result which indicated that there was a high milk yield from one breast and a low yield from the other was doubtful, and in such cases further investigation is necessary before deciding the best method of feeding the infant.

The influence of the stage of lactation upon the chloride content of women's milk is discussed.

REFERENCES


PART 4: RESULTS AND THEIR RELATIONSHIP TO MILK YIELD AND TO DURATION OF LACTATION

BY

R. A. MILLER and I. I. A. JACKSON

It has been shown that the estimation of electrical conductivity and chloride content of women's milk are of equal value as methods of determining the adequacy of lactation. It is evident that these tests would prove of practical value if it were shown that the electrical conductivity or chloride content of milk from one breast could be correlated with the daily milk yield from that breast, and similarly if these tests when performed on milk taken from women in the first month of lactation were shown to give some indication of the length of time these women would breast-feed their infants. This paper deals with the investigation of these two problems.

Daily Milk Yield from One Breast Correlated with Electrical Conductivity and Chloride Content

For the correlation of the daily yield from one breast with the electrical conductivity and chloride content of the milk a series of observations was made on women who were breast-feeding their infants. The mothers who were subjected to the investigation were apparently healthy and had infants who fixed well on the breast. Each had been lactating from between two weeks to five months. Forty-nine mothers in the first month of lactation and 61 mothers in the second to fifth month of lactation were tested. The amount of milk secreted by one breast in a day was measured by weighing the infant before and after it was put to that breast. The residual milk was not expressed and measured because this could not be supervised or performed skilfully by every woman who was examined. Every specimen used for conductivity and chloride tests consisted of approximately 4 ml. of milk. One specimen was taken before the early morning feed, one before the mid-day feed, and one before the evening feed, and each was taken on the day that the baby was test-weighed.

Results

The average daily milk yield for one breast for women secreting milk of a particular electrical conductivity is shown in Table 1A.

The minimum yield was 0.5 oz. when the conductivity of the milk was 371 to 390 × 10⁻⁵ ohm⁻¹ cm⁻¹, the maximum yield was 13.1 oz. with a conductivity of 170 to 190 × 10⁻⁵ ohm⁻¹ cm⁻¹. From Table 1A it is apparent that there is an inverse

<table>
<thead>
<tr>
<th>Group</th>
<th>Milk Conductivity (×10⁻⁵ ohm⁻¹ cm⁻¹)</th>
<th>Average Milk Volume (oz. per day)</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>170-190</td>
<td>13·1</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>191-210</td>
<td>10·0</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>211-230</td>
<td>7·8</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>231-250</td>
<td>6·3</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>251-270</td>
<td>6·75</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>271-290</td>
<td>5·4</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>291-310</td>
<td>4·3</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>311-330</td>
<td>1·75</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>331-350</td>
<td>2·25</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>351-370</td>
<td>0·5</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>371-390</td>
<td>0·5</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 1A

RELATIONSHIP OF THE MEAN ELECTRICAL CONDUCTIVITY VALUE OF MILK FROM ONE BREAST TO THE DAILY YIELD FROM THE SAME BREAST
relationship between the average milk yield and the electrical conductivity of the milk. It has, however, been shown that the milk volume of individual feeds does not bear a significant relationship to the electrical conductivity of the milk taken at the beginning of that feed (Miller, 1949). The milk yields of individual women who constitute any one group may differ markedly from each other. This variation in milk yield for women secreting milk of a given electrical conductivity value is well shown in Fig. 1a. In this figure the volume of milk obtained from one breast in one day has been plotted against the mean electrical conductivity value of that milk. The daily milk volumes range from 0·4 to 20 oz. per day and the mean conductivity values of milk from 164 to 540 × 10⁻⁵ ohm⁻¹ cm⁻¹. The variation in milk yield between women secreting milk of a given conductivity value differs in extent; this variation is negligible when the conductivity value is in the region of 540 × 10⁻⁵ ohm⁻¹ cm⁻¹, but becomes progressively greater as the conductivity value diminishes, the maximum variation amounting to 20 oz. when women secrete milk with a conductivity of 171 × 10⁻⁵ ohm⁻¹ cm⁻¹. Therefore, this method of investigation does not form a reliable method of determining the milk yield of individual women.

