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Applying suggested new terminology and definitions for human milk feeding in the Alberta Pregnancy Outcomes and Nutrition (APrON) longitudinal pregnancy cohort

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Abstract

The complexity of human milk-feeding behaviours may not be captured using simpler definitions of "exclusive" and "non-exclusive" breastfeeding. New definitions have been suggested to describe variation in these behaviours more fully but have not been widely applied. We applied the new definitions to data derived from 3-day human milk-feeding diaries. Participants ($n = 1091$) recorded the number, beginning/end time, and modes of feeding of infants aged 3 months. Data were used to create six exclusive groups according to feeding mode(s): (1) human milk at-breast only; (2) human milk at-breast and human milk in a bottle; (3) human milk at-breast and infant formula in a bottle; (4) human milk at-breast and human milk and infant formula mixed in the same bottle; (5) human milk at-breast, human milk in a bottle, and infant formula in a bottle (not mixed); and (6) a bottle that sometimes contained human milk and sometimes infant formula (not mixed), never at-breast. Differences in maternal and infant characteristics were examined among groups. Fifty-seven percent fed at-breast only (Group 1). Those in Group 1 spent a similar amount of time feeding directly at-breast (median 132 (IQR 98–172) min/day) as those in Groups 2 (124 (95–158)), 3 (143 (100–190)), and 5 (114 (84–142)) ($p > 0.05$), indicating that adding bottle feeding did not always reduce the time infants were fed at-breast. Applying new suggested definitions to describe human milk-feeding behaviours from the mothers' perspective highlights the complexity of patterns used and warrants further application and research to explore impacts on health outcomes.

Key words: breastmilk feeding, human milk, infant feeding behaviour, expressed breastmilk, bottle feeding

Introduction

The ways in which researchers and health professionals describe behaviours related to providing human milk to infants have received considerable attention by experts in this field over many decades (Clavano 1982; Thulier 2010). In large studies of infant feeding practices, milk providers have often been categorized into groups such as "exclusive breastfeeding", "partial or mixed breastfeeding", "ever breastfed", and "never breastfed" (Kendall-Tackett et al. 2011; Bobrow et al. 2013; Neville et al. 2014; Chowdhury et al. 2015). This reductionist approach may serve to obscure information on how feeding patterns and subsequent outcomes differ within these groups. In 1990, Labbok and Krasovec, on behalf of the Interagency Group for Action of Breastfeeding (IGAB), outlined a framework for defining feeding human milk to infants in the hope that it would assist researchers and agencies to better describe and interpret the complexity of human milk-feeding practices from the point of view of the milk provider (Labbok and Krasovec 1990). In 2008, the World Health Organization (WHO) also published their, widely used, definitions of breastfeeding behaviours, which focus on infant nutrition (i.e., the milk receiver) rather than the behaviour of the milk provider (World Health Organization (Department of Child and Adolescent Health and Development) 2008). Rasmussen et al. (2017) and Boies (2017) have since noted that the methods used to feed human milk to infants have evolved over time, and that the WHO and IGAB frameworks lack reference to the specific mode by which human milk is delivered to infants, making it difficult to differentiate between feeding milk from the breast directly and feeding expressed human milk from a bottle (Rasmussen et al. 2017), the latter becoming an increasingly popular method for providing human milk to infants (Labiner-Wolfe et al. 2008; Clemons and Amir 2010; Boies 2017; Rasmussen et al. 2017). Such an omission could blur our understanding of the impact of these different modes of feeding human milk on infant outcomes such as cognitive development (Quigley et al. 2012), gut microbiome composition (Fasano 2018), development of asthma (Oddy et al. 1999) or overweight/obesity (Harder et al. 2005), and maternal outcomes such as

postpartum weight retention (Neville et al. 2014). Similar sentiments were expressed by Yourkavitch and Chetwynd (2019) and others (Labbok and Krasovec 1990; Thulier 2010), and assessed collectively, the literature suggests that researchers should consider using more detailed and consistent definitions of human milk feeding to advance broader understanding of how human milk-feeding practices impact infant and maternal health outcomes.

Yourkavitch and Chetwynd (2019) have proposed a taxonomy of terms, definitions, and measurement to describe human milk feeding. They recommend that researchers be clear about how human milk feeding is defined and measured and highlight that these definitions and terminologies may differ, depending on the perspective of the study: for instance, whether the study is focused on physiology, biology, or behaviour, and from the perspective of the milk provider or the infant. In addition to defining human milk-feeding behaviours, it would also be prudent to understand the characteristics of individuals who carry out these different behaviours. For instance, prior research has shown that pregnant individuals with more positive attitudes towards human milk feeding at-breast are more likely to initiate feeding via the breast and continue for longer (Cernadas et al. 2003).

