



# Tongue movement and intra-oral vacuum in breastfeeding infants

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## KEYWORDS

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## Abstract

**Objective:** The mechanism by which the breastfeeding infant removes milk from the breast is still controversial. It is unclear whether the infant uses predominantly intra-oral vacuum or a peristaltic action of the tongue to remove milk from the breast. The aim of this study was to use ultrasound to observe movements of the tongue during breastfeeding and relate these movements to both milk flow and simultaneous measurements of intra-oral vacuum.

**Methods:** Submental ultrasound scans of the oral cavity of 20 breastfed infants (3–24 weeks old) were performed during a breastfeed. Intra-oral vacuums were measured simultaneously via a milk-filled supply line (SNS) connected to a pressure transducer.

**Results:** Vacuum increased during the downward motion of the posterior tongue and at the same time milk flow and milk ducts in the nipple was observed. Peak vacuum ( $-145 \pm 58$  mmHg) occurred when the tongue was in the lowest position.

**Conclusions:** Ultrasound imaging demonstrated that milk flow from the nipple into the infant's oral cavity coincided with both the lowering of the infants tongue and peak vacuum. Therefore vacuum is likely to play a major role in milk removal from the breast.

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## 1. Introduction

Suckling of the mammary gland to obtain milk for nourishment is behaviour unique to mammals. Besides nourishment, suckling causes numerous responses in both the mother and infant and these are thought to have evolved to promote survival of the infant in harsh environmental conditions [1]. The close body contact during breastfeeding regulates infant respiration, acid-base balance and temperature, helps

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conserve energy reserves [2] and soothes the infants [3,4]. Furthermore, breastfeeding impacts upon the normal oral facial development of the infant [5]. However, one of the primary roles of suckling is to remove milk from the mammary gland and adequate milk removal is essential to sustain milk synthesis for a successful lactation.

Historically two theories have evolved, through observation, to explain how the infant removes milk from the breast. One theory suggests that compression of the breast by the infant's jaw and a peristaltic action of the tongue to express milk into the mouth is the major factor in milk removal during breastfeeding [6,7,8]. and this theory presupposes the existence of lactiferous sinuses. Since these are not present in the human breast [9] this theory must be re-examined. The second theory suggests that vacuum applied by the infant results in efficient milk removal from the breast [10]. The few studies that have tested these theories [7,8] have still not clarified the sucking mechanism in detail. Most of the studies performed on breastfeeding infants have involved imaging in order to determine the tongue motion in relation to the nipple. One early study used fluoroscopy (X-Radiation) to image the infant breastfeeding [7]. The mother and infant were unable to feed in a 'normal position' and milk flow was not identified. In subsequent studies ultrasound imaging was the modality of choice due to being non-invasive and safe (compared to X-radiation). However, large transducers with limited image resolution compared to current technology were used. Improved image resolution of current machines allows real-time imaging of infant oral structures such as the tongue, hard and soft palate [11]. The aim of the study was to examine the relationship between tongue movement and intra-oral vacuum generated during breastfeeding by the infant.

## 2. Methods

### 2.1. Participants

Twenty mothers and infants (3-24 weeks old) were recruited through either the Australian Breastfeeding Association or community health centres. All infants were successfully breastfed and mothers supplied written, informed consent to participate in the study, which was approved by the Human Research Ethics Committee of The University of Western Australia.

### 2.2. Determination of milk intake

The amount of milk consumed during a breastfeed was determined by test weighing the baby using an electronic balance (Medela Electronic Baby-Weigh Scales, Medela AG, Switzerland) prior to and after breastfeeding. No correction for infant insensible water loss was made; therefore milk intake may be underestimated by  $10 \pm 12\%$  (mean  $\pm$  SD) [12].

