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ORIGINAL ARTICLE

Combining hand techniques with electric pumping increases milk production in mothers of preterm infants

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Objective: Pump-dependent mothers of preterm infants commonly experience insufficient production. We observed additional milk could be expressed following pumping using hand techniques. We explored the effect on production of hand expression of colostrum and hands-on pumping (HOP) of mature milk.

Study Design: A total of 67 mothers of infants <31 weeks gestation were enrolled and instructed on pumping, hand expression of colostrum and HOP. Expression records for 8 weeks and medical records were used to assess production variables.

Result: Seventy-eight percent of the mothers completed the study. Mean daily volumes (MDV) rose to 820 ml per day by week 8 and 955 ml per day in mothers who hand expressed >5 per day in the first 3 days. Week 2 and/or week 8 MDV related to hand expression ($P<0.005$), maternal age, gestational age, pumping frequency, duration, longest interval between pumpings and HOP ($P<0.003$). Mothers taught HOP increased MDV (48%) despite pumping less.

Conclusion: Mothers of preterm infants may avoid insufficient production by combining hand techniques with pumping.
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Keywords: hand expression; insufficient milk production; breastmilk; breastfeeding; lactation; preterm infants

Introduction

Many immediate and long-term benefits of breastfeeding for the preterm infant and mother depend on exclusivity and duration,[1] with the strongest determinant of both being milk production.[2–4] Insufficient production in the first 6 weeks postpartum is the most common reason for discontinuing lactation, 2.8 times more frequent in mothers of preterm than those of term infants.[5–7] Also, average milk output in mothers of preterm infants has been shown to falter after 2 to 3 weeks, decline over the next 3 weeks and consistently remain below that of mothers of term infants.[6] Mothers of preterm infants are pump dependent for months before establishing non-pump-dependent breastfeeding, making the sustained, upward trajectory of milk production over months the critical factor.[5,8]

If nutrition from breastfeeding is inadequate for the preterm infant, mothers must 'triple feed' (that is, breastfeed, bottle-feed and pump) to maintain production. This regimen likely causes the high breastfeeding attrition rates seen in mothers with low production. Volumes <500 ml per day by postpartum week 6 predict early weaning.[3] In contrast, higher volumes facilitate the transition from bottle (or tube) feeding to breastfeeding[4] by reducing the effort required for milk transfer. Thus, maximizing milk production is essential for prolonged breastfeeding.

For decades, efforts to improve production have focused primarily on pumping schedules and pump design (that is, electrical vs manual, single vs double, and vacuum patterns).[9–12] Other factors that can potentially affect establishment and maintenance of lactation include 'predetermined' and 'modifiable' variables. Predetermined variables are maternal demographics, perinatal issues and other variables inconsistently reported to affect lactation. The influence of these variables in mothers of term vs preterm infants may differ. For example, race and socioeconomic factors influence initiation rates for term infant mothers, but not for mothers who deliver prematurely and learn the protective benefits of their milk.[7] Modifiable variables are pumping initiation (time between birth and first expression), frequency and duration, and the longest interval between two pumping sessions (potential sleeping time). However, few studies have evaluated the use of manual techniques to increase milk yield and/or milk quality.[13–16]

We have observed that pump suction alone often fails to remove a significant fraction of milk as more can be expressed using manual techniques. Before mature milk 'comes in', hand expression may more effectively remove colostrum. Once volume increases, a combination of pump suction, breast compression and, if needed, hand expression—collectively referred to as 'hands-on pumping' (HOP)—may remove a greater fraction of milk than

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pump suction alone. Hypothesizing that more milk is removed using manual techniques, our objective was to use a prospective observational cohort study to determine whether the use of two manual techniques, hand expression of colostrum and HOP of mature milk, could promote establishment and sustainability of a sufficient milk supply. In addition, variables that may affect lactation in preterm infant mothers were examined.

Methods

Study population

From 2004 to 2006, a convenience sample of eligible mothers of preterm infants (<1500 g infants, <31 weeks gestation) were invited to participate in this observational study. Exclusion criteria included a moribund infant, breast surgery, substance abuse, severe maternal illness and known plans to transfer the infant to another facility. Written informed consent was obtained from all participants. The study was approved by the Stanford University Institutional Review Board.