A better understanding of human milk-feeding behaviours from the perspective of the milk provider and the characteristics associated with different behaviours may allow for more targeted support strategies for optimal milk-feeding behaviours to be developed. Therefore, this study had two aims: (1) to describe human milk feeding at 3 months postpartum among mothers enrolled in a large cohort study in Alberta, Canada, using the "behaviour of the provider" terminology proposed by Yourkavitch and Chetwynd (2019) and (2) to examine maternal and infant feeding characteristics in relation to the mode of providing human milk to their infants.

Methods

Design

The Alberta Pregnancy Outcomes and Nutrition (APrON) study is a longitudinal, prospective cohort study of 2189 women during pregnancy and postpartum and their infants.

Sample and setting

Participants were recruited between May 2009 and November 2012 through advertisements in the media and in physician offices in Calgary and Edmonton, Alberta. Eligibility criteria were as follows: being aged 16 years or older, being literate in English, and having <27 weeks gestation. People who provided written informed consent were invited to attend a study centre once in each trimester following enrollment and once at approximately 3 months postpartum. Further details on the development and recruitment of the APrON study have been published elsewhere (Kaplan et al. 2014). Ethics approval for the APrON study was obtained from the Health Research Ethics Board at the University of Calgary and the Alberta Health Research Ethics Biomedical Panel at the University of Alberta, Canada.

