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Abstract

The objective of this study was to compare the efficacy of a mini-electric pump (MEP) and a novel manual breast pump (MP) designed to operate more physiologically. Sixty term breastfeeding mothers used the MP and MEP in randomized order 8 weeks postpartum, expressing for 10 minutes from each breast. Milk volume, fat content, and pattern of milk flow were measured. Mothers rated pump characteristics by questionnaire. There was no significant difference in the milk volume or fat content when mothers used the pumps in randomized order. The MP was rated significantly better overall and more comfortable and pleasant to use. Significantly more mothers kept the MP than the MEP. Despite the greater complexity and expense of the MEP, the pumps showed similar efficacy. The MP was preferred by mothers. The novel, more physiological operation of the MP represents an advance in milk expression technology.

Keywords: breast milk expression, breast pumps, manual, electric

Breast pumps have been in existence for decades. All pumps to date, whether manual, battery, or electric, operate by simple suction. The suction does not mimic the physiology of infant feeding, since during normal breastfeeding the infant compresses the breast beyond the areola, and only minimal suction is needed to empty the milk ducts of milk that has been forced forward by the infant's compressing action. The new ISIS pump (Canon Avent, Glemsford, Suffolk, UK) is a manual breast pump that has petal massage cushions designed to simulate the infant's compressive action on the areola during normal breastfeeding. This more physiological action is expected to result in a more efficient letdown reflex and improved milk flow. Initial unpublished manufacturer's data from mothers of 148 term infants showed that compared with their existing breast pump (a number of different models,

principally other manual pumps), the ISIS pump resulted in the mother obtaining around one-third more milk in one-third less time. The ISIS pump also scored significantly higher on a scale of consumer preference.

The large electric pumps (e.g., Egnell Ameda) are regarded as the gold standard and are used in most maternity units in the United Kingdom. Such pumps also have an established role in neonatal units for mothers wishing to provide expressed breast milk for preterm infants that are too immature to breastfeed. In a large parallel study with mothers of preterm infants, we showed that the same manual pump used in this study was at least as effective as the much more expensive large electric pump and, indeed, was preferred by mothers.¹

The purpose of the current study, in mothers of term infants, was to assess the efficacy of the novel manual pump in the postneonatal period when mothers were in established lactation. At this stage, many mothers choose to express milk to enable their infant to have breast milk when they are unavailable—for example, while they are at work. These mothers may purchase one of the manual or battery pumps that are small and therefore portable. Five previous studies with mothers of term infants have compared different methods of breast expression²⁻⁶ and have shown that the chosen method can influence both the volume and composition of milk obtained. In general, the best response (both volume of milk and composition) has been reported when an electric pump is used.

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This study was designed to test the hypothesis that the volume of milk expressed by mothers in a fixed 20-minute period using the novel manual pump would be greater than that produced by mothers using a mini-electric breast pump (MEP), which would generally be regarded as superior to a manual pump (MP) based on previous comparative studies.^{2,6} A subsidiary hypothesis was that the amount of fat produced in 20 minutes would be greater with the MP due to either an increase in the total volume of milk produced or an increase in the proportion of hind milk expressed.

Method

The study was conducted in Cambridge (UK) between August 1998 and January 2000. Mothers delivering term infants (37 weeks gestation or above) were approached with regard to participation in the study while on the postnatal wards at the Rosie Maternity Hospital. If they agreed, they were contacted at home when their infant was approximately 6 weeks old. Once consent had been obtained, the order for use of the two breast pumps (Avent ISIS and Medela mini-electric powered from the domestic electricity supply) was determined by randomization. Assignments were held in sealed opaque envelopes, and randomization was in permuted blocks of randomized length.

Each pump was tested on a single occasion during mid to late morning, when the infant was approximately 8 weeks old. The mother was given each pump 48 hours before the measurements were to be made to enable her to become familiar with its function. The second pump was tested 2 to 3 days after the first. The mother was asked to use each pump for a set 20-minute period, pumping for 10 minutes on each side, in the presence of the two research staff members. During the investigation, milk was expressed in the normal manner but collected via thin tubing into preweighed sterile bottles at 1-minute intervals. The collection procedure did not interfere with the mother's use of the pump. The following measurements were made on each occasion: (1) total volume (weight) of milk produced from each breast, (2) weight of milk produced in each 1-minute period (to examine the pattern of milk flow), and (3) creatocrit at 1-minute intervals (in a capillary tube) for estimation of fat content. Capillary tubes were centrifuged for 15 minutes, and the cream layer was read with vernier callipers to the nearest .05 mm and expressed as a

percentage of the length of milk in the column, as described previously.⁷ Apart from these small samples, milk was retained by the mother to use for her infant.