Study design

Mothers were given a Symphony pump (Medela Inc., McHenry, IL, USA) for the duration of the study or the hospitalization of the infant—whichever was longer. Maternal perinatal information and histories were obtained through chart review, questionnaires and interviews. Mothers recorded their own milk expression information, including date, time, duration and volume removed from each breast for 8 weeks.

Hand expression and electric pumping

Participants were instructed to begin pumping within the first 6 h postpartum. During lactogenesis phase I (before the onset of copious milk production), they were instructed to 'double pump' (pump both breast simultaneously) 8 times per day for 15 min, and to hand express colostrum as frequently as possible in the first 3 postpartum days (Figure 1a). After lactogenesis II (once mature milk 'came in'), mothers were advised to pump ⩾8 times per day until they could express only drops. One investigator (JM) gave the same instruction to each participant.

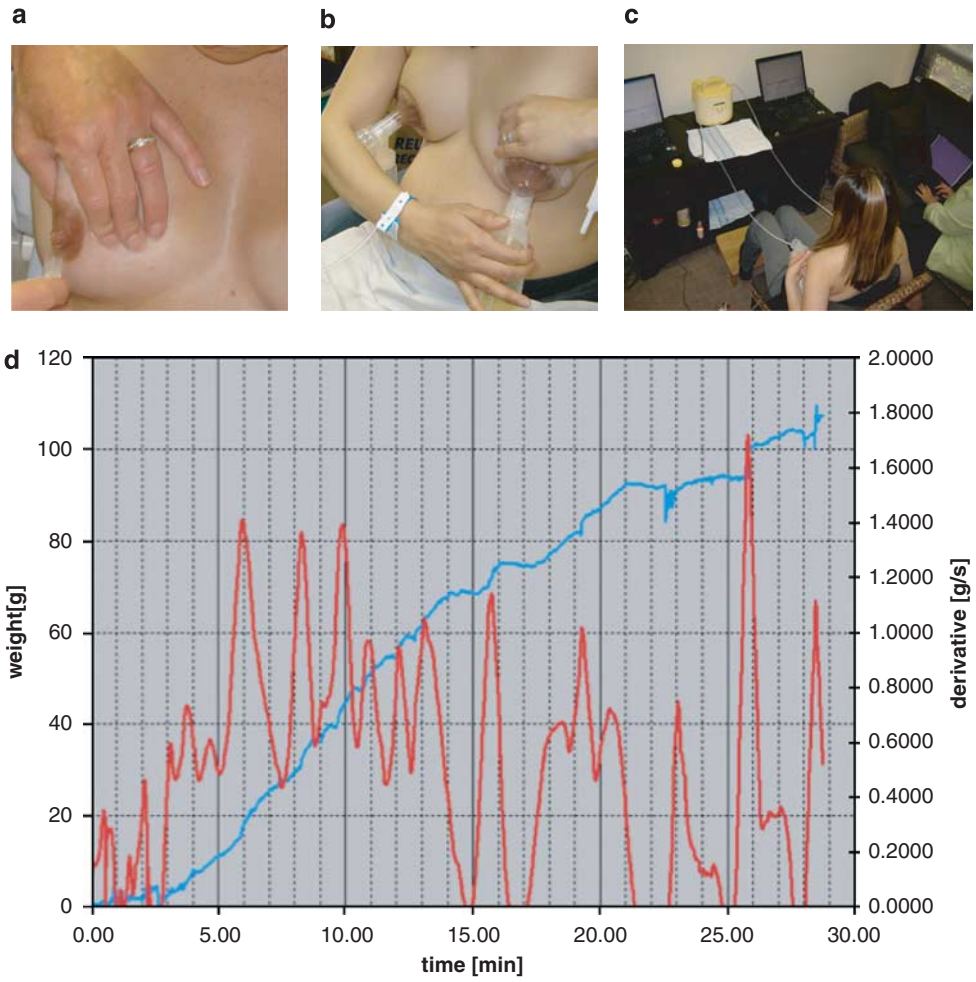

Figure 1 Manual techniques. (**a**) Hand expression of colostrum; (**b**) Hands-on pumping (HOP); (**c**) Monitored, instructional pumping sessions and (**d**) Computerized pictorial of milk expression from one breast as mother is taught HOP. Gradual ascending line represents cumulative volume; saw-toothed line depicts rate of expression over 30 min.

