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Feeding Neonates by Cup: A Systematic Review of the Literature

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Abstract *Objective* WHO and UNICEF recommend cup feeding for neonates unable to breastfeed in low-resource settings. In developed countries, cup feeding in lieu of bottle feeding in the neonatal period is hypothesized to improve breastfeeding outcomes for those initially unable to breastfeed. Our aim was to synthesize the entire body of evidence on cup feeding. *Methods* We searched domestic and international databases for original research. Our search criteria required original data on cup feeding in neonates published in English between January 1990 and December 2014. *Results* We identified 28 original research papers. Ten were randomized clinical trials, 7 non-randomized intervention studies, and 11 observational studies; 11 were conducted in developing country. Outcomes evaluated included physiologic stability, safety, intake, duration, spillage, weight gain, any and exclusive breastfeeding, length of hospital stay, compliance, and acceptability. Cup feeding appears to be safe though intake may be less and spillage greater relative to bottle or tube feeding. Overall, slightly higher proportions of cup fed versus bottle fed infants report any breastfeeding; a greater proportion of cup fed infants reported exclusive breastfeeding at discharge and beyond. Cup feeding increases breastfeeding in subgroups (e.g. those who intend to breastfeed or women who had a Caesarean section). Compliance and acceptability is problematic in certain settings. *Conclusions* Further research on long-term breastfeeding outcomes and in low-resource settings would be helpful. Research data on high risk infants (e.g. those with cleft palates) would be informative. Innovative cup feeding approaches to minimize spillage, optimize compliance, and increase breastfeeding feeding are needed.

Keywords Cup · Cup feeding · Paladai · Neonates · Preterm · Feeding · Systematic review

Significance

What is known about this subject? Two Cochrane reviews summarized 4 randomized clinical trials and found that women who cup versus bottle or tube fed their infant were more likely to fully breastfeed at discharge. Cup feeding had no effect on any breastfeeding but extended length of stay.

What this study adds? Twenty-four studies on cup feeding cover questions and clinical outcomes that have never been synthesized. We provide the first comprehensive review of original research on a wide range of cup feeding outcomes (physiologic stability, intake, breastfeeding, length of stay, compliance, acceptability) and propose new areas for research.

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Introduction

Breastfeeding offers the best nutrition and is the optimal method for feeding neonates [1, 2]. Unfortunately, not all infants can be breastfed. Preterm infants, infants with an oral cleft or other anomalies, and infants with metabolic, neurologic, or developmental immaturities may encounter breastfeeding difficulties [3, 4]. In some cases, infants are unable to breastfeed because the mother is unavailable, sick, or has nipple damage [4, 5].

Cup feeding has a long history of being a neonatal feeding option [6–8]. In high-resource settings, nasogastric tubes and bottles are the default tools of choice when an infant is unable to breastfeed. Feeding cups in high-resource settings are used by some in the short-term to deliver supplemental feeding and to avoid 'nipple confusion', a theory that exposure to artificial nipples interferes with a neonate's ability to breastfeed [9]. WHO and UNICEF recommend cup feeding in low-resource settings where water quality is poor and electricity unreliable [4, 10–12]. In these settings, nasogastric tubes may not be available and bottles have crevices that promote infection [13, 14]. Cups are easier to keep clean and are less likely than bottles to be used for long-term storage of milk which can facilitate bacterial contamination. Cup feeding may supplement breastfeeding, minimize exposure to nasogastric tubes, or serve as a long-term feeding solution for those never able to breastfeed [3, 4, 15]. Advantages of cup feeding include enhanced bonding, a greater sense of maternal control and confidence, the ability to engage other family members in the infant's care, and freeing up nursing staff when caregivers conduct feedings [3, 4, 15–19]. Studies propose that cup feeding provides the infant positive oral, tactile, and auditory stimulation, exposure to the smell and taste of breast milk, tongue and motor skill experience, and the ability to control feeding pace [3–5, 8, 17]. Reported concerns about cup feeding include that it is too slow, prone to spillage, results in insufficient intake [19–21], or that milk poured from a cup into the infant's mouth increases the risk of choking or aspiration [5, 19].

Two Cochrane reviews evaluated the extent to which cup feeding and avoidance of bottle-feeding in the neonatal period influenced breastfeeding outcomes [22, 23]. These reviews included four of ten published RCTs. The outcomes in the Cochrane reviews were limited. There are 24 studies on cup feeding that have never been summarized, including a recently published RCT [24] and numerous observational studies that examine outcomes not in the reviews. Synthesizing the breadth of outcomes has important implications for understanding cup feeding and identifying gaps in knowledge. We conducted a systematic review of neonatal cup feeding to synthesize the broad body of evidence and identify gaps to facilitate research.