The comparison of milk volume with the chloride content of that milk has been made. The average daily milk yields for women secreting milk with particular percentages of chloride are given in Table 1B, the minimum yield being 1·3 oz. per day plotted against the mean chloride value of the milk from the same breast. The milk volumes range from 0·5 to 24 oz. per day and the mean chloride values of milk from 40 to 199 mg. %. The conclusion drawn from the results as presented in Table 1B is that there is an inverse relationship between average milk yield and the chloride content of milk. That obtained from Fig. 1b is that milk yield from women secreting milk of a particular chloride content can vary considerably.

### Discussion

Important deductions can be made, however, from this investigation; when the electrical conductivity of milk is at least 280 × 10⁻⁵ ohm⁻¹ cm⁻¹ or the chloride content of milk is 110 mg. % or more, it is almost certain that the daily milk yield from the breast will not exceed 6 oz. If both breasts have the same functional capacity, the quantity will be inadequate for a normal infant. Secondly, if the electrical conductivity of milk is 260 to 220 × 10⁻⁵ ohm⁻¹ cm⁻¹ or the chloride content of milk is 90 to 70 mg. % during the neonatal period, the daily milk yield from one breast is likely to be 6·3 to 8·35 oz.; therefore, from two breasts it may be 12·5 to 17 oz., and this quantity is usually sufficient for infants 2 to 3 weeks old. Thirdly, mothers in the second to fifth month of lactation must have milk with an electrical conductivity not greater than 200 × 10⁻⁵ ohm⁻¹ cm⁻¹ or 60 mg. % of chloride if their infants are to obtain the amount necessary to maintain their health and normal development.

The estimation of either electrical conductivity or chloride content is valuable if the result is relatively high, i.e. an electrical conductivity over 210 × 10⁻⁵ ohm⁻¹ cm⁻¹ or chloride value over 60 mg. %, but when the electrical conductivity values are less than 210 × 10⁻⁵ ohm⁻¹ cm⁻¹ or chloride values less than 60 mg. %, their significance is sometimes doubtful because the variation in milk yield which accompanies such values is very great and amounts to 20 oz. There are at least two reasons for this great variation in milk yield. The first and most probable explanation is that in almost a third of the cases with relatively low conductivity and chloride values the demand made upon the breast was not great, because the infants suckled were under a month old (values 0 in Figs. 1a and 1b). In such cases, the relatively low quantity of milk obtained almost certainly reflected the demands of the infant rather than the potentialities of the breast. Low milk yields accompanying milk with low conductivity and chloride values may also be due to hypoplasia or to a hypogalactic type of breast. In the present series of observations this condition was diagnosed
COMPARISON OF MILK VOLUME FROM ONE BREAST IN ONE DAY WITH THE MEAN VALUE FOR ELECTRICAL CONDUCTIVITY OF THE MILK TAKEN ON THE SAME DAY

○ = MILK TAKEN IN FIRST MONTH OF LACTATION
× = MILK TAKEN IN 2nd-5th MONTH OF LACTATION

Fig. 1a.

COMPARISON OF MILK VOLUME FROM ONE BREAST IN ONE DAY WITH THE MEAN CHLORIDE VALUE OF THE MILK TAKEN ON THE SAME DAY

○ = MILK TAKEN IN FIRST MONTH OF LACTATION
× = MILK TAKEN IN 2nd-5th MONTH OF LACTATION

Fig. 1b.
in 4% of the women when the electrical conductivity measurement of their milk was compared with their milk yield and in 12% when the chloride content of their milk was compared with their daily milk yield. In each case the milk specimen was taken from a woman in the second to fifth month of lactation, and the milk yield from each of the affected breasts did not exceed 7 oz. though the conductivity or chloride value of that milk was relatively low. It is, therefore, apparent that such cases will be a source of error when interpreting the significance of the electrical conductivity and chloride values of milk in relation to milk yield.