### 2.3. Intra-oral pressure

A supply line (SNS) filled with the mother's expressed breastmilk was placed alongside the nipple and connected via a silicon tube (650 $\times$ 4 mm) and three-way tap to a disposable

pressure transducer (Cobe Laboratories, Frenchs Forest, NSW 2086, Australia). The transducer was connected via an interconnect cable (Cobe Laboratories) to an amp bridge (ADInstruments, Castle Hill, NSW 2154, Australia) and the output was recorded using computer hardware, Power Lab (ADInstruments) and software package Chart v5.0.2 (ADInstruments) on a laptop computer (Mac OS X v10.3.8). This method allowed for the direct measurement of the vacuums during each suck cycle over the course of the breastfeed. No fluid was removed from the SNS line during the breastfeed thus measured vacuum was not affected by additional milk flow.

### 2.4. Ultrasound equipment and imaging

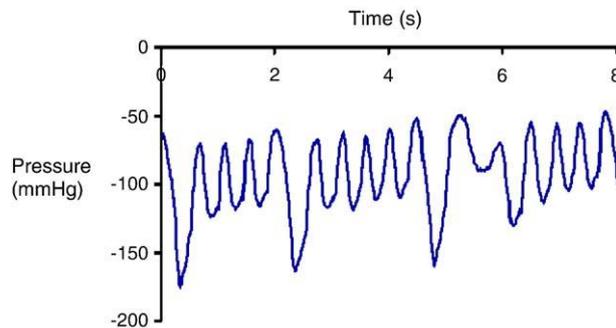
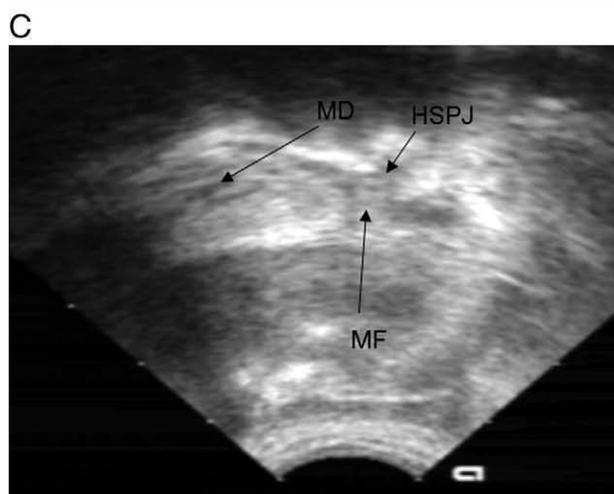
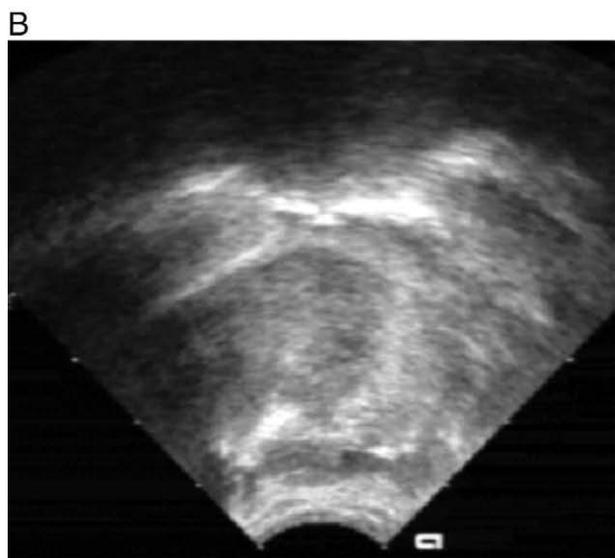
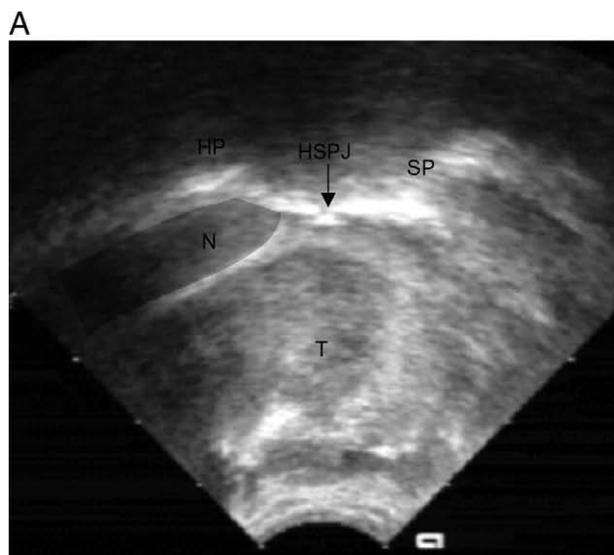
Submental scans of the midline of the infant's oral cavity were performed [11,13] by an experienced ultrasonographer. For 10 infants an Acuson, XP10 (Siemens, Mountain View, California, USA) with an endocavity convex transducer (EC7) was used to acquire ultrasound images. The remaining 10 infants were scanned using Toshiba SSA-770A/80, Aplio 80 (Tokyo, Japan) using the PVT-661VT transducer. Parker Ultrasonic Gel (Fairfield, New Jersey, USA) was used. This transducer has a long handle which is both easy to manipulate and is less invasive than bulkier transducers. Further more this transducer provides a wide convex field of view (160°) facilitating a panoramic view of the hard and soft palate. The transducer was positioned along the midsagittal line of the infant's body and light pressure was used to maintain contact with the infant's chin. The transducer was rotated until the image of the nipple was both at its maximum length and widest diameter and a clear view of the hard-soft palate junction was achieved (Fig. 1A, B). Since the supply line (SNS) measuring intra-oral pressure was positioned alongside the nipple this was not visible in the midline. However the position of the supply line in the infant's mouth could be confirmed by moving the transducer laterally and visualizing the tube as hyperechoic (white) lines. The position of the transducer was altered accordingly with infant movement to maintain a midline sagittal view. Average setting values for the Acuson, XP10 were gained: 50 db, dynamic range: 57 db, frequency: 7 MHz and for the Toshiba, Aplio 80 they were gain 55 db, dynamic range: 60 db, frequency: 8.8 MHz. Two focal zones were used to narrow the ultrasound beam and hence improve image resolution. One was placed at the hard palate and the other at the nipple-tongue apposition. Further adjustments were made to the gain, dynamic range and time gain compensation to optimise the image during scanning. In some cases lowering of the frequency of the probe from 8.8 MHz to 7.3 or 5.8 MHz was necessary to improve imaging at depth in older and larger infants. All ultrasound scans began when the infant attached to the breast and ended when the infant finished feeding. The scan was videotaped for later analysis. The ultrasound images and the intra-oral pressure were recorded simultaneously.