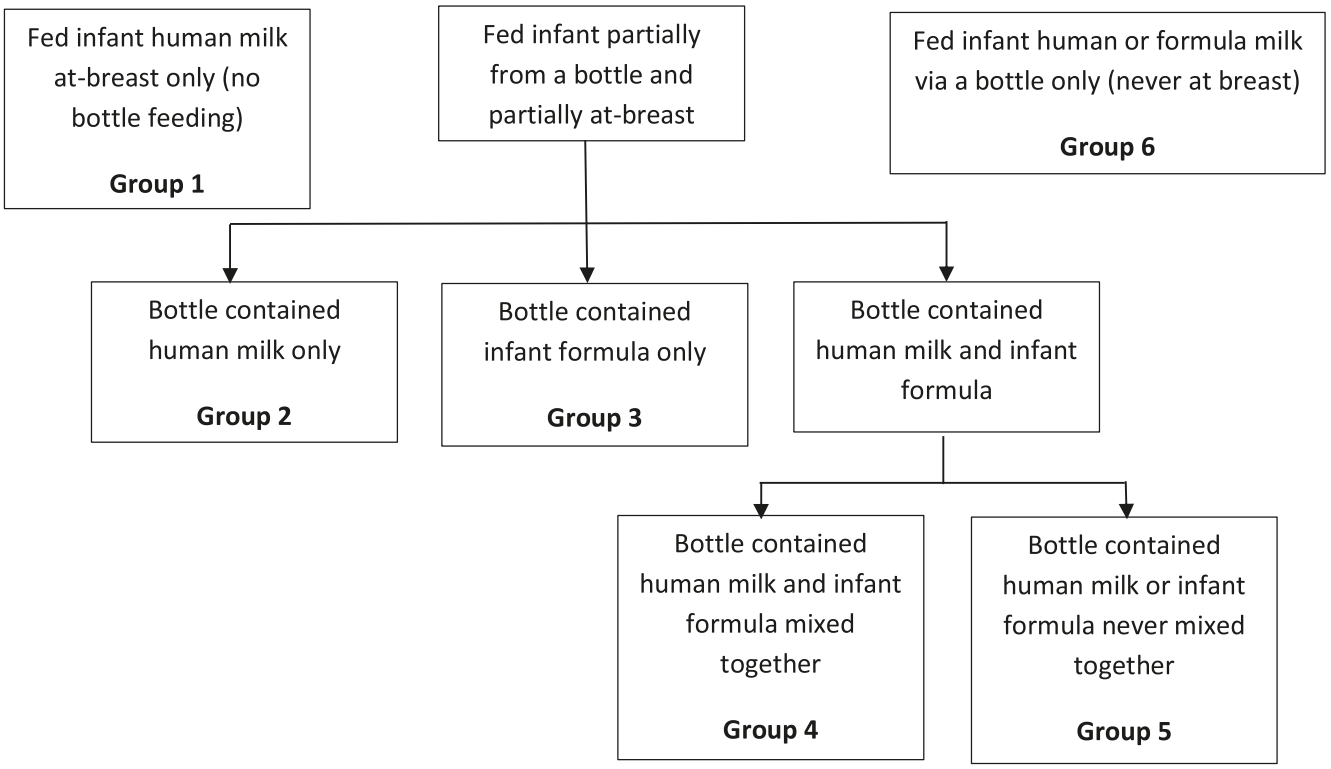
Assessments

Upon enrollment, participants completed questionnaires concerning pre-pregnancy weight, age, parity, marital status, ethnicity, family income, and education. At each study visit, trained staff measured participant's weight to the nearest 0.01 kg (Healthometer Professional 752KL) and height to the nearest 0.1 cm (Charder HM200P Portstad Portable Stadiometer). Pre-pregnancy body mass index (BMI) was calculated using self-reported pre-pregnancy weight and measured height at enrollment, and participants were classified as underweight (BMI < 18.5 kg/m^2), healthy weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), or having obesity ($\geq$30 kg/m^2). Total gestational weight gain (GWG) was calculated by subtracting pre-pregnancy body weight from the highest body weight during pregnancy (both measures were self-reported). For adherence to the Institute of Medicine (IOM) GWG guidelines (Rasmussen and Yaktine 2009), within each pre-pregnancy BMI group, women were categorized as "below" if they gained less than the lower limit of the recommended amount of total weight, "met" if they gained within the recommended weight range, or "above" if they exceeded the upper limit of the recommended amount of weight gain. Participants provided their Alberta healthcare number and consent to facilitate access to the birth record that contained infant birthweight information. At the 3-month postpartum study visit, participants reported their highest weight in pregnancy, and infant weight was also measured. Attitudes towards human milk feeding at-breast were assessed in the 3rd trimester of pregnancy using the Iowa Infant Feeding Attitude scale (Mora et al. 1999). This is a 17-item scale assessed on a 5-point Likert scale from "strongly disagree" to "strongly agree". Responses are coded (1–5; some items reverse scored), and responses from all 17 items are summed to produce an overall score between 17 and 85. A higher score indicates more favourable attitudes towards human milk feeding at-breast.

Human milk-feeding diaries

At the 3-month postpartum visit, which took place between January 2010 and November 2013, all participants who reported any human milk feeding ($n = 1586$) were asked to complete 3-day prospective milk-feeding diaries. Participants were asked to make a diary entry at each milk-feeding episode (regardless of the mode or type of milk). Details captured in the diary included number of feeds, timing and duration of each feed, the type of milk given (human milk or formula milk), and open-text comments relating to each feed. Timing of feeds were categorized as "morning" (4:01–10:00 am), "daytime" (10:01 am–4:00 pm), "evening" (4:01–10:00 pm), or "night" (10:01 pm–4:00 am) (Kent et al. 2006). Only the average duration of feeds at-breast per day was calculated for each participant. Average daily duration of at-breast feeds was summarized as median (interquartile range), minutes/day. The different modes of milk feeding reported in the diaries were "fed at-breast", "fed expressed human milk in a bottle", "fed infant formula in a bottle", and "fed expressed human milk and infant formula mixed in the same bottle." Information about feeding of any other liquids (including

Fig. 1. Definition of feeding groups according to modality of milk feeding.



water) or foods to infants was collected as part of the maternal 3-month postpartum questionnaire. Groups were defined solely based on milk-feeding behaviours of the participant and did not account for any other liquids received by the infant, including water.

Maternal behaviours for feeding human milk and infant formula

Data from the diaries were used to categorize participants into one of six groups according to their modes of feeding milk to their infant. The six groups are described in Fig. 1 and are as follows: (1) "fed human milk at-breast only" (only fed their infant human milk directly from their breasts), (2) "partially bottle-fed—bottle contained human milk only" (sometimes fed their infant at-breast and sometimes using a bottle); the bottle only contained human milk, (3) "partially bottle-fed—bottle contained infant formula" (sometimes fed their infant at-breast and sometimes using a bottle); the bottle only contained infant formula, (4) "partially bottle-fed—bottle contained a mixture of human milk and infant formula" (sometimes fed their infant at-breast and sometimes using a bottle); the bottle contained human milk mixed with infant formula in the same bottle, (5) "partially bottle-fed—bottle sometimes contained human milk and sometimes infant formula" (sometimes fed their infant at-breast and sometimes using a bottle); the bottle either contained human milk or infant formula but never mixed together, and (6) bottle-fed only (this group only fed their infants milk using a bottle); the bottle sometimes contained human milk and sometimes infant formula, and this group never fed infants directly at-breast.

Statistical analysis

Descriptive statistics for maternal and infant characteristics were calculated for each feeding group. Maternal postpartum weight retention at 3 months was determined by subtracting weight (kg) measured at the 3-month visit from self-reported pre-pregnancy weight. Infant weekly weight gain (g) was calculated by subtracting birth weight obtained from the infant birth record from their measured weight at the 3-month visit and dividing by infant age in weeks. For continuous variables (maternal age, attitude towards feeding at-breast score, postpartum weight retention, and weekly rate of infant weight gain), differences among feeding groups were assessed using linear regression models with feeding group as a non-ordered, categorical, independent variable. Group 1 was the reference category in these unadjusted linear models.