Each mother completed a questionnaire for both pumps, scoring on an analog scale between 1 (best) and 7 (worst) for five consumer characteristics (ease of use, adequacy of suction, comfort, pleasant to use, and overall opinion of pump). On this scale, a score of 4 represented a neutral opinion, 5 to 7 represented worse than neutral, and 1 to 3 represented better than neutral. After the study, the mother could keep one pump; her choice was recorded.

Additional information was collected from each mother, including details about the pregnancy and delivery, previous children, previous experience of breastfeeding, use of breast pumps (both with previous children and with the current infant), and information (obtained orally) about the infant's feeding pattern over the 24 hours prior to the measurement (including time and duration of last feed).

Sample Size

Sample size was calculated based on unpublished manufacturer's data from 64 women who expressed using the ISIS pump and their own breast pump for 30 minutes each. The mean difference in volume of milk expressed with the two pumps was 0.77 ± 1.05 oz (more with the ISIS pump). In the current study, 60 participants would therefore enable a difference of around 0.5 oz to be detected between pumps with 80% power at 5% significance.

Statistics

Creatocrit values were converted to fat content using the following formula: $\text{fat(g/l)} = \text{crematocrit (\%)} - .59/1.146$.⁷ The weight of milk and creatocrit of milk produced by each participant using the two pumps were compared by paired *t* test or Wilcoxon signed rank test. Comparisons of total weight and final creatocrit of milk produced during the first and second tests according to the pump used were made by unpaired *t* test. The patterns of milk flow and creatocrit with each pump over each 10-minute period were compared by repeated-measures analysis of variance. Questionnaire scores for the two pumps for each participant were compared by Wilcoxon signed rank test.

Table 1. Mean Weight and Fat Content of Milk Expressed at 1-Minute Intervals by Mothers Using the Manual Pump (MP) Compared With the Mini-Electric Pump (MEP)*

	Weight of Milk, g		Fat, g/dl	
	MP $\bar{x} \pm SD$	MEP $\bar{x} \pm SD$	MP $\bar{x} \pm SD$	MEP $\bar{x} \pm SD$
Side one				
1 minute	20.1 ± 6.2	20.6 ± 5.8	2.27 ± 1.65	1.92 ± 1.31
2 minutes	29.1 ± 13.0	30.6 ± 13.9	2.54 ± 1.51	2.34 ± 1.03
3 minutes	41.2 ± 20.9	41.7 ± 20.5	3.16 ± 1.65	3.09 ± 1.10
4 minutes	51.3 ± 26.0	51.8 ± 26.1	3.5 ± 1.65	3.84 ± 1.45
5 minutes	59.7 ± 30.9	60.1 ± 30.8	4.18 ± 1.79	4.39 ± 1.79
6 minutes	64.8 ± 32.2	67.1 ± 34.7	4.94 ± 1.65	5.08 ± 1.99
7 minutes	71.9 ± 33.6	72.8 ± 38.4	5.14 ± 1.86	5.55 ± 2.06
8 minutes	75.5 ± 35.5	76.3 ± 42.1	5.49 ± 1.92	5.83 ± 1.99
9 minutes	79.9 ± 36.7	79.5 ± 42.2	5.76 ± 2.06	5.69 ± 2.20
10 minutes	81.7 ± 39.8	80.5 ± 45.3	6.03 ± 2.27	6.03 ± 2.06
Side two				
1 minute	19.9 ± 4.5	21.4 ± 5.7	4.46 ± 1.65	3.57 ± 1.58
2 minutes	25.4 ± 8.5	27.8 ± 10.5	4.18 ± 1.79	3.77 ± 1.79
3 minutes	32.4 ± 13.2	35.2 ± 16.0	4.18 ± 1.86	3.64 ± 1.79
4 minutes	40.6 ± 20.1	44.4 ± 21.7	4.53 ± 1.92	3.91 ± 1.86
5 minutes	46.3 ± 23.7	50.8 ± 27.4	5.08 ± 3.16	4.53 ± 2.06
6 minutes	52.3 ± 27.7	56.4 ± 31.5	5.28 ± 3.5	5.08 ± 2.13
7 minutes	57.6 ± 29.8	61.0 ± 33.2	5.83 ± 3.57	5.62 ± 2.20
8 minutes	61.6 ± 32.7	64.9 ± 35.4	5.69 ± 3.43	5.62 ± 2.40
9 minutes	65.4 ± 36.1	67.8 ± 36.6	6.17 ± 4.12	6.10 ± 2.35
10 minutes	68.0 ± 38.2	69.9 ± 38.3	6.65 ± 3.98	6.51 ± 1.99

*Weights are cumulative; fat content is given for each separate 1-minute interval.