### 2.5. Statistical analysis

The tongue motion was linked to pressure measurement and frame by frame analysis of tongue position was performed for at least three full suck cycles during which milk flow was evident on the ultrasound image (Fig. 1C). Further ultrasound

measurements were made of the nipple diameter, nipple to hard-soft palate junction (N-HSPJ) and depth of the milk flow area.

For all mothers descriptive statistics of the breastfeed were calculated. The statistics: mean vacuum, peak vacuum



**Figure 2** A typical infant intra-oral pressure trace during a breastfeed. Peak vacuum (mean minimum pressure) ranges from  $-110$  to  $-170$  mmHg. Baseline pressure (mean maximum pressure) ranges from  $-50$  to  $-60$  mmHg.

(mean minimum pressure; Fig. 2) and baseline vacuum (mean maximum pressure; Fig. 1) was generated by the Chart v5.0.2 analysis software.

Paired *t*-tests were performed and two sided *P*-values are quoted. A *P*-value  $< 0.05$  was regarded as statistically significant. Results are presented as mean  $\pm$  SD.

### 3. Results

The mean breastfeed duration was 8 min 16 s  $\pm$  2 min 45 s with a mean milk intake of 63  $\pm$  31 g. The mothers regarded the behaviour of the infant during the test breastfeed as normal.