Methods

We broadly included all studies with original data collection on cup feeding in the neonatal period conducted in humans and written in English between 1990 and 2014. We searched the MEDLINE database and a global health database, CABdirect, for all papers that met these criteria. Search terms included cup*, palada* (paladai), suthi* AND newborn or infant AND human AND English from January 1, 1990 to December 2014. The search was last conducted February 27, 2015. The symbol * denotes the root word of the search. A paladai (also referred to as a suthi) is an infant feeding cup used in India which is a small (10 ml) metal cup with a long slender pour spout (Fig. 1) [14]. Research on spoon feeding was excluded.

We reviewed abstracts to identify original research articles. We also reviewed the reference lists of all included papers and abstracted additional articles for review. All studies including case reports, case series, observational studies, non-randomized intervention studies and RCTs were included. We abstracted study design and country, type of participants, gestational of age, number of participants, comparison, and outcomes into Excel. To the extent available, we reported original results including means, mean differences, *p* values, prevalence relative risks, and 95 % confidence intervals (CIs). When not calculated, we used raw frequencies to calculate these statistics to facilitate comparisons. We grouped studies according to study design because RCTs typically have less bias that observational studies and by gestational age since effects in the outcomes we report (e.g. physiologic measures, breastfeeding outcomes) may differ based on gestational age.

Results

We reviewed 342 abstracts and 681 references to identify 28 studies that meet inclusion criteria (Fig. 2). There were ten RCTs, seven non-randomized intervention studies, and eleven observational studies (Table 1). Five studies employed a cross-over design where the infant acted as her own control. [21, 25–28] Four studies evaluated provider and/or caregiver preferences [29–32]. All RCTs except for one [33] were conducted in high-resource countries. Six studies were conducted in upper-middle income countries (e.g. Brazil, Turkey) and five studies were in lower-middle income countries (e.g. India, Egypt); no studies were in the least developed countries (Table 1) [34]. Twenty-three studies employed a comparison group using a different feeding method. Nineteen compared a cup to a bottle, six compared breastfeeding to a cup and/or bottle, two compared Paladai to bottle-feeding, and one compared Paladai

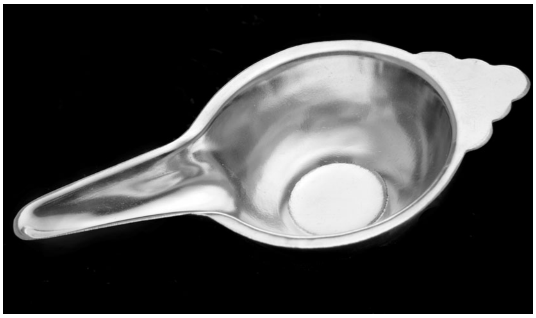


Fig. 1 A type of feeding cup known as a paladai used in South India

to tube feeding (Table 1). Most studies did not describe the cup or bottle used [20, 24, 26, 28, 30, 35–39]. The scope of research was broad and fell into five domains: (1) Physiologic stability and safety; (2) Intake, duration, spillage and weight gain/loss; (3) Breastfeeding outcomes; (4) Duration of hospitalization; and (5) Feeder compliance and acceptability. We also ordered studies by topic (see Online Resource 1).

Physiologic Stability and Safety

Many clinical practitioners express concern that cup feeding may increase adverse events such as aspiration, or oxygen desaturation [5, 19, 40]. Overall, compared to bottle feeding, cup feeding tended to have higher oxygen saturation levels, and a smaller fraction of infants experiencing oxygen saturation <90 and <85 % and equivalent or less elevation of heart and respiratory rates (Table 2). There were no consistently reported adverse physiologic events across studies. Collins et al. [41] reported no adverse events in early premature infants. Marinelli et al. [25] found no differences in choking, spitting up or apnea, or bradycardia between cup and bottle fed infants (all p values > 0.05), although these were noted in both groups of neonates. Aloysius, et al. (n = 15) reported that 73 % had stress cues when paladai feeding compared to 20 % bottle feeding, but there was no difference in preterm neonate stress cues ($p = 0.67$) [26]. A case report proposes infant aspiration can occur with an improper feeding technique, but a recent RCT with 522 infants reported no apnea or aspiration [10, 24]. A case series of the paladai in very preterm infants found 12/68 feedings had desaturation but 7 feedings occurred in 2 infants [42].