As the capability of the mothers varied, partners and family members were invited to learn the techniques to help with hand expression.

HOP

Once discharged mothers were capable and available for monitored, instructional pumping sessions (Figure 1b), they were invited to return to the hospital and were observed for entire pumping sessions utilizing a setup described by Ramsay *et al*.[17] Milk was collected via two tubes connecting the breast shields to bottles placed on two electric scales, which were linked to computer to record milk removal every 5 s over the entire (unlimited) expression period (Figure 1c).

During each session, mothers were advised to use the maximum comfortable vacuum and to accept only comfortable techniques. They began each session by double pumping (both breasts at the same time) with the electric pump, while simultaneously compressing their breasts and massaging firmer areas. Recommendations were given to support the breast shields to free their hands for HOP. Sprays of milk from the nipple would be observed in the tunnel of the breast shield, guiding mothers' assessment as to where and how to use their hands. Additionally, they could watch the computer screen demonstrating milk removal from each breast (Figure 1d). When milk flow stopped, double pumping was stopped and breasts were massaged briefly (1 to 2 min). Following the massage, mothers were then instructed to attempt removal of remaining available milk using whatever techniques they chose. Some mothers resumed double pumping, whereas others elected to single pump, using both hands and the pump on one breast and then the other. A few chose to complete the session using only hand expression. At home, all mothers initiated expression by double pumping as described above and then experimented with postmassage expression to find the most effective, acceptable technique(s).

Variables affecting milk production

As the variables that affect establishment of lactation may differ from those affecting maintenance, we examined predetermined and modifiable variables at both 2 and 8 weeks postpartum. Only participants who completed $\geqslant 6$ days of records for weeks 2 and 8 were included in these assessments, because of day-to-day differences in pumping variables and the inherent hazards of estimations.

Predetermined variables were (1) maternal demographics (age, education, marital status),[18] (2) perinatal issues (*in vitro* fertilization (IVF), length of gestation,[19,20] route of delivery,[21] singleton vs multiples;[3,22] and infant birthweight[23]) and (3) other variables inconsistently reported to affect lactation (maternal body mass index (BMI),[24] and previous history of breastfeeding[18]).

Modifiable variables were pumping initiation (elapse between birth and first expression), pumping frequency, pumping duration and the longest interval between two pumping sessions (potential sleeping time).

Statistical analyses

Statistical analyses were performed using SAS v9.2 Software (SAS Institute Inc., Cary, NC, USA). The factors affecting changes in milk production for an individual mother were analyzed using ANOVA and with Student's paired *t*-tests. Comparisons of milk production volumes for any given timeframe were done using unpaired *t*-tests. Pearson's correlations were used to detect potential differences in demographic status among compared groups. The level of significance was set at a $P \leqslant 0.05$. All data are expressed as mean $\pm$ s.d.

Results

Demographics

A total of 71 mothers were recruited. Three refused and one was ineligible due to breast implants. Of the 67 enrolled mothers, 52 remained in the study for the entire 8 weeks. Complete records ($\geqslant 6$ day of records for weeks 2 and 8) were available for 55 and 48 participants, respectively. Records of 19 participants were incomplete for both weeks 2 and 8. Of these, nine participants withdrew early (five infants expired, four mothers became too ill or found the study too complicated). Six withdrew later because their infants were either transferred ($n = 3$) or they discontinued pumping ($n = 3$). The remaining four mothers recorded inconsistently. To investigate whether pump-dependent mothers using HOP could reach and sustain sufficient milk production over the 8-week study, mean daily volumes (MDV) over the 3 days before HOP instruction were compared to week 8 MDV for each mother with complete pre- and postrecords. Of the 48 who participated in the monitored instructional sessions, 42 had complete records. No significant demographic differences were noted between HOP participants and participants with complete records (Supplementary Table 1).

Supplementary Table 1 shows the sample demographics for all participants (Composite Group, $n = 67$), participants with complete records for both weeks 2 and 8 ($n = 48$) and those with incomplete records ($n = 19$). Mothers with complete records were significantly older ($P < 0.001$), had more formal education ($P < 0.02$) and were more likely to have undergone IVF ($P < 0.03$).