#### 3.1. Intra-oral pressure

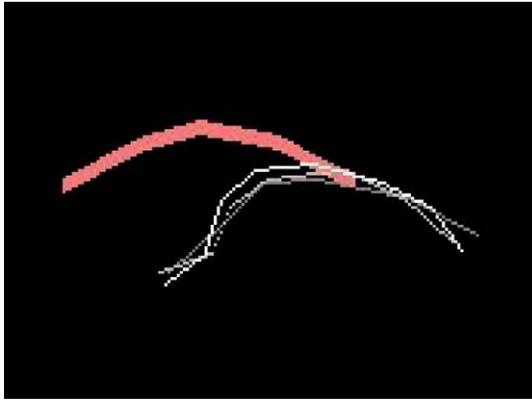
The mean vacuum was  $-114 \pm 50$  mmHg. The peak vacuum was  $-145 \pm 58$  mmHg and baseline vacuum was  $-64 \pm 45$  mmHg. Milk intake was not related to the peak vacuum, baseline vacuum or duration of the breastfeed.

#### 3.2. Ultrasound

On ultrasound imaging the hard palate appears as an echogenic (white) line whereas the soft palate appears as a grey structure (3-4 mm) with an echogenic border. The nipple on the left side of the image appears as a grey soft tissue structure and milk ducts within the nipple appear as hypoechoic (black) thin tubular structures. Milk flow was visualised as hypoechoic fluid containing echogenic flecks. The echogenic flecks are the fat globules in the milk (Fig. 1) [14].

Tongue motion during a suck cycle showed that at baseline vacuum the posterior tongue was in apposition with the

**Figure 1** Submental ultrasound images of the intra-oral cavity of an infant during breastfeeding. A, B. The infant's tongue (T) is up in apposition with the hard palate (H). The end of the nipple is not at the hard soft palate junction (HSPJ). The soft palate (SP) is in line with the hard palate. C. The infant's tongue (T) is down and milk ducts (MD) are visible within the nipple (N). Milk flow (MF) is visible within the oral cavity and the nipple has moved closer to the hard soft palate junction (HSPJ).



**Figure 3** Schematic representation of tongue movement through one suck cycle. Note that the border of the nipple is not markedly indented by the tongue.

palate (up position) and the anterior tongue did not markedly indent the nipple border (Fig. 3). Vacuum was generated as the posterior (proximal) tongue and soft palate moved downward (down position), coinciding with observed milk flow (Fig. 4). In addition milk ducts became visible within the nipple as thin black lines (Fig. 1C). Peak vacuum occurred when the posterior tongue was maximally lowered (down position). As the vacuum was released the anterior tongue momentarily rose slightly and milk was seen to pass under the soft palate. Both the posterior tongue and soft palate then rose and milk continued to flow toward the pharyngeal region (swallow). When the posterior tongue reached the palate (up position) the vacuum returned to baseline levels (Fig. 4).

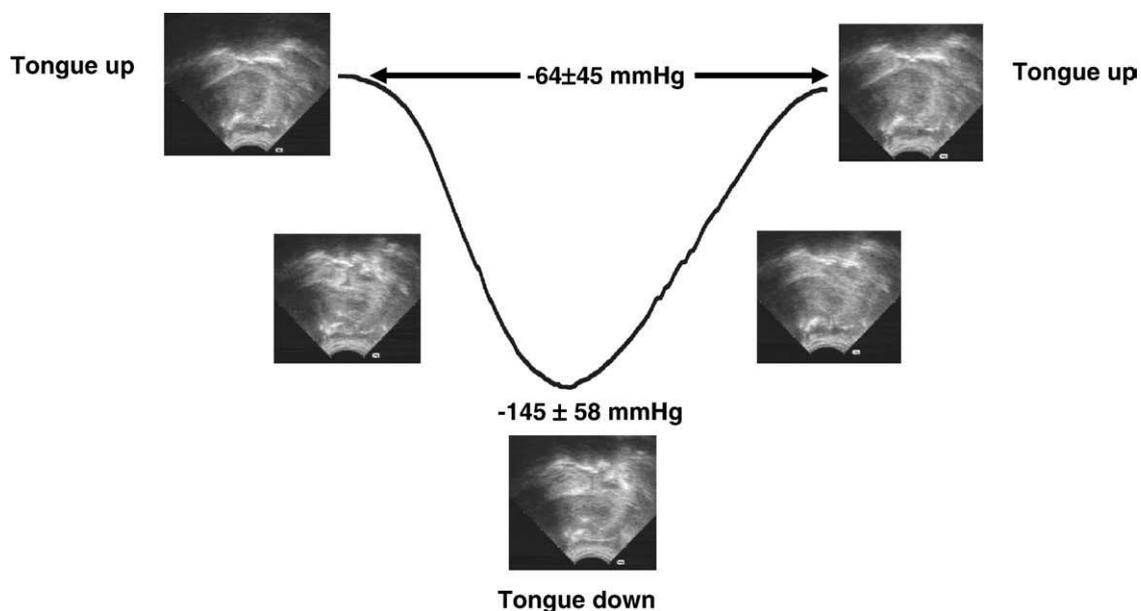
Nipple diameter was greater when the tongue was in the down position than when the tongue was up. The distance from the tip of the nipple to the hard/soft palate junction (N-HSPJD)