For categorial variables (education, household income, marital status, parity, pre-pregnancy BMI, ethnicity, return to work, concordance with IOM GWG guidelines, and infant sex), Fisher's exact test was used to determine differences among feeding groups. This approach was selected because Fisher's exact test is appropriate for testing the independence of two categorical variables, i.e., feeding group and any categorical variable of interest, particularly when small numbers of participants are present in some cells.

The frequencies of milk feeds/day, different feeding modes used, milk feeds by time of day, and at-breast feeds by time of day, along with the total duration of at-breast feeds

(minutes/day) were described for each feeding category. For some participants ($n = 7$), the daily duration of at-breast feeds exceeded 12 hours/day, resulting in a highly skewed distribution. In these cases, the mean for feeding duration for the whole group was imputed and used for analyses to retain the maximum number of participants in each feeding group and reduce the skewness in the data. Group 1 was the reference category for these analyses. Differences in the frequency of daily feeding behaviours were assessed using linear regression with feeding mode as a non-ordered, categorical independent variable and were adjusted for education, parity, pre-pregnancy BMI, attitude toward at-breast feeding scores, and ethnicity. Differences in the duration of at-breast feeds were assessed in a quantile regression model with Group 1 as the reference category and adjusted for education, parity, pre-pregnancy BMI, attitude toward at-breast feeding scores, and ethnicity. Analyses were carried out using Stata version 14.0 (StataCorp 2015), and a p value of <0.05 was considered statistically significant.

Results

A total of 1586 participants reported that they were providing human milk to their infants at 3 months postpartum. Those who were excluded did not complete a milk-feeding diary ($n = 445$), had a twin pregnancy ($n = 2$), or gave birth at <37 weeks gestation ($n = 48$), leaving $n = 1091$ with complete data (Table 1). The majority (57%) reported feeding their infant human milk directly from their breast (Group 1). Participants who completed a milk-feeding diary had higher household incomes and were more likely to be married/cohabiting than those who did not complete a diary (Supplementary Table S1). Differences were also observed in the pre-pregnancy BMI category and adherence to IOM GWG guidelines.

Characteristics associated with feeding groups

Participants in the feeding groups that provided some infant formula to their infants (Groups 3, 4, 5, and 6) had significantly lower scores on the attitudes towards feeding at-breast questionnaire, assessed in the third trimester of pregnancy, than those who fed human milk at-breast only (Group 1) ($p < 0.05$). In contrast, those in Group 2, the partial bottle feeding containing human milk only group, had similar scores to those in Group 1.

Other factors that were related to membership in a feeding group other than Group 1 (fed human milk at-breast only) included education, parity, pre-pregnancy BMI, and ethnicity (Table 1). Approximately, 30 participants (3%) reported having given water to their infant at 3 months postpartum (Supplementary Table S2).

Variability in frequency and duration of milk-feeding behaviours by feeding group

The daily frequency and timing of milk feeding and the duration of at-breast feeding, by feeding group, are presented in Table 2. The average number of milk feeds per day varied across feeding groups with those in Group 4 (partial bottle with human milk and infant formula mixed in same bottle) and Group 6 (fed only using a bottle) feeding their infants about 0.5–1 times less per day than mothers in Group 1 ($p < 0.05$). About 60% of milk feeds took place between 10:00 am and 10:00 pm in all feeding groups. Group 6 (fed only using a bottle) provided fewer feeds in the morning compared to those in Group 1 (fed human milk at-breast only) ($p < 0.05$).

The number of times each mode of feeding was used per day shows that participants who partially bottle-fed containing human milk only (Group 2) fed their infant using a bottle approximately once per day. Participants who partially bottle-fed containing infant formula only (Group 3) fed their infant using a bottle around twice per day. Participants in the other partial bottle-feeding groups (Groups 4 and 5) reported using a bottle to feed their infants around 3 times per day. The median (IQR) amount of time spent feeding infants human milk from the breast was similar in Groups 1, 2, 3, and 5 at between 143 and 114 min/d, while those in Group 4 spent significantly less time feeding their infant at the breast per day than those in Group 1 ($p < 0.01$).