Effect of hand expression of colostrum

Figure 2 shows the MDV for all 67 mothers (Composite Group) over the 8-week study. All mothers were taught hand expression on the first postpartum day and were instructed to use it as frequently as possible. Forty-nine reported their frequency of use in days 1 to 3. Based on the frequency of hand expression, these participants were stratified into three self-selected groups: Group I (no/low, <2 times per day, $n = 15$); Group II (medium, 2 to 5 times per day,

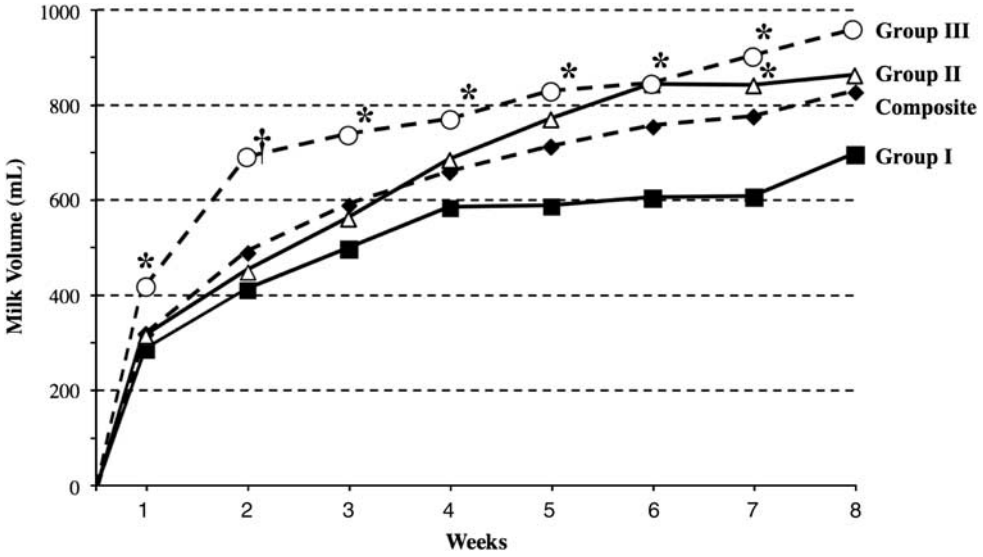

Figure 2 Mean daily volumes (MDV). MDV of expressed milk over the course of the 8-week study of three groups as defined by frequency of hand expression during the first 3 postpartum days. Group I (<2 times per day, $n = 15$), Group II (2 to 5 times per day, $n = 18$) and Group III (>5 times per day, $n = 16$) volumes are shown along with the output data of the Composite Group. Statistical comparisons using ANOVA were performed only between Groups I, II and III. $P <= 0.05$ *vs Group I, †vs Groups I and II.

Table 1 Pumping variables of participants who were stratified into three groups based on frequency of hand expression use on postpartum days 1 to 3

	Mean daily pumping frequency		*Mean daily volume; mean ± s.d. (range)*		
Group	*Day 1–3*	*Day 1–14*	*Week 2*	*Day 14*	*Week 8*
I ($n = 15$)	3.9 ± 1.3	5.9 ± 1.0	392 ± 196 (120–779)	443 ± 217 (149–791)	658 ± 267 (160–1101)
II ($n = 18$)	4.4 ± 1.6	5.9 ± 1.3	448 ± 318 (73–1448)	488 ± 352 (75–1621)	859 ± 430 (204–2005)
III ($n = 16$)	5.0 ± 1.5	6.3 ± 1.3	710 ± 402* (247–1711)	780 ± 496† (228–1958)	955 ± 667∂ (445–3160)

Group I (<2 times/day), Group II (2 to 5 times/day) and Group III (>5 times/day).
*$P<0.005$ compared to Group I and $P = 0.023$ compared to Group II, by ANOVA.
†$P<0.011$ compared to Group I and $P = 0.030$ compared to Group II, by ANOVA.
∂$P \leqslant 0.060$ compared to Groups I and II, by ANOVA.