was greater when the tongue was up compared to when it was down. The maximum distance of the posterior tongue from the hard palate (Table 1) coincided with peak vacuum.

#### 4. Discussion

Recent advances in the resolution of ultrasound imaging have allowed more detailed examination of the sucking dynamics of the infant, most notably the identification of milk flow. In addition, the use of a long-handled convex transducer has minimised interference during a breastfeed. With the synchronisation of ultrasound imaging of the infant's oral structures and the measurement of vacuum applied by the infant to the breast this study found that when the infant lowered its tongue the intra-oral vacuum increased. Peak vacuum coincided with the tongue in its lowermost position and subsequently as the infant raised its tongue the vacuum decreased and milk flow ceased (Fig. 4). This study has shown that milk only flows into the infant oral cavity when the downward movement of the posterior tongue creates an intra-oral vacuum, highlighting the importance of vacuum in milk removal rather than the stripping action of the tongue in milk removal by the breastfeeding infant. The mechanism of milk removal used by the breastfeeding infant has remained controversial for many years. Generally it is believed that the infant sucking dynamic consists of a stripping action by upward movement of the tongue considered to be essential for milk removal and the application of vacuum which is believed to create a pressure gradient between the positive pressure in the milk ducts (generated by milk ejection) to refill the milk ducts in the breast [8].

The role of intra-oral negative and positive pressure in infant feeding has been based on cineradiographic studies of bottle-feeding infants. These studies showed that the infant occluded the teat with the front of the tongue and compressed the teat expressing a radio-opaque mixture of



**Figure 4** The changes in infant tongue position during one suck cycle.

**Table 1** Ultrasound measurements of the nipple, nipple hard soft palate junction distance and height of the cavity into which milk flowed during breastfeeding ( $n=20$  infants)

	Tongue up	Tongue down
N-HSPJD	6.9 ± 1.3 mm	5.2 ± 1.6 mm**
Nipple diameter	7.5 ± 0.3 mm	9.8 ± 1.2 mm*
Tongue distance		4.2 ± 1.2 mm

Ultrasound measurements made during a suck cycle. Nipple hard soft palate junction distance = N-HSPJD, Tongue distance is the distance from the hard palate to the surface of the posterior tongue \*\*denotes significance  $P < 0.01$  \* $P < 0.05$ .

formula and barium into the oral cavity. The teat then re-filled as the mandible lowered and intra-oral negative pressure decreased [7,15]. Despite the inability to demonstrate milk flow on both cineradiographic and previous ultrasound studies during breastfeeding it has been assumed that "The mechanism of breastfeeding is probably similar to bottle-feeding" [15]. Bottles and teats are remarkably different to the breast in both design and flow-rate, therefore it is not unreasonable to expect that removal of milk would be different to breastfeeding. Indeed studies measuring orofacial muscle function have shown significantly reduced masseter muscle activity in bottle-fed infants [16]. Furthermore differences in perioral muscle function between breastfed and bottle-fed infants appear to persist into the second and third year of life [17]. It is interesting to note that significant reduction in growth of the mandible has been observed in bottle-fed mice compared to those suckled by the dam [18]. These differences in oral motor function and mandibular growth are highly likely to be a response to a non-physiological feeding method, thus differences in the mechanics of milk removal during breastfeeding compared to bottle-feeding would be expected.