**Relationship of Duration to Electrical Conductivity and Chloride Content in the First Month of Lactation**

The electrical conductivity and chloride values of milk taken in the second to fourth week of lactation were correlated with the duration of lactation. The specimens of breast milk were obtained from 88 mothers in the second week of lactation and from 40 mothers in the third and fourth weeks of lactation. Each mother provided 4-8 ml. of milk before the 6 a.m. breast feed and a similar amount before the mid-day feed. The mean of the two conductivity values and of the two chloride values for each woman was calculated, and the duration of her lactation recorded.

**Results**

The results are divided into three groups: one for mothers with milk with a conductivity value $150 \times 10^{-5}$ to $200 \times 10^{-5}$ ohm$^{-1}$ cm.$^{-1}$; another for mothers with milk with a conductivity value $201 \times 10^{-5}$ to $250 \times 10^{-5}$ ohm$^{-1}$ cm.$^{-1}$; and a third for mothers with milk with a conductivity value $251 \times 10^{-5}$ to $300 \times 10^{-5}$ ohm$^{-1}$ cm.$^{-1}$ (Table 2A). The number of mothers in each group is given. The number of mothers in each group lactating for one, two, three, four, and five months is stated as a percentage of the total number of mothers in the group (Fig. 2a).

The conclusions drawn from Table 2A and Fig. 2a are, first, that the lower the electrical conductivity of milk in the first month of life, the more likely is a mother to breast-feed her infant for five months, and, secondly, that the largest proportion of failures to breast-feed occur in the first two months of lactation. The former statement was shown to be statistically significant by applying the $\chi^2$ test to the data. Additional information obtained from this investigation was that the 32 mothers who did not need to complement their breast feeds during the first five months of lactation had milk with a conductivity value of not more than $275 \times 10^{-5}$ ohm$^{-1}$ cm.$^{-1}$ during the second to fourth weeks of lactation, while women with a milk conductivity value about...
ELECTRICAL CONDUCTIVITY AND CHLORIDE CONTENT OF WOMEN’S MILK. IV. 333

275 × 10⁻⁵ ohm⁻¹ cm⁻¹ in the second to fourth weeks of lactation found it necessary to give complementary feeds to their infants if they breast-fed them for five months.

The results of the chloride estimations are divided into three groups: 0 to 50 mg. %; 51 to 100 mg. %; and over 100 mg. % (Table 2B). The number of mothers in each group is given. The number of mothers in each group lactating for one, two, three, four, and five months is stated as a percentage of the total number of mothers in the group (Fig. 2b).

It may be seen, first, that the lower the chloride content of the milk in the first month of life, the more likely is a mother to breast-feed her infant for five months, and, secondly, that the largest proportion of failures to breast-feed occur in the first two months of lactation. The former conclusion was shown to be statistically significant by applying the χ² test to the data.

The 32 mothers who did not need to complement their breast feeds during the first five months of lactation had a milk chloride value of not more than 110 mg. % during the second to fourth weeks of lactation. But women with a milk chloride value of more than 110 mg. % in the second to fourth weeks of lactation found it necessary to give complementary feeds to their infants if they breast-fed them for five months.

**Discussion**

When using either the electrical conductivity or chloride content of milk to predict the possible duration of lactation it is important to take into account certain abnormalities in the health of the mother which may occur during the first month of lactation and give rise to milk of either relatively high electrical conductivity (over 275 × 10⁻⁵ ohm⁻¹ cm⁻¹) or high chloride content (over 110 mg. %), because in these cases, if the abnormal condition subsides, lactation may proceed normally for five months. The first type of abnormality affected two mothers who had undergone Caesarean section. The establishment of breast feeding in these cases was delayed, partly due to the operation and partly to the fact that the babies were not put to the breast until they were 5 days old. The second type of abnormality was one involving the breasts. Here, breast feeding was interrupted in order to rest the breast for 48 hours. In one case this was because the mother had a cracked nipple, and in two other instances mastitis. In these patients the milk electrical conductivity and chloride values during the resting phase was high, but eventually lactation progressed normally. A third maternal condition, pyrexia, was associated with milk of relatively high