Results

Sixty mothers were recruited, and 58 successfully completed tests using both pumps. Their mean age was 32 ± 5 years. Of the mothers, 71% were social class 1 or 2 (the two highest social classes), 70% had a degree or higher professional qualification, 58% were primiparous (28% had one other child, 8% had two, 3% three, and 2% four), 38% had breastfed at least one previous child, and 60% (36) had used a breast pump before. Thirty-two mothers were randomized to use the MP first and 28 the MEP first.

Paired Results From Each Mother Using the MP and the MEP

The total weight of milk produced when using the MP (regardless of order) was not significantly different from that produced using the MEP (144 ± 64 g vs. 146 ± 65 g). The mean weight and fat content of milk produced at 1-minute intervals using the MP and the MEP are shown in Table 1; differences were not significant. The same

Table 2. Mean Weight of Milk (g) Expressed by Mothers Using the Manual Pump or the Mini-Electric Pump According to Order

	Manual $\bar{x} \pm SD$	Mini-Electric $\bar{x} \pm SD$
First pump		
Side one*	81.4 ± 43.2	68.5 ± 37.4
Side two	59.9 ± 33.6	51.3 ± 27.5
Total	142 ± 60	118 ± 44
Second pump		
Side one	80.7 ± 37.9	93.2 ± 49.5
Side two	66.1 ± 43.5	72.3 ± 43.0
Total	149 ± 71	164 ± 73

*Significant difference between pumps, $P = .008$.

pattern of increasing fat content during the course of the pumping session was seen with both pumps. Results were the same for mothers with and without previous experience with a breast pump.

Unpaired Results From First and Second Pumps According to Which Pump Was Used

When the MP was assigned as the first pump, there was a trend toward higher milk production (142 ± 60 g vs. 118 ± 44 g for MP and MEP, respectively). However, when the MP was assigned as the second pump, mothers produced slightly less milk (149 ± 71 g vs. 164 ± 73 g for MP and MEP, respectively). Results for the individual sides are given in Table 2. The *pattern* of milk production over each 10-minute period was compared (by repeated-measures analysis of variance). For the first pump and first breast expressed, milk flow was significantly greater in mothers using the MP rather than the MEP ($P = .008$), but there were no significant differences for the second breast, or for either breast using the second pump (Figure 1).

The weight of milk produced using the second pump, irrespective of pump type, was significantly higher than using the first pump (158 ± 72 g vs. 133 ± 54 g, respectively; $P = .008$). The peak fat content reached was not significantly different between the first and second pumps.

Effect of Breastfeeding Pattern Prior to Test

There were no significant differences in the number of hours since the last feed prior to using the MP or the MEP (1.8 ± 1.0 hours for both), the number of feeds in the 24 hours preceding each test (8 ± 3 feeds for both), or