Discussion

This study aimed to describe human milk feeding using updated definitions and terminology specified by Yourkavitch and Chetwynd (2019), reflecting calls from breastmilk and lactation experts (Thulier 2010; Rasmussen et al. 2017; Yourkavitch and Chetwynd 2019) to support more detailed exploration of associations between these detailed infant feeding groups and maternal characteristics. We discovered that the way in which participants provided milk to their 3-month old infants was more complex than typically reported using the categories of "breastfeeding", "parital/mixed", or "no breastfeeding". In this cohort, using expressed human milk in a bottle was a popular mode of feeding an infant. Those who partially fed their infant using a bottle were not feeding their infant human milk at their breast for less time (in minutes per day) than those who reported feeding their infant human milk at the breast only. The majority of milk feeds, regardless of mode, took place at a similar time of the day (between 10:00 am and 10:00 pm). Participants in the groups that included any formula feeding (Groups 3, 4, 5, or 6) reported a less positive attitude towards human milk feeding at-breast in the 3rd trimester of pregnancy.

Interpretation and implications

A systematic review on the prevalence of using expressed human milk via a bottle and associated outcomes in healthy-term babies highlighted that there is a paucity of research on the use of expressed human milk in non-premature babies (Johns et al. 2013). In the APrON cohort, 29% reported this behaviour at least once in the 3-day reporting period. This frequency is lower than two studies that reported prevalence of "ever expressing" human milk to feed non-premature babies from the USA (85%; $n = 1329$) and Australia (98%; $n = 885$) (Labiner-Wolfe et al. 2008; Clemons and Amir 2010). However, as the prevalence reported in the present study was based on a prospective 3-day diary at 3 months postpartum,

Table 1. Maternal and infant characteristics by feeding category.

	Feeding group						
	Group 1: Fed only human milk at-breast	Group 2: Partial bottle—bottle contained only human milk	Group 3: Partial bottle—bottle contained only infant formula	Group 4: Partial bottle—human milk and formula mixed in same bottle	Group 5: Partial bottle—bottle contained human milk or formula separately	Group 6: Fed only using a bottle—bottle contained human milk or infant formula	*P*
Number of participants (*N* (%))	621 (57)	208 (19)	89 (8)	84 (8)	44 (4)	45 (4)	—
Maternal age in years (mean (SD))	31.3 (3.8)	31.2 (4.3)	31.4 (4.5)	32.6 (4.3)	32.3 (4.9)	30.9 (4.8)	0.065
Education (*N* (%))							
Less than university	150 (24)	35 (17)	36 (40)	23 (27)	11 (25)	17 (38)	<0.01
University level	458 (74)	173 (83)	50 (56)	60 (72)	32 (73)	27 (60)	
Missing	13 (2)	0	3	1 (1)	1 (2)	1 (2)	
Household income (*N* (%))							
<$100 000 pa	261 (42)	77 (37)	42 (47)	25 (30)	13 (29)	21 (47)	0.195
≥$100 000 pa	348 (56)	127 (61)	47 (53)	58 (69)	29 (66)	23 (51)	
Missing	12 (2)	4 (2)	0	1 (1)	2 (5)	1 (2)	
Marital status (*N* (%))							
Single/separated/divorced	12 (2)	8 (4)	3 (3)	0	1 (2)	1 (2)	0.440
Married or cohabiting	601 (97)	200 (96)	86 (97)	83 (99)	42 (95)	44 (98)	
Missing	8 (1)	0	0	1	1 (2)	0	
Parity (*N* (%))							
Nulliparous	311 (50)	142 (68)	40 (45)	59 (70)	31 (70)	39 (87)	<0.001
Multiparous	300 (48)	64 (31)	49 (55)	23 (28)	12 (27)	6 (14)	
Missing	10 (2)	2 (1)	0	2 (2)	1 (2)	0	
Pre-pregnancy BMI (*N* (%))							
Underweight	31 (5)	3 (1)	2 (2)	1 (1)	1 (2)	0	<0.05
Normal weight	395 (64)	138 (66)	48 (54)	53 (63)	24 (55)	22 (49)	
Overweight	102 (16)	41 (20)	19 (21)	15 (18)	10 (23)	13 (29)	
Obese	52 (8)	12 (6)	15 (17)	10 (12)	7 (16)	5 (11)	
Missing	41 (7)	14 (7)	5 (6)	5 (6)	2 (5)	5 (11)	
Ethnicity (*N* (%))							
Non-white	111 (18)	21 (10)	34 (38)	18 (21)	2 (5)	9 (20)	<0.001
White	500 (81)	186 (89)	55 (62)	65 (78)	41 (93)	35 (78)	
Missing	10 (2)	1 (0)	0	1 (1)	1 (2)	1 (2)	
Attitudes toward feeding at-breast score (mean (SD))	68.5 (7.2)	67.5 (6.8)	64.2 (8.2)***	66.6 (6.7)*	66.3 (6.7)*	63.2 (8.1)***	<0.001

Table 1. (*concluded*).