$n = 18$) and Group III (high, >5 times per day, $n = 16$; Table 1). Group III MDV at week 1 through week 7 were statistically different from Group I. Group II MDV at week 7 were also statistically different from Group I. Week 2 and day 14 MDV were significantly different between Group III and Groups I ($P = 0.017$) and II ($P = 0.029$). By week 8, the difference in MDV of Group I compared to Groups II and III was not significant ($P = 0.060$ and 0.058, respectively). No significant demographic differences among the three groups were found. No statistical differences in mean pumping frequency in Groups I, II and III over the first 3 days postpartum or over days 1 to 14 were found ($P = 0.113$ and 0.538, respectively).

Effect of HOP

The first day of HOP instruction was given at 20.6 ± 9.6 days postpartum. MDV decreased in 3/42 mothers (7.1%). Of these, one developed mastitis, another failed to pump more than 4 times per day and a third experienced a personal tragedy. Milk production increased in 39/42 (92.9%) participants. Figure 3 demonstrates pre- and postproduction in mothers taught HOP. MDV increased 48% (583 ± 383 to 863 ± 506 ml per day, $P<0.003$) after HOP instruction. In addition, when comparing pre- and postinstruction data, Table 2 demonstrates a statistically, but not clinically, significant increase in the mean duration of pumping sessions from 23.6 to 25.5 min per session ($P = 0.035$), a significant increase of 54 min in the longest unpumped interval ($P = 0.001$) and a decrease in daily pumping frequency ($P = 0.003$). When the mean daily frequency is multiplied by the mean duration of each session, the average daily pumping time remained unchanged (153.4 to 150.4 min per day).

Effect of variables

For the 48 participants with complete records at 2 and 8 weeks, we found that of the predetermined variables selected, maternal age

was inversely associated with week 2 MDV ($P = 0.019$, Pearson's correlation $= -0.316$), but was no longer apparent by week 8 ($P = 0.511$, Pearson's correlation $= -0.097$). Gestational age was inversely associated with week 8 MDV ($R = -0.294$, $P = 0.043$). No other predetermined variables influenced MDV at 2 or 8 weeks.

Electric pumping frequency was the only modifiable variable directly associated with week 2 MDV ($P = 0.008$). However, week 8 MDV were directly associated with electric pumping frequency ($P = 0.002$), pumping session duration ($P = 0.033$) and longest interval between pumping sessions ($P < 0.01$).

High frequency pumping ($\geqslant 7$ times per day) significantly influenced MDV at 2 weeks ($P = 0.030$), but not at 8 weeks ($P = 0.170$; Figure 4).

When participants with complete and incomplete records were combined (that is, the Composite Group) at week 8, MDV rose steadily to 820 ml with 75% of mothers having >500 ml (Table 3). At this time point, there was also a slight increase in pumping session duration, but no significant change in pumping frequency or in the longest interval between any two pumping sessions.

Discussion

The most intriguing findings in this study were the following: first was the unfaltering and impressive breastmilk volume of preterm infant mothers, who are considered to be at high risk for impaired milk production; second was the finding that two practices not routinely prescribed, hand expression of colostrum and HOP expression of mature milk, may influence volume; and finally, the lack of correlation between volume and variables believed to influence production in breastfeeding mothers (type of delivery, maternal BMI, history of previous breastfeeding, multiples, IVF) suggests that these factors may be mitigated by techniques supporting effective and frequent milk removal.

Mothers of preterm infants may remain pump dependent for weeks to months before they can rely on the breastfeeding infant to maintain their supply. Yet, most reports of milk output focus only on the first month.[15,25–27] Ours is the first report of a steady increase in production over 8 weeks, which surpasses reference levels for mothers of term infants. Hill *et al*.[6] who compared output of mothers of preterm infants to that of mothers of term breastfeeding infants over a 6-week period, found a decline after 2 to 3 weeks in mothers of preterm infants with similar birth weight, gestational age and pumping frequency to those in our study. For illustrative purpose only, Figure 5 shows week 6 MDV of mothers of preterm infants in Hill's study[6] of 541 ± 450 ml with 48% >500 ml compared to week 6 MDV of our participants of 755 ± 400 ml with 70% >500 ml. Adequacy of milk output (>500 ml per day) at week 6 appears to be a predictor for extended breastfeeding of preterm infants.