The importance of vacuum in milk removal from the breast is further supported by data gathered during the expression of milk using an electric breast pump. This study showed that using the mother's maximum comfortable vacuum resulted in the expression of significantly more milk than using vacuums of lower magnitude [19]. In addition the pump (using vacuum only) removed on average as much milk as the breastfeeding infant. Our results therefore lend weight to the theory of both Waller [10] and Smith et al. [20] that vacuum applied to the breast facilitates milk removal.

During this study neither milk flow nor milk ducts within the nipple were observed when the posterior tongue was squeezing the nipple or when it was in apposition with the palate. In periods of milk flow, during the application of increasing vacuum by the infant (as the tongue was lowered) the nipple expanded rendering milk ducts visible and the nipple moved closer to the hard-soft palate junction (Fig. 1C). The expansion of the nipple diameter as the tongue moved down is in contrast to the observations during studies of bottle-feeding where the teat is compressed and milk expressed [21]. The tongue movement demonstrated in this ultrasound study was not consistent with a marked peristaltic action (Fig. 3), which is in agreement with results of Smith et al. [20]. Weber et al [13] using ultrasound described a "rolling" peristaltic motion during breastfeed-

ing. They examined six infants between 2 and 6 days of age and did not measure the milk intake of the breastfeed. The discrepancy between the ages of the infants we examined may explain some differences in the tongue action. The peristaltic action is believed to strip milk from the breast [8]. Indeed some authors have speculated that positive pressure produced by the tongue and upper gum on either the base of the nipple or areola pushes milk forward into the oral cavity. This speculation is based on the ability to express milk by squeezing the breast between the thumb and fingers to elicit a jet of milk and presumes that the proximity of the jaw to the location of the milk ducts has the same effect. Ardran and Kemp [22] noted that the tip of the tongue rises slightly just before the distal part of the tongue lowers, however they are cautious about the significance of this motion stating that evidence is lacking to support compression of the milk ducts under the areola during breastfeeding. Therefore the role of the tip of the tongue in milk removal to date is speculative. A stripping motion is more feasible during bottle-feeding as the teat can be compressed and milk squeezed from the teat. This is illustrated well in premature infants who are able to express milk from a bottle without exerting vacuum [23]. However they become more efficient when they use both expression and vacuum to remove milk [24]. Furthermore premature infants may be able to feed effectively from a bottle but have difficulty removing adequate amounts of milk from the breast suggesting that there are different mechanisms of milk removal between bottle and breastfeeding [25].

The position of the nipple in the infant's mouth has been of great interest and it is widely accepted that the nipple should be in close proximity to the hard-soft palate junction for breastfeeding to be comfortable and effective [8,26]. Measurements performed on ultrasound scans showed that the nipple rarely reaches the hard-soft palate junction (Fig. 2; Table 1). These results agree with the findings of Jacobs et al. [11] although their measurements include both the tongue up and tongue down phase of the suck cycle which does not account for movement of the nipple. In addition we found that increasing vacuum was associated with shorter N-HSPJD distances and wider nipple diameter. Therefore both the peak and baseline vacuum applied by the infant may at least in part determine the position of the nipple. Should the nipple be positioned at the hard-soft palate junction the application of vacuum would cause the soft palate to descend to the tip of the nipple and effectively there would be no space for the milk to flow into the oral cavity. In addition gag sensors are present on the surface of the soft palate and if milk is ejected directly onto the soft palate the gag reflex may be stimulated [26,27]. In this respect it may be possible to position the nipple too close to the soft palate during breastfeeding. The reason why the infant places the nipple close to the hard-soft palate junction is still not clear. Some investigators have assumed that if vacuum were the only mechanism involved in the removal of milk the infant would feed by placing the nipple at the lips [15]. This assumption does not take into account the interaction of swallowing. Furthermore clinically it has been well documented that nipple pain is associated with poor positioning and attachment of the infant to the breast (not enough of the breast in the infant's mouth) [26,27]. The study of all three components of breastfeeding: sucking, swallowing and

breathing is essential to gain a complete understanding of the mechanisms of sucking during breastfeeding.