	Feeding group						
	Group 1: Fed only human milk at-breast	Group 2: Partial bottle—bottle contained only human milk	Group 3: Partial bottle—bottle contained only infant formula	Group 4: Partial bottle—human milk and formula mixed in same bottle	Group 5: Partial bottle—bottle contained human milk or formula separately	Group 6: Fed only using a bottle—bottle contained human milk or infant formula	*P*
Returned to work (*N* (%))							
Yes	28 (4)	6 (3)	8 (9)	3 (4)	3 (7)	4 (9)	0.071
No	498 (80)	156 (75)	59 (66)	66 (78)	31 (70)	34 (76)	
Missing	95 (15)	46 (22)	22 (25)	15 (18)	10 (22)	7 (15)	
Institute of Medicine Gestational Weight Gain guidelines (*N* (%))							
Below	106 (17)	34 (16)	18 (20)	22 (26)	7 (16)	11 (25)	0.859
Within	192 (31)p'0	67 (32)	27 (30)	25 (30)	16 (36)	10 (22)	
Above	279 (45)	92 (44)	38 (43)	31 (37)	19 (43)	19 (42)	
Missing	44 (7)	15 (7)	6 (7)	6 (7)	2 (5)	5 (11)	
Postpartum weight retention (kg) (mean (SD))	3.8 (5.3)	4.1 (5.1)	4.0 (4.7)	3.2 (4.4)	3.3 (5.8)	3.5 (6.0)	0.841
Infant sex (*N* (%))							
Female	281 (45)	90 (43)	39 (44)	37 (44)	24 (55)	24 (53)	0.921
Male	305 (49)	106 (51)	46 (52)	43 (51)	19 (43)	20 (45)	
Missing	35 (6)	12 (6)	4 (4)	4 (5)	1 (2)	1 (2)	
Weekly rate of infant weight gain (g/week)	225 (102)	217 (108)	236 (107)	237 (102)	235 (84)	253 (131)	0.457

Note: For continuous variables (maternal age, attitude towards feeding at-breast score, postpartum weight retention, and weekly rate of infant weight gain), differences among feeding groups were assessed using linear regression with feeding group as a non-ordered, categorical independent variable. Group 1 was the reference category for all analyses of continuous variables. Models were not adjusted for any other variable. Significant differences relative to Group 1 are indicated as $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$. For categorical variables, differences among feeding groups were assessed using Fisher's exact test.

Table 2. Daily frequency and duration of milk-feeding behaviours by feeding group.

	Feeding group					
	Group 1: Fed only human milk at-breast	Group 2: Partial bottle—bottle contained only human milk	Group 3: Partial bottle—bottle contained only infant formula	Group 4: Partial bottle—human milk and formula mixed in same bottle	Group 5: Partial bottle—bottle contained human milk or formula separately	Group 6: Fed only using a bottle—bottle contained human milk or infant formula
Frequency of milk feeds (mean #/day (SD))	8.6 (2.3)	8.4 (2.0)	8.3 (1.6)	8.0 (2.2)*	8.4 (1.9)	7.6 (2.5)*
Frequency of different feeding modes used (mean #/day (SD))						
Human milk at-breast	8.6 (2.3)	7.7 (2.3)	6.7 (1.8)	5.3 (2.9)	5.8 (2.7)	0
Expressed human milk in bottle	0	0.9 (1.1)	0	0.5 (0.9)	1.1 (1.0)	3.6 (3.9)
Formula milk in bottle	0	0	1.7 (1.4)	0.9 (1.6)	1.7 (1.9)	3.8 (4.1)
Mixture of expressed human milk and formula milk in the same bottle	0	0	0	1.4 (1.6)	0	0.4 (1.1)
Frequency of milk feeds by time of day (mean #/day (SD))						
Morning (4:01–10:00 am)	2.2 (0.8)	2.1 (0.8)	2.1 (0.8)	2.0 (0.7)	2.0 (0.6)	1.8 (0.7)*
Daytime (10:01 am–4:00 pm)	2.5 (0.9)	2.6 (0.8)	2.5 (0.7)	2.4 (0.7)	2.7 (0.8)	2.4 (0.9)
Evening (4:01–10:00 pm)	2.7 (1.0)	2.8 (0.9)	2.7 (0.8)	2.5 (0.9)	3.0 (1.0)	2.4 (1.1)
Nighttime (10:01pm–4:00 am)	1.1 (0.7)	1.0 (0.6)	1.1 (0.6)	1.0 (0.7)	1.0 (0.6)	1.0 (0.7)
Frequency of at-breast feeds by time of day† (mean #/day (SD))						
Morning (4:01–10:00 am)	2.2 (0.8)	2.0 (0.8)	1.9 (0.8)	1.5 (0.9)	1.6 (0.8)	0
Daytime (10:01 am–4:00 pm)	2.5 (0.9)	2.3 (0.8)	1.9 (0.8)	1.6 (1.0)	1.8 (1.0)	0
Evening (4:01–10:00 pm)	2.7 (1.0)	2.4 (1.0)	2.0 (0.8)	1.4 (0.9)	1.8 (1.1)	0
Nighttime (10:01 pm–4:00 am)	1.1 (0.7)	0.9 (0.6)	0.9 (0.6)	0.7 (0.7)	0.6 (0.5)	0
Duration of at-breast feeds (min/day) (Median (IQR))	132 (98–172)	124 (95–158)	143 (100–190)	106 (63–162)**	114 (84–142)	0