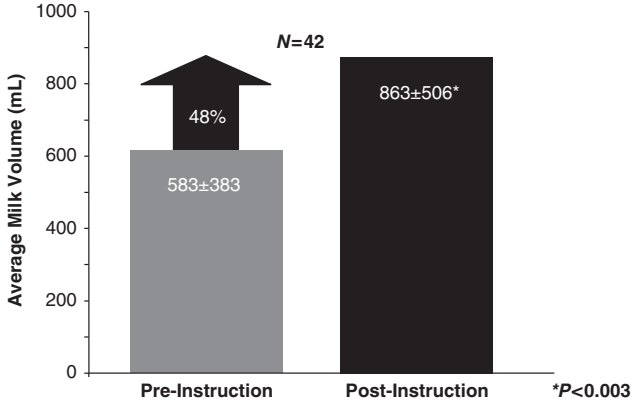

Figure 3 Mean daily volumes (MDV) pre- and postinstruction of hands-on pumping (HOP). In 42 mothers, MDV increased by 48%, comparing each mother's MDV 3 days before her first monitored pumping session (preinstruction) to week 8 (postinstruction) MDV. Data are shown as mean ± s.d. ml.

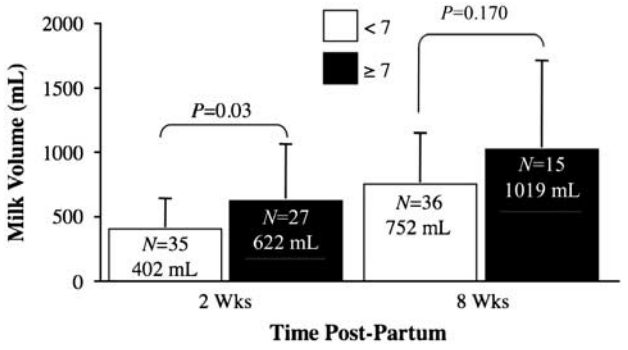

Figure 4 The effect of pumping frequency on early (2 weeks) and late (8 weeks) output. Mothers who pumped with a low frequency (<7 times per day) were compared to those who pumped with a high frequency ($\geqslant 7$ times per day). Data are shown as mean ± s.d. ml. High frequency pumping significantly influenced mean daily volumes (MDV) at 2 weeks ($P = 0.030$), but not at 8 weeks ($P = 0.170$).

Table 2 Pre- and postinstruction of hands-on pumping (HOP): four pumping variables

Variable	*3 Days before instruction*	*Days 50 to 56*	P *value*
Daily pumping frequency; mean ± s.d. (*n*)	6.5 ± 1.4 (42)	5.9 ± 1.4 (42)	0.003
Duration of each session (minute); mean ± s.d. (*n*)	23.6 ± 10.1 (38)	25.5 ± 10.0 (36)	0.035
Daily longest interval (minute); mean ± s.d. (*n*)	373 ± 126 (42)	427 ± 124 (42)	0.001
Mean daily volumes (MDV); ml per day (*n*)	583 ± 383 (42)	863 ± 506 (42)	<0.003

Table 3 Pumping variables of composite group

Postpartum week	*Daily frequency*	P *value*	*Session duration (min)*	P *value*	*Daily longest interval (min)*	P *value*	*Mothers (<500 ml per day)*	*Volume (ml per day)*	P *value*
Day 6–7 (*n*)	6.4 ± 1.6 (59)	—	21.3 ± 8.0 (43)	—	390 ± 148 (59)	—	84% (48/57)	314 ± 219 (57)	—
2	6.4 ± 1.4 (58)	0.85	22.3 ± 8.7 (45)	0.61	389 ± 128 (57)	0.97	62% (36/58)	489 ± 338 (58)	0.001
3	6.5 ± 1.4 (57)	0.62	23.0 ± 9.4 (53)	0.36	383 ± 120 (55)	0.76	47% (27/57)	591 ± 358 (57)	<0.001
4	6.4 ± 1.3 (55)	0.81	23.8 ± 8.1 (52)	0.14	395 ± 122 (54)	0.85	26% (14/54)	659 ± 332 (54)	<0.001
5	6.3 ± 1.3 (56)	0.78	25.5 ± 9.5 (50)	0.025	401 ± 119 (56)	0.67	30% (17/56)	711 ± 386 (56)	<0.001
6	6.4 ± 2.1 (54)	0.97	25.0 ± 8.8 (46)	0.046	398 ± 118 (53)	0.75	30% (16/54)	755 ± 400 (54)	<0.001
7	6.0 ± 1.5 (53)	0.23	25.2 ± 9.3 (46)	0.037	414 ± 136 (53)	0.38	28% (15/53)	776 ± 432 (53)	<0.001
8	6.0 ± 1.5 (52)	0.20	24.9 ± 9.6 (45)	0.06	427 ± 143 (52)	0.18	25% (13/52)	820 ± 480 (52)	<0.001