The intra-oral pressure measurements in this study were comparable to that of other studies of babies of similar age (peak vacuum  $-197 \pm 10$  mmHg [28];  $-150$  mmHg [15]). Younger infants of 4-5 days old exert lower vacuums on average (peak vacuum  $-112$  mmHg) [29] and may be due to the maturity of the infant. In this study we were unable to find a relationship between the volume of milk consumed by the infants and the intra-oral vacuum parameters measured. This suggests that other factors such as either infant appetite or the amount of milk available in the breast may indeed influence milk intake and sucking parameters. As noted previously the duration of the feed is not solely indicative of milk intake [14]. Infants applied a baseline vacuum of approximately  $-60$  mmHg over the whole breastfeed (Fig. 2). Previously baseline vacuums have not been reported in breastfeeding infants; however, similar vacuums have been described in the piglet [30]. It is likely this vacuum reflects the seal formed on the breast by the infant prior to active sucking and it is reflected in the small amount of movement of the nipple when the infant applies vacuum by the downward movement of the tongue. Furthermore this vacuum may be important in instances where infants have difficulty latching to the breast resulting in poor milk transfer. For example it would be of interest to determine if infants with ankyloglossia and pre-term infants who find it difficult to remain at the breast have low or absent baseline vacuums.

## 5. Conclusion

This study demonstrated that during breastfeeding milk flow occurred when the infant's mid-to posterior portion of the tongue was lowered and increasing vacuum was applied without accentuated peristaltic action. This suggests that vacuum plays an integral role in the removal of milk from the breast by the infant. The role of the movement of the tip of tongue in milk removal still remains speculative requiring further investigation. Furthermore a lack of baseline vacuum (the seal applied to the breast by the infant) may be important in conditions where the infant is unable to remain attached to the breast.