Note: Differences in the frequency of daily feeding behaviours were assessed using linear regression with feeding group as a non-ordered, categorical independent variable. Group 1 was the reference category for all analyses. Models were adjusted for education, parity, pre-pregnancy BMI, attitude toward at-breast feeding scores, and ethnicity. Significant differences relative to Group 1 are indicated as $^{*}p < 0.05$.
Differences in duration of at-breast feeds were assessed in a quantile regression model for the median duration. Group 1 was the reference category for this analysis. Models were adjusted for education, parity, pre-pregnancy BMI, attitude toward at-breast feeding scores, and ethnicity. Significant differences relative to Group 1 are indicated as $^{**}p < 0.01$.
†By definition of the categorization of the feeding groups, the number of times human milk at-breast was given by time of day was significantly lower at all times of day in all feeding groups compared to those in the "fed human milk at-breast only" group ($P < 0.001$ for all comparisons).

rather than asking later in the postpartum period whether they "ever" expressed, it is perhaps not surprising that the prevalence in our study appears lower. Those in the "partially bottle-fed using human breastmilk only" group reported giving their infant expressed breastmilk in a bottle around once per day. Qualitative studies that have examined the reasons as to why parents are choosing to express breastmilk have suggested this behaviour to be more common in those returning to work (Fein et al. 2008; Labiner-Wolfe et al. 2008) and in those with a higher BMI (Leonard et al. 2011; Geraghty et al. 2012). However, our data did not find these associations as the majority of APrON study participants had not returned to work at the time they completed the feeding diaries (Table 1). This implies that using expressed human milk was widely done and was not a strategy used only by mothers who are returning to work. We did not ask participants to report the length and storage method of the expressed human milk given to the infants in our study. Given that these may be important factors in defining infant feeding behaviours (Rasmussen et al. 2017), future studies may wish to consider asking for this information. Furthermore, we were not able to determine the proportions of participants who used human milk that was not their own. It is unclear how common this behaviour is in countries such as Canada where maternity leave is supportive of meeting the recommendations for human milk feeding their infants at the breast beyond 6 months. The argument to consider these factors in future research and practice seems based on evidence gathered from the USA only; however, the USA does not have broadly applied maternity leave policies that support long-term feeding of human milk to infants at-breast. Further research on the implications of using expressed human milk may be warranted as there is some evidence that greater use of expressed human milk in a bottle, or indeed any bottle feeding, is associated with poorer self-regulation of milk intake in the infants, which may increase the risk of childhood obesity (Li et al. 2010). In addition, researchers have suggested that the increased handling of human milk may increase the risk of infection (Geraghty and Rasmussen 2010), and that storage of human milk in the freezer and subsequent reheating prior to feeding results in some vitamin losses (Garza et al. 1982; Boo et al. 2001). There was also evidence from a large birth cohort study that milk-feeding an infant from a bottle (whether containing human milk or formula) compared to feeding directly from the breast at 3 months postpartum was associated with greater risk of the child developing asthma at 3 years (Kloop et al. 2017). In terms of the benefits, there has been some research indicating that increased use of expressed human milk is associated with human milk feeding at the breast beyond 6 months. In a study of 587 parents in Australia, those who expressed human milk had a lower risk of discontinuing feeding at-breast prior to 6 months compared to those who never expressed (RR 0.71; 95% CI: 0.52–0.98). We also found that 8% ($n = 85$) of participants in our study mixed expressed human milk and infant formula in the same bottle and therefore assigned these participants into a separate group. From the point of view of the behaviour of the milk provider, the reasons underlying this behaviour require more research, ideally qualitative exploration. Going torwards a more comprehensive list of standard definitions is required; the taxonomy of terminologies as suggested by Yourkavitch and Chetwynd (2019) seems to be a useful step in this direction. Use of these definitions needs applying to other data, both from the perspective of the milk provider and milk receiver and in multiple countries.