Intake, Duration of Feeding, Spillage, and Weight Gain

Clinical practitioners express concern that cup feeding may not provide sufficient intake, is time-consuming, and that spillage results in decreased intake [19]. All comparative studies that examined intake reported lower intake with a cup compared to bottle or tube (Table 3). Of the five studies with hypothesis testing, only one reported a statistically significant lower intake with cup feeding. Findings on feeding duration were variable. Two studies reported cup feeding took more time [25, 26]; two less time [33, 43]; and one the same time [24] as bottle feeding. Cup feeding took less time than breastfeeding [27]. Cup feeding was associated with a threefold increase in spillage compared to a bottle [21, 26] and more spillage than the paladai [21]. These comparisons were statistically stable (p values < 0.01) [21, 26]. The mean spillage when using a cup was high (25–39 %) [16, 21]. No studies found statistically significant differences in newborn weight loss/gain with the cup versus bottle feeding [24, 33, 39–41, 44]. Data from six studies on weight gain were not tabulated because of variability in measures reported (see Online Resource 1) [24, 33, 39–41, 44].

Breastfeeding Outcomes

The primary reason to cup feeding in high-resource settings is to optimize the likelihood the infant will successfully initiate and sustain breastfeeding. Consequently, the extent to which cup, as compared to bottle, influences breastfeeding in infancy is a primary outcome of interest. We identified eleven reports on breastfeeding outcomes; seven of these were RCTs [24, 33, 36, 38, 39, 41, 44] and four were observational studies [3, 30, 35, 45]. The most commonly reported breastfeeding outcomes were any or exclusive/full breastfeeding. Exclusive breastfeeding was similarly defined by most studies as receiving all food from the breast [3, 35, 36, 38, 41, 44]. Two studies classified infants who had taken vitamins or minerals as exclusively breastfed [24, 41]. Two studies defined 'full breastfeeding' and 'almost exclusive breastfeeding' as breastfeeding with infrequent feedings (e.g. <1 per day) of other liquids such as water or herbal drinks [35, 44].

Breastfeeding was reported at or near the time of hospital discharge and up to 6 months of age (Table 4). Any breastfeeding at hospital discharge was reported by eight studies. All of the studies that employed a comparison group reported a greater proportion of cup-fed as compared to bottle-fed infants with any breastfeeding at hospital discharge, but the differences were mostly small and only the largest RCT [24] showed statistically significant differences [24, 30, 33, 36, 41]. Findings were similar when any breastfeeding outcomes post-discharge up to 6 months were examined. Other statistically significant differences for cup versus bottle fed infants for any breastfeeding were in subgroups (e.g. mothers who had a Caesarean section).

Table 1 Original research studies on cup feeding ordered by study design characteristics and sample size

	References	Study design details and population	N	GA (weeks)	Country	Feeding methods used: cup/paladai	Bottle/tube/breast	Domains
Randomized clinical trials (RCT)								
1	Howard et al. [44]	Healthy neonates	700	36–42	USA	Cup + early pacifier = 185 Cup/late pacifier = 179	Bottle/early pacifier = 169 Bottle/late pacifier = 179	Intake, duration and spillage Breastfeeding outcomes Compliance and acceptability
2	Yilmaz et al. [24]	Late preterm	607	32–35	Turkey	Cup = 254	Bottle = 268	Breastfeeding outcomes Intake, duration and spillage Duration of hospital stay
3	Schubiger et al. [39]	Healthy full-term neonates	602	>37	Switzerland	UNICEF protocol that included cup or spoon with no artificial teats = 294	Standard protocol of bottle post-breastfeeding, pacifier offered = 308	Breastfeeding outcomes Compliance and acceptability Duration of hospital stay
4	Collins et al. [41]	Early preterm neonates	303	23–33	Australia	Cup, no pacifier = 82 Cup + pacifier = 69	Bottle, no dummy = 70, Bottle + dummy = 82	Physiology and safety Intake, duration, spillage, weight breastfeeding outcomes Duration of hospital stay Compliance and acceptability
5	Howard et al. [43]	Healthy neonates	98	36–42	USA	Cup = 51	Bottle = 47 Breast = 25	Physiology and safety Intake, duration and spillage
6	Rocha et al. [33]	Preterm neonates	78	32–36	Brazil	Cup = 44	Bottle = 34	Physiology and safety Intake, duration and spillage Breastfeeding outcomes
7	Marinelli et al. [25]	Early preterm neonates, cross-over study	56	≤34	USA	Cup = 56	Bottle = 56	Physiology and safety Intake, duration and spillage
8	Gilks [36]	Early preterm neonates	54	25–34	UK	Cup = 27	Bottle = 27	Breastfeeding outcomes Compliance and acceptability