<p>| Table 2B |
| Correlation of Milk Chloride Values with Duration of Lactation in the First Month of Lactation |
| Milk Chloride (mg. %) | Percentage Mothers* Lactating for |</p>
<table>
<thead>
<tr>
<th>Week of Lactation</th>
<th>Number of Mothers</th>
<th>One Month</th>
<th>Two Months</th>
<th>Three Months</th>
<th>Four Months</th>
<th>Five Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>2</td>
<td>8</td>
<td>100 (8)†</td>
<td>75 (6)</td>
<td>63 (5)</td>
<td>63 (5)</td>
</tr>
<tr>
<td>51-100</td>
<td>2-4</td>
<td>7</td>
<td>100 (7)</td>
<td>86 (6)</td>
<td>75 (5)</td>
<td>72 (5)</td>
</tr>
<tr>
<td>101-150</td>
<td>2</td>
<td>25</td>
<td>71 (37)</td>
<td>47 (25)</td>
<td>43 (22)</td>
<td>33 (17)</td>
</tr>
<tr>
<td></td>
<td>3-4</td>
<td>28</td>
<td>100 (25)</td>
<td>68 (17)</td>
<td>64 (16)</td>
<td>64 (16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>61 (17)</td>
<td>29 (8)</td>
<td>25 (7)</td>
<td>14 (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>63 (5)</td>
<td>13 (1)</td>
<td>13 (1)</td>
<td>13 (1)</td>
</tr>
</tbody>
</table>

* Women in the second to fourth week of lactation, whose milk is of relatively low chloride content lactate, on the average, longer than those who have milk of a relatively high chloride content.
† Figures in brackets denote the number of mothers in the group.
conductivity and chloride content in the second to
fourth week of lactation, yet the mother so affected
lactated satisfactorily on recovering normal health.

Summary

The relationship of the electrical conductivity and
chloride content of milk to daily milk yield was
studied. Specimens of milk from apparently healthy
women during the second week to fifth months of
lactation were examined. From the results it was
apparent that an inverse relationship existed between
the average daily milk yield from one breast and
both the electrical conductivity and the chloride
content of the milk from that breast.

Low values obtained for milk were with few
exceptions associated with high milk yields, while
high values were usually accompanied by relatively
low milk yields. However, with milk chloride values
below 60 mg. % or electrical conductivity measure-
ments below $210 \times 10^{-5}$ ohm$^{-1}$ cm.$^{-1}$ the milk yield
might vary by as much as 20 oz. Therefore an
accurate assessment of milk yield in ounces by either
of these estimations was impossible. If, however,
the electrical conductivity or the chloride content
of the milk was relatively high, it was possible to
calculate the milk yield in ounces with a fair degree
of accuracy. Thus high milk values gave more
accurate information regarding milk yield than low
milk values.

In the second investigation, the electrical con-
ductivity and the chloride content of milk taken in
the second to fourth week of lactation were correlated
with the duration of lactation. One hundred and
twenty-eight cases were investigated, and the results
of both the electrical conductivity measurements
and the chloride estimations made on specimens
from each woman were correlated with the duration
of her lactation.

It was concluded from the second investigation
that the electrical conductivity or chloride content
of women's milk taken in the second to fourth week
of lactation gave an indication of the probable
duration of lactation.

The influence of the mother’s health upon both
the electrical conductivity and the chloride content
of her milk was discussed.

REFERENCES

and Composition in Relationship to the Mother’s
Ability to Breast-feed her Infant.’ Ph.D. Thesis,
Edinburgh.
The Electrical Conductivity and Chloride Content of Women's Milk: Part 4: Results and Their Relationship to Milk Yield and to Duration of Lactation

R. A. Miller and I. I. A. Jackson

Arch Dis Child 1951 26: 329-334
doi: 10.1136/adc.26.128.329

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