It was of particular interest that those in the partial bottle-feeding infant formula only group (Group 3) and the partial bottle-feeding human milk only group (Group 2) still fed their infants directly at-breast for a similar length of time per day to those in the fed human milk at-breast only group (Group 1). This observation suggests that the use of a bottle once or twice a day did not impact the overall time the infant spent directly feeding at the breast for many participants. Previous studies focused on outcomes associated with human milk feeding would have grouped caregivers who were partially feeding infant formula in a bottle into a single category of "mixed" or "non-exclusive" breastfeeders (Kendall-Tackett et al. 2011; Bobrow et al. 2013; Neville et al. 2014). This may present challenges when examining predictions and outcomes associated with human milk feeding and highlights the need for future studies to consider capturing more detailed information about human milk-feeding behaviours.

Our findings regarding attitudes towards human milk feeding at-breast and associations with human milk-feeding behaviours are broadly consistent with those reported by other studies. In a study of 185 participants, those who initiated human milk feeding at-breast had higher attitude scores than those who did not ($P = 0.02$) (Holbrook et al. 2013). In a study of 587 milk-providing caregivers in Australia, higher attitude scores towards human milk feeding at-breast were positively associated with longer duration of human milk feeding at-breast ($P < 0.05$) (Scott et al. 2006). Our study provides further evidence from a large cohort that more positive attitudes towards human milk feeding at-breast in pregnancy were associated with increased likelihood of human milk feeding. In addition, it highlighted that scores obtained on this scale were not significantly different from those who fed human milk directly at the breast or expressed human milk in a bottle.

Finally, consistent with earlier findings (Amir and Donath 2007), we identified that compared to those who fed human milk at-breast only, a greater proportion of participants who had introduced any infant formula had obesity prior to pregnancy. A greater proportion who partially bottle-fed using infant formula only (no expressed human milk) were from a non-white ethnic background compared to those who fed human milk at-breast only. Variation in mode of milk feeding for infants by milk providers' ethnic group has been documented in studies with greater ethnic diversity than the APrON study (Hurley et al. 2008). However, owing to a lack of ethnic diversity in the APrON cohort, we were not able to explore the impact of ethnicity on infant feeding behaviour fully, and our observation should be interpreted with caution.

Strengths and Limitations

We completed a detailed analysis of human milk-feeding behaviours using 3-day prospective milk-feeding diaries in a

cohort of 1091 mothers in Alberta. The APrON cohort provides the most contemporary prospective data on women during pregnancy and their children in Canada. Particular strengths include the detail of information from using 3-day prospective feeding diaries and therefore the ability to classify and describe human milk-feeding behaviours according to the updated definitions, thus addressing an important gap in the literature. However, this study is not without its limitations. Assessments between human milk-feeding behaviours and factors such as maternal postpartum weight retention and infant weekly weight gain were all carried out at the same time point and in early postpartum, when the effects of varying human milk-feeding behaviours may not yet have yielded enough variation to explore differences. We were unable to distinguish between nutritive and non-nutritive suckling in the human milk-feeding diaries and therefore "time spent at breast/per day" may overestimate how long infants were receiving human milk from the breast. It would have been of interest to further partition the "bottle-feeding only" group into those that (1) only fed expressed human milk, (2) only fed infant formula, and (3) fed a mixture of human milk and formula; however, the numbers of participants in these groups would have been too small to support a robust evaluation of differences between groups. Assessment of differences among these groups will be an important area for research in the future. The number of feeds from the four time periods does not always add up to the total number of feeds/day for some participants, where a single feed crossed the timing boundaries; it was counted as a feed in both time categories but as a single feed in the sum of all feeds/day. Data collected in this study are 7–10 years old. However, policies on maternity leave in Canada have remained stable over this period and therefore we believe that these data are highly likely to represent contemporary feeding patterns.

Conclusion

This analysis from the APrON study highlights variation in behaviours used to provide milk to infants at 3 months postpartum. It confirms that feeding human milk and/or infant formula from a bottle is popular, and that the behaviours and motivations of caregivers who use infant formula some of the time need to be assessed in more detail than is available when data are aggregated into a single group. Using more detailed definitions of human milk-feeding behaviours will allow for better understanding of how these behaviours can impact on health outcomes of both the milk provider and infant. Furthermore, future studies should consider assessing patterns of milk-feeding behaviours over longer periods than the three days used in the current study. Longer data collection periods will help generate more insight into variations and patterns in milk-feeding behaviours and may contribute to initiatives that aim to support the milk feeding of infants in line with established guidelines.

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Data availability

Data are available upon reasonable request from the APrON management team.

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Author contributions

MJ designed the study, carried out the analysis with YS, and wrote the manuscript under the supervision of PJR and RCB. YY provided expertise on the data analysis and presentation; YS and MM assisted with data preparation and analyses. RCB is the Principal Investigator of the ENRICH program and Co-Investigator of the APrON study. All authors contributed to the writing of the manuscript.

Competing interests

The authors declare no competing interests.

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Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/apnm-2021-0658.

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