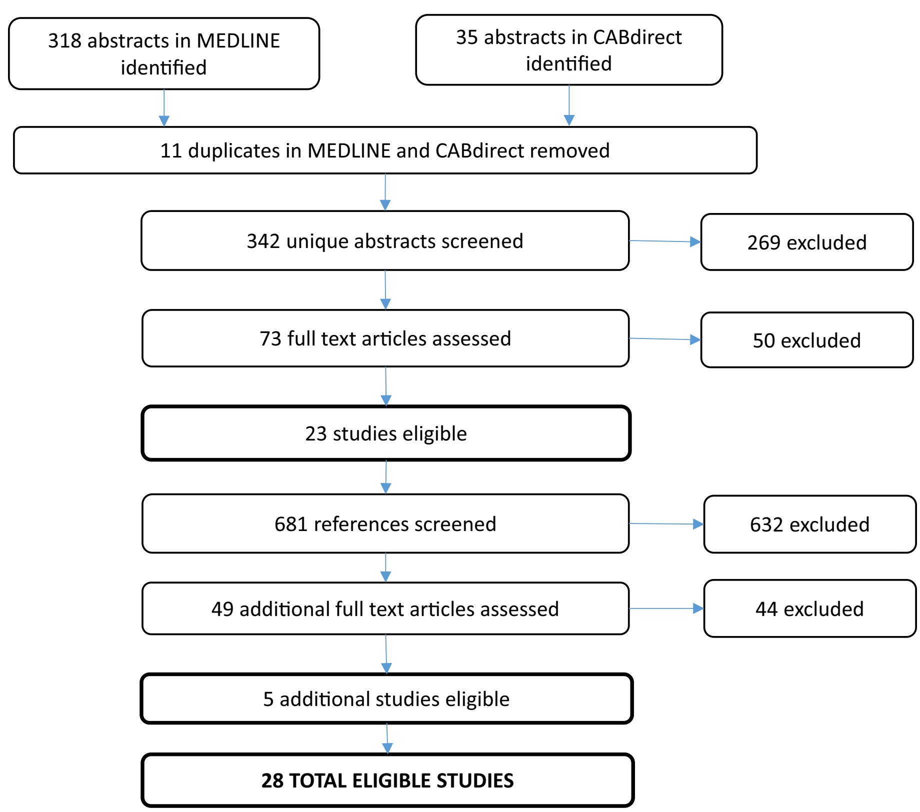
Table 1 continued

	References	Study design details and population	N	GA (weeks)	Country	Feeding methods used: cup/paladai	Bottle/tube/breast	Domains
9	Aloysius and Hickson [26]	Preterm neonates, cross-over study	15	32–36	UK	Paladai = 15	Bottle = 15	Physiology and safety Intake, duration and spillage Compliance and acceptability
10	Mosley et al. [38]	Preterm neonates	14	32–37	UK	Cup = 6	Bottle = 8	Breastfeeding outcomes
Non-randomized intervention studies								
11	Huang, et al. [20]	Full term singleton neonates, no congenital anomalies, vaginal birth	205	>37	Taiwan	Cup = 67	Bottle = 62 Breast = 76	Intake, duration and spillage
12	Malhotra et al. [21]	Cross-over study, neonates in special care nursery, also included evaluation of nurses	100	All	India	Cup = 100 Paladai = 100	Bottle = 100	Intake, duration and spillage Compliance and acceptability
13	Abouelfettoh et al. [35]	Late preterm neonates	60	34–37	Egypt	Cup = 30	Bottle = 30	Breastfeeding outcomes
14	Freer [27]	Preterm neonates, cross-over study	20	28–31	UK	Cup = 32 feedings	Bottle = 32 feedings	Physiology and safety Intake, duration and spillage
15	Gomes et al. [37]	Healthy full-term infants 2–3 months of age	60	>37	Brazil	Cup + breast = 20	Bottle + breast = 20 Breast = 20	Physiology and safety
16	Rekha and Rao [40]	Preterm neonates	32	33–37	India	Paladai = 16	Tube = 16	Intake, duration and spillage Duration of hospital stay
17	Lopez et al. [28]	Preterm neonates, cross-over study	19	34–36	Brazil	Cup = 19	Bottle = 19	Physiology and safety
Observational studies								
18	Lang [8]	Cohort study, neonates	475	All	UK	Cup = 85	Not cup = 372	Breastfeeding outcomes
19	Al-Sahab et al. [32]	Cross-sectional, providers	103	n/a	Canada	n/a	n/a	Compliance and acceptability
20	Franca et al. [55]	Cross-sectional, term	81	37–42	Brazil	Cup = 27	Bottle = 27, Breast = 27	Physiology and safety
21	Brown et al. [30]	Cross-sectional, neonatesfull term	63	>37	UK	Cup = 30	Bottle = 33	Intake, duration and spillage Breastfeeding outcomes Duration of hospital stay
22	Cloherty et al. [29]	Ethnographic study of mothers and providers	60	n/a	UK			Compliance and acceptability