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## References

- [1] Winberg J. Mother and newborn baby: mutual regulation of physiology and behavior - a selective review. *Dev Psychiatry* 2005;47:217-29.
- [2] Christensson K, Siles C, Moreno L, Belaustequi A, De La Fuente P, Lagercranz H, et al. Temperature, metabolic adaptation, and crying healthy full-term newborns cared for skin-to-skin or in a cot. *Acta Paediatr* 1992;81:488-93.
- [3] Christensson K, Cabrera T, Christensson E, Uvnas-Moberg K, Winberg J. Separation distress call in the human neonate in the absence of maternal body contact. *Acta Paediatr* 1995;84:468-73.
- [4] Michelsson K, Christensson K, Rothganger H, Winberg J. Crying in separated and non-separated newborns: sound spectrographic analysis. *Acta Paediatr* 1996;85:471-5.
- [5] Labbok MH, Hendershot GE. Does breast-feeding protect against malocclusion? An analysis of the 1981 Child Health Supplement to the National Health Interview Survey. *Am J Prev Med* 1987;4:227-32.
- [6] Cooper AP. The anatomy of the breast. Longman, Orme, Green, Browne and Longmans; 1840.
- [7] Ardran GM, Kemp PH, Lind J. A cineradiographic study of bottlefeeding. *Br J Radiol* 1958;31:156-62.
- [8] Woolridge MW. The anatomy of infant sucking. *Midwifery* 1986;4:164-71.
- [9] Ramsay DT, Kent JC, Hartmann RL, Hartmann PE. The anatomy of the lactating breast redefined with ultrasound imaging. *J Anat* 2005;206:525-34.
- [10] Waller H. The force exerted by the baby. *Clinical studies in lactation*. William Heinemann Ltd; 1936.
- [11] Jacobs LA, Dickinson JE, Hart PD, Doherty DA, Faulkner SJ. Normal nipple position in term infants measured on breastfeeding ultrasound. *J Hum Lact* 2007;23:52.
- [12] Arthur PG, Hartmann PE, Smith M. Measurement of milk intake of breastfed infants. *J Pediatr Gastroenterol Nutr* 1987;6:758-63.
- [13] Weber F, Woolridge MW, Baum JD. An ultrasonographic study of the organization of sucking and swallowing by newborn infants. *Dev Med Chil Neurol* 1986;28:19-24.
- [14] Ramsay DT, Kent JC, Owens RA, Hartmann PE. Ultrasound imaging of milk ejection in the breast of lactating women. *Pediatrics* 2004;113:361-7.
- [15] Ardran GM, Kemp FH. A correlation between suckling pressures and the movements of the tongue. *Acta Paediatr* 1959;48:261-72.
- [16] Inoue N, Sakashita R, Kamegai T. Reduction of masseter muscle activity in bottle-fed babies. *Early Hum Dev* 1995;42:185-93.
- [17] Jacinto-Goncalves SR, Gavião MB, Berzin F, de Oliveriera AS, Semeguini TA. Electromyographic activity of perioral muscle in breastfed and non-breastfed children. *J Clin Pediatr Dent* 2004;29:57-62.
- [18] Oseko T, Kuroe K, Matsuo H, Utsu H, Ono H, Oshikawa S, et al. An experimental study on feeding style and development of jaws. *J Orthod* 1988;33:33-8.
- [19] Kent JC, Cregan MD, Doherty DA, Mitoulas LR, Ramsay DT, Hartmann PE. The effect of vacuum on the removal of milk using an electric breast pump. 12th International Conference of the International Society for Research in Human Milk and Lactation (ISRHML). Cambridge, UK: Queens' College; September 10 - 14, 2004.
- [20] Smith WL, Erenberg A, Nowak AJ. Imaging evaluation of the human nipple during breast-feeding. *Am J Dis Child* 1988;142:76-8.
- [21] Hayashi Y, Hoashi E, Nara T. Ultrasonographic analysis of sucking behavior of newborn infants: the driving force of sucking vacuum. *Early Hum Dev* 1997;49:33-8.
- [22] Ardran GM, Kemp PH, Lind J. A cineradiographic study of breastfeeding. *Br J Radiol* 1958;31:156-62.
- [23] Lau C, Sheena HR, Shulman RJ, Schanler RJ. Oral feeding in low birth weight infants. *J Pediatr* 1997;130:561-9.
- [24] Lau C, Kusnierczyk I. Quantitative evaluation of infant's nonnutritive and nutritive sucking. *Dysphagia* 2001;16:58-67.
- [25] Meier PP. Supporting lactation in mothers with very low birth weight infants. *Pediatr Ann* 2003;32:317-25.
- [26] Neifert MR. Breastmilk transfer: positioning, latch-on, and screening for problems in milk transfer. *Clin Obstet Gynecol* 2004;47:656-75.

- [27] Miller AJ. Oral and pharyngeal reflexes in the mammalian nervous system: their diverse range in complexity and the pivotal role of the tongue. *Crit Rev Oral Biol Med* 2002;13:409–25.
- [28] Prieto CR, Cardenas H, Salvatierra AM, Boza C, Montes CG, Croxatto HB. Sucking vacuum and its relationship to milk transfer during breastfeeding in humans. *J Reprod Fertil* 1996;108:69–74.
- [29] Mathew OP, Bhatia J. Sucking and breathing patterns during breast- and bottle-feeding term neonates. *AJDC* 1989;143:588–92.
- [30] Thexton AJ, Crompton AW, Owerkowicz T, German RZ. Correlation between intra-oral vacuums and tongue movements in the suckling pig. *Arch Oral Biol* 2004;49:567–75.