All comparisons were made to postpartum days 6 to 7 using Student's paired *t*-tests.
All data are shown as mean ± s.d.
Data in parentheses indicate number of participants.

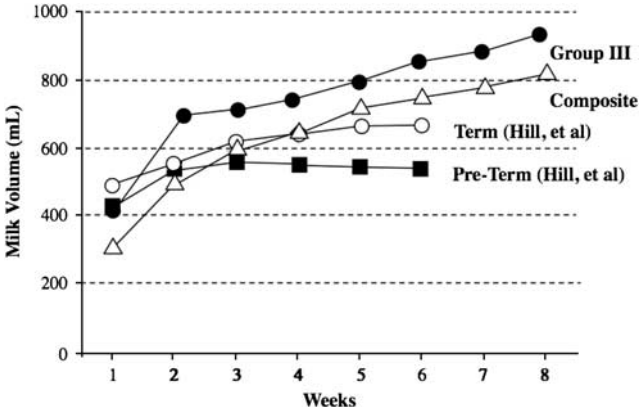

Figure 5 Comparison between milk output of mothers of term and preterm infants. Milk outputs reported by Hill *et al*.[6] were compared to those of mothers from our study (Composite Group only). The top line shows output of mothers who used hand expression >5 times per day in the first 3 postpartum days (Group III). (Adapted with permission from the *J Hum Lact*.)

In the first 3 postpartum days, mothers who used hand expression >5 times per day (Group III) had MDV of 860 ± 490 and 955 ± 667 ml at 6 and 8 weeks, respectively. These volumes exceeded the average intake (812 ml per day) reported for healthy 3-month-old breastfed term babies.[28] Our *post hoc* analysis of expressed volumes suggests that hand expression of colostrum increases milk production in the first 2 weeks and longer, depending on the frequency of use on days 1 to 3. The robust MDV in Group III mothers may reflect more frequent colostrum removal (the combination of hand expression and pumping), or, alternatively, more effective removal of colostrum with hand expression may stimulate subsequent production.

Other interventions to improve effective removal of colostrum have generally been reported to be unsuccessful. Oxytocin nasal spray administered with each pumping in the first 5 days, increased milk removal in primiparous mothers in one study,[29] but was subsequently shown to have no significant effect.[30] Primiparous mothers delivered by C-section who combine breastfeeding with pumping do not improve colostrum removal during the first 72 h, and they breastfeed for a shorter duration than mothers who only breastfeed.[31] Yet, it remains common practice to provide newly delivered breastfeeding mothers with pumps and instruction to pump frequently to augment their production.

In mothers with established production, the degree rather than the frequency of breast emptying is directly associated with short-term control of milk synthesis.[32] Previous research suggests the presence of an autocrine regulation of production with a feedback inhibitor of lactation, which appears to act locally on the apical portion of the alveolar cell to inhibit production.[33,34] Frequency of breastfeeding does not correlate with production, and by one method of calculation, infants remove an average of 63 to 72% of available breastmilk per feed.[35] In Hill's study,[6] exclusively breastfed infants between 1 and 6 weeks of age fed more frequently

than our study mothers expressed (8 vs 6 times per day). Once mature milk 'came in', by using HOP, our participants may have removed a greater percentage of milk per expression than breastfeeding mothers, permitting them to maintain higher production levels with less frequent expression. If study mothers were dependent solely on pump suction, stopping when the flow ended, available milk would have remained unexpressed.