Table 1 continued

	References	Study design details and population	N	GA (weeks)	Country	Feeding methods used: cup/paladai	Bottle/tube/breast	Domains
23	Gupta et al. [45]	Case-series, neonatespreterm	59	<37	India	Cup		Breastfeeding outcomes (not comparable)
24	Nyqvist and Strandell [31]	Evalaution of nurses and parents' use of two cups	48		Sweden	Medicine cup Spouted cup		Compliance and acceptability
25	Dalal et al. [42]	Case series, preterm neonates	20	28–32	India	Paladai = 20		Physiology and safety Intake, duration and spillage
26	Dowling et al. [16]	Case series, neonatespreterm	8	30–37	USA	Cup		Physiology and safety Intake, duration and spillage
27	Gomes et al. [56]	Case series, preterm	5	28–35	Brazil	Cup = 1	Bottle = 2, Breast = 2	Physiology and safety
28	Thorley [10]	Case report	1	n/a	Australia	Cup		Physiology and safety

Fig. 2 Flow chart of abstracts, references and papers reviewed to identify eligible studies



Most measures of exclusive breastfeeding were collected around the time of hospital discharge. Of the six studies that employed a comparison group [24, 35, 36, 38, 41, 44], all but one small study [38] reported a higher prevalence or longer duration of exclusive breastfeeding in cup versus bottle fed infants. The larger [24, 41] but not the smaller [36, 38] RCTs in preterm infants reported statistically significant differences in exclusive breastfeeding at

Table 2 Physiologic stability and safety measures by type of comparison, gestational age and study design

References	Comparison	GA	Study design	Heart Rate (beats/min)				Respiratory rate (breaths/min)			
				Cup	Comparison	Difference	P	Cup	Comparison	Difference	p
Marinelli et al. [25]	Cup versus bottle	PT	RCT	168.4	171.8	−3.4	0.009	49.7	48.8	0.9	0.46
Rocha et al. [33]	Cup versus bottle	PT	RCT	–	–	–	–	–	–		–
Howard et al. [43]	Cup versus bottle	FT	RCT	–	–	−3.6	0.11	–	–	0.3	0.74
Howard et al. [43]	Cup versus breast	FT	RCT	–	–	6.5	0.22	–	–	−2.7	0.01
Freer [27]	Cup versus breast	PT	Interv.	155	159	−4	0.08	–	–		
Dalal et al. [42]	Paladai	PT	Observ.	142	–			–	–		

References	Comparison	GA	Study design	Oxygen saturation (mean %)				Proportion (%) of infants with O_2 saturation <85 or 90 %				
				Cup	Comparison	Difference	p	% < O_2 Saturation	Cup	Comparison	Difference	p
Marinelli et al. [25]	Cup versus bottle	PT	RCT	96.5	94.5	2.0	0.02	<90 %	5.0	13.0	−8.0	0.02
Rocha et al. [33]	Cup versus bottle	PT	RCT	90.8	87.7	3.1	ns	<85 %	13.6	35.3	−21.7	0.02
Howard et al. [43]	Cup versus bottle	FT	RCT	Diff		0.2	0.78	<85 %	***5.9***	***14.9***	−9	ns
Howard et al. [43]	Cup versus breast	FT	RCT	Diff		1.4	0.04	<85 %	***5.9***	***0***	5.9	–
Freer [27]	Cup versus breast	PT	Interv.	94	96	−2.0	0.05					
Dalal et al. [42]	Paladai	PT	Observ.	–	–			–	–	–		

Bolded, italicized estimates were calculated based on data provided in the paper

GA, gestational age; PT, preterm; FT, fullterm; Observ., observational study; RCT, randomized clinical trial; Interv., intervention study; "–", means not reported; %, percent; Diff, difference in means only reported, not actual values by type; ns, not statistically significant

discharge. The only RCT to examine exclusive breastfeeding at 3 and 6 months post discharge reported cup fed infants were more likely to exclusively breastfeed than bottle-fed infants ($p < 0.001$) [24]. Statistically significant differences were reported in subgroups (Table 4).

Length of Stay in