Maturational changes in the feeding behaviour of infants – a comparison between breast-feeding and bottle-feeding. *Acta Paediatr* 2010;99:61-67.
25. **Mizuno K., Ueda A.** Development of sucking behavior in infants with Down's syndrome. *Acta Pædiatr* 2001;90:1384-88.
26. **Barlow S.M.** Synthetic orocutaneous stimulation entrains preterm infants with feeding difficulties to suck. *J Perinatol* 2008;28:541.
27. **Miller J.L., Kang S.M.** Preliminary ultrasound observation of lingual movement patterns during nutritive versus non-nutritive sucking in a premature infant. *Dysphagia* 2007;22:150-60.
28. **Sakalidis V.S., Williams T.M., Garbin C.P. et al.** Ultrasound imaging of infant sucking dynamics during the establishment of lactation. *J Hum Lact* 2013;29:205-13.
29. **Kramer S.** Special swallowing problems in children. *Gastrointest Radiol* 1985;10:241-50.
30. **Cichero J., Murdoc B.E.** *Dysphagia: Foundation, Theory and Practice*. Hoboken: John Wiley & Sons; 2006.
31. **Arvedson J.** Swallowing and feeding in infants and young children. *GI Motility Online* 2006;doi:10.1038/gimo17.
32. **Gewolb I.H., Vice F.L.** Maturational changes in the rhythms, patterning, and coordination of respiration and swallow during feeding in preterm and term infants. *Dev Med Child Neurol* 2006;48:589-94.
33. **Selley W.G., Ellis R.E., Flack F.C., Brooks W.A.** Coordination of sucking, swallowing and breathing in the newborn: its relationship to infant feeding and normal development. *Br J Disord Commun* 1990;25:311-27.
34. **Kelly B., Huckabee M., Jones R., Frampton C.** The first year of human life: coordinating respiration and nutritive swallowing. *Dysphagia* 2007;22:37-43.
35. **Lau C., Smith E., Schanler R.** Coordination of suck-swallow and swallow respiration in preterm infants. *Acta Paediatr* 2003;92:721-27.
36. **Carroll J.L.** Developmental plasticity in respiratory control. *J Appl Physiol* 2003;94:375-89.
37. **Rogers B., Arvedson J.** Assessment of infant oral sensorimotor and swallowing function. *Ment Retard Disabil Res Rev* 2005;11:74-82.
38. **Bu'Lock F., Woolridge M.W., Baum J.D.** Development of co-ordination of sucking, swallowing and breathing: ultrasound study of term and preterm infants. *Dev Med Child Neurol* 1990;32:669-78.
39. **Prime D.K., Geddes D.T., Hepworth A.R. et al.** Comparison of the patterns of milk ejection during repeated breast expression sessions in women. *Breastfeed Med* 2011;6:183-90.
40. **Goldfield E.C., Richardson. Lee K.G., Margetts S.** Coordination of sucking, swallowing, and breathing and oxygen saturation during early infant breast-feeding and bottle-feeding. *Pediatr Res* 2006;60: 450-55.
41. **Mathew O.** Nipple units for newborn infants: a functional comparison. *Pediatrics* 1988;81:688-91.
42. **Qureshi M.A., Vice F.L,. Taciak V.L. et al.** Changes in rhythmic suckle feeding patterns in term infants in the first month of life. *Dev Med Child Neurol* 2002;44:34-39.
43. **Chen C.H.** The effect of breast-and bottle-feeding on oxygen saturation and body temperature in preterm infants. *J Hum Lact* 2000;16:21.
44. **Lappi H., Valkonen-Korhonen M., Georgiadis S. et al.** Effects of nutritive and non-nutritive sucking on infant heart rate variability during the first 6 months of life. *Infant Behav Dev* 2007;30:546-56.