The triple combination of external breast compression, pump suction and the milk ejection reflex possibly removes a greater fraction of milk from individual alveoli, and/or from a greater percentage of alveoli, than 'hands-off' pumping. In support of this theory, an experimental pump combining suction with a tactile compression feature increased the rate of flow and the volume of expressed milk compared to suction alone when the compression was stopped.[36] Using ultrasonography of mammary ducts during electric pumping, milk flow reversed with the abatement of the milk ejection reflex in the nonexpressed breast.[17] Breast compression during HOP may increase intramammary and intraductile pressure, thereby enhancing milk removal. The effect of seeing one's own milk output increase with HOP is reassuring and may be important, but its exact contribution to an increase in milk production was not investigated.

Of the modifiable factors we studied, the pumping frequency was important to the establishment and maintenance of lactation. Our data support the importance of frequent colostrum removal in the first 3 days.[5,20] The need to establish a lower threshold limit of pumping frequency has long been recognized.[9] Yet, a precise frequency more than five times per day has not been defined.[5,27] We found that the use of high-frequency pumping ($\geqslant 7$ times per day) was more important for establishment rather than for maintenance of lactation (Figure 4). Some mothers, once HOP was introduced, were able to maintain and increase volume despite pumping less frequently. Beyond a variable maternal threshold, increased frequency or duration of pumping may be less effective than improved emptying.

Finally, our results suggest that predetermined variables do not account for compromised production, although a larger sample size is needed to confirm this finding. The inverse correlation between gestational age and 8-week MDV may be spurious. Mothers of larger vs smaller neonatal intensive care unit infants may have failed to accurately record all the milk consumed by their breastfeeding infants as measured by pre- and post-feed weights, a potentially inaccurate method for assessing milk transfer.[37]

Acceptability of combining manual techniques with electric pumping was noted by Jones *et al*.[14] in a crossover study measuring expressed milk with and without breast massage. They found that output increased using massage and mothers initially assigned to pump with massage voiced reluctance to pump without it. In our study, when invited to comment on any aspect of participation, most participants focused on the importance of manual techniques. It was evident to participants who spoke with nonparticipant mothers of preterm babies that they had an advantage, and most attributed the difference to their use of manual techniques. Impressed by the value of hand techniques, participants volunteered to participate in educational videos to comment on their experience and demonstrate these techniques to other mothers and care providers.

The two hand techniques are demonstrated at: http://newborns.stanford.edu/Breastfeeding/ (See 'Hand Expressing Milk' and 'Maximizing Milk Production').

Limitations

Interpretation of our date may be limited due to several factors: our expertise in HOP instruction, the lack of a control group, a single hospital-based population with a high level of education and lack of ethnic diversity. At our institution, it was not feasible to randomize instruction because hand expression is commonly practiced. The beneficial influence of two manual techniques, hand expression of colostrum and HOP in mothers with established production, requires confirmation in larger, appropriately controlled studies. Additionally, the attention our participants received make it questionable whether similar results could be achieved in non-study mothers. A randomized study would eliminate this concern with intent-to-treat analysis.

We surmise that HOP may be more advantageous if initiated earlier, as soon as a mother can visualize sprays of milk in the collecting system to guide her hand usage. Additionally, the wide range of duration of expression in this study from 15 to 45 min, averaging 25 min, suggests that specifying a time frame for pumping duration for any mother, as mentioned by Kent *et al*.,[38] could negatively impact volume.

Conclusion

Although a larger, prospective, randomized, controlled trial is needed to validate the observed benefits of manual techniques in mothers of preterm infants, other pump-dependent mothers and mothers otherwise at risk for insufficient milk production, our results clearly suggest that mothers of preterm infants can attain and sustain high production levels by combining the use of electrical pumps with manual techniques, such as hand expression and HOP. We propose that increased milk production may result from more effective breast emptying rather than increasing the frequency or duration of pumping sessions. Although the availability and use of high quality pumps are important, we speculate that reliance on electrical pumping alone may compromise milk production potential in pump-dependent mothers. Studies measuring the effectiveness of pumps in milk removal should factor in the use of manual techniques.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

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Supplementary Information accompanies the paper on the Journal of Perinatology website (http://www.nature.com/jp)