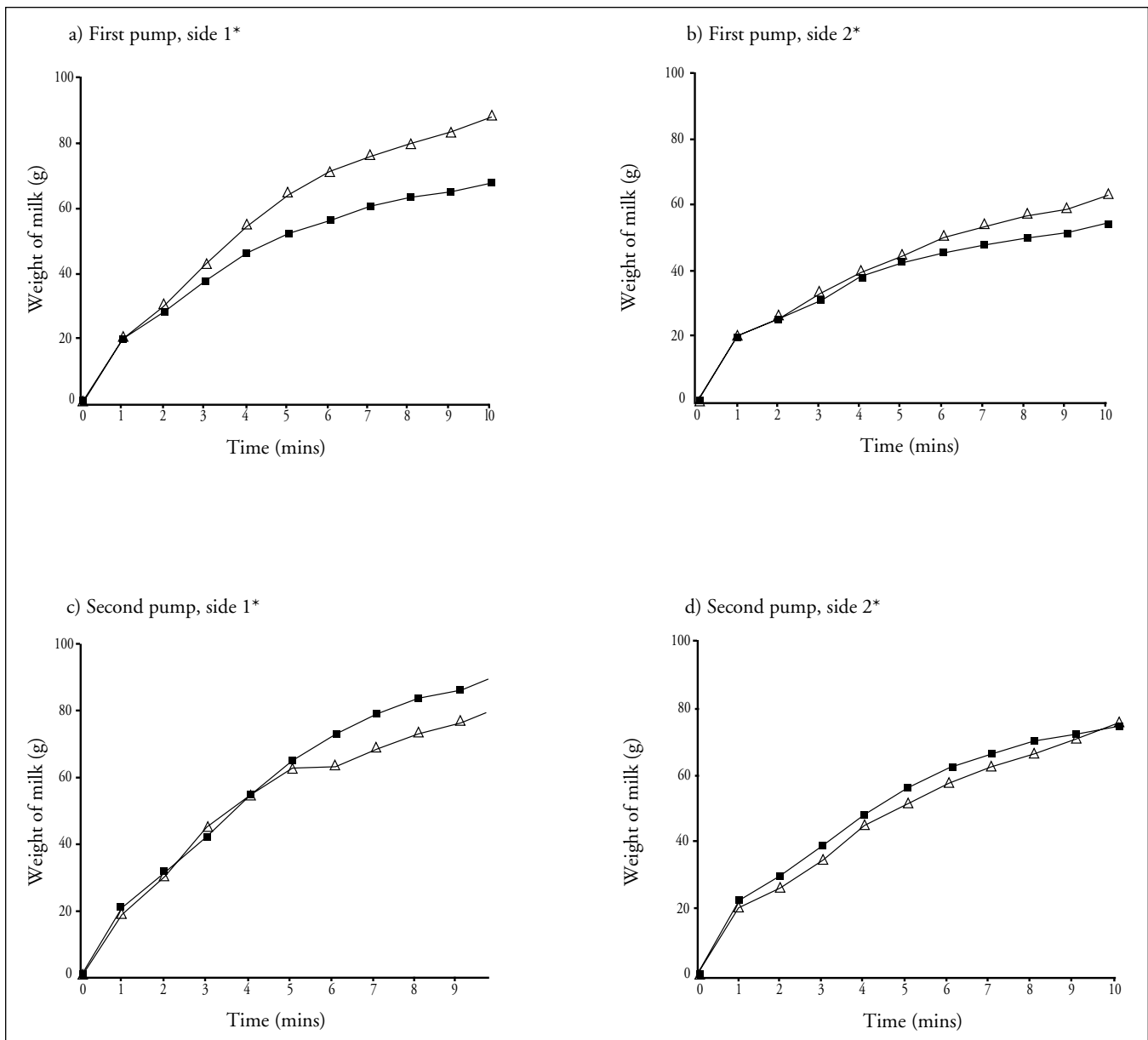


Figure 1. Weight of milk expressed over a 10-minute period according to pump used.

*Open triangle=manual pump, filled square=mini-electric pump.

the duration of the last breast feed (19 ± 16 minutes for the MP vs. 15 ± 11 minutes for the MEP).

The total amount of milk expressed during the first pumping session was significantly affected by the time since the start of the last breastfeed (increase of 23 ml [95% confidence interval = 9 to 38] per hour since last feed). The peak fat content of milk produced during both pumping sessions was also affected by the time since the start of the last feed (decrease of 0.83 g/dl per hour since last feed for first pump and 0.28 g/dl per hour since last feed for second pump). The duration of the last feed and the total number of feeds in the preceding 24 hours did not influence the amount or the fat content of expressed milk.

Maternal Opinions of Pumps

Questionnaire results are shown in Table 3. Mothers awarded significantly higher scores for the MP than the MEP for the categories of “comfort,” “pleasant to use,” and “overall opinion of pump.” Thirty-seven mothers (64%) chose to keep the MP, and 21 (36%) chose to keep the MEP ($P = 0.49$). Two mothers did not keep either pump.

Discussion

The novel MP and the MEP showed similar efficacy when used by mothers of term infants over a fixed 20-minute period at 8 weeks postpartum. There was evidence of

Table 3. Questionnaire Results

Rank†	1	2	3	4	5	6	7
	n (%)						
Easy to use							
Manual	18 (30)	20 (33)	9 (15)	9 (15)	2 (5)		
Mini-Electric	23 (38)	16 (27)	9 (15)	11 (18)		1 (2)	
Amount of suction							
Manual	19 (32)	21 (35)	11 (18)	6 (10)	1 (2)	1 (2)	
Mini-Electric	29 (48)	14 (23)	6 (10)	6 (10)	2 (3)	3 (5)	
Comfortable to use							
Manual**	27 (45)	17 (28)	8 (13)	5 (8)	2 (3)		
Mini-Electric	3 (5)	9 (15)	9 (15)	27 (45)	7 (12)	4 (7)	1 (2)
Pleasant to use							
Manual**	23 (38)	12 (20)	9 (15)	10 (17)	4 (7)	1 (2)	
Mini-Electric	2 (3)	10 (17)	9 (15)	20 (33)	14 (23)	2 (3)	3 (5)
Overall opinion							
Manual*	19 (32)	22 (37)	12 (20)	5 (8)	1 (2)		
Mini-Electric	4 (7)	21 (35)	18 (30)	10 (17)	6 (10)	1 (2)	

†1 = best score, 7 = worst score.

* $P = .001$, ** $P < .001$ (Wilcoxon signed rank test for manual pump vs. mini-electric pump).

greater milk flow for the first breast expressed when the first pump was the MP, which might indicate that the MP is more rapidly mastered than the MEP, or that it worked more efficiently under the novel and presumably stressful situation of the test. However, no such effect was present for the second breast expressed, or for the second pump. The fat content of milk expressed using both pumps was similar. Mothers awarded the MP significantly better scores overall and for the categories of "comfort" and "pleasant to use."

Four previous studies have investigated different methods of milk expression in mothers of term infants. Garza and colleague³ compared single-breast expression with the Egnell pump to hand expression in 11 mothers and found significantly greater volumes of milk were obtained using the Egnell pump, with a 25% higher fat content. Green and colleagues⁴ compared hand expression to expression using three pumps (Egnell electric, Loyd B [a trigger-handled hand pump], and the Evenflo [a bulb-operated hand pump]) in 6 women. Significantly more milk was obtained using the Egnell pump than with any other method, although the fat content of the milk did not vary. Boutte and colleagues⁵ compared the Egnell electric pump with the Medela hand pump (a cylinder-operated pump) in 10 mothers and found that milk expressed using the electric pump had a significantly higher energy content. In addition, the variance of fat and energy content was greater in milk produced using the hand pump. Finally, Zinaman and

colleagues⁶ compared the hormonal response to breastfeeding, hand expression, and expression using three types of breast pump (White River electric, Gentle Expression manual, and Medela Manualelectric) in 23 women on consecutive days. The electric pump most closely reproduced the prolactin response seen during a normal breastfeed, and mothers produced the highest volumes of milk using the electric pump compared with any other method of expression. These studies have collectively suggested that electric pumps are more efficient at removing breast milk and that they may favorably influence the composition of the expressed milk. It is therefore interesting that our study is the first to show that a manual pump performs as well as an electric one. It is possible that this reflects the novel physiological operation of the manual pump.

The MP received significantly better (lower) scores than the MEP on three of the five consumer characteristics (comfort, pleasant to use, and overall opinion of pump), and significantly more mothers elected to keep the MP. Four times as many mothers gave the MP the top two scores for comfort compared with the MEP (73% vs. 20%), and almost three times as many awarded these scores for the category "pleasant to use" (58% vs. 20%). Conversely, taking scores above 4 as representing, to some degree, a negative experience, only 3% of mothers rated the MP in this category for "comfort" compared with 21% for the MEP, and only 9% of mothers awarded the MP a negative rating for the

category “pleasant to use” compared with 31% for the MEP. It is interesting in this respect that although mothers generally report breastfeeding to be a pleasant experience, most mothers do not feel the same about mechanical milk expression. The possibility that the better scores awarded to the MP for the “comfort” and “pleasant to use” categories reflects differences in the underlying physiology of milk expression—for example, greater oxytocin release—requires further investigation. Zinaman and colleagues⁶ failed to find differences in plasma oxytocin in mothers using different modes of milk expression, but these investigators used spot plasma samples at 10-minute intervals (and may therefore have missed real differences in oxytocin, which is notoriously labile), and, in any case, none of the pumps in that study incorporated the novel design principles of the manual pump used here.

An additional factor not specifically addressed by our study but relevant to a mother’s choice of breast pump if she is going to express milk outside the home is that of noise; the MEP would make it more difficult to express discretely in a quiet environment. Moreover, the MP avoids the problem of dead batteries or the need to locate an electrical outlet.

The time since the start of the last breastfeed was found to affect both the amount of milk and the fat content of milk expressed; the volume of milk expressed increased and the fat content decreased as the time since the last feed increased. However, there was no significant difference within individual mothers in the time since the last feed prior to using the MP or the MEP, and this factor is unlikely to have confounded the results. Nevertheless, the data we provide on the effect of time interval from the last breastfeed on milk volume and fat content obtained during milk expression may prove

helpful in attempts to optimize the quality and quantity of expressed milk.

In summary, the novel manual pump was preferred by mothers, and our results demonstrate for the first time that an inexpensive MP can be designed to achieve the same efficacy as an MEP? Furthermore, work is needed to explore the physiological and psychological bases for the effects observed—for instance, the markedly higher proportion of mothers who found that using the MP was a positively pleasant experience. Our findings suggest that the novel principles incorporated in the design of the MP studied here may represent a significant advance in the technology of human milk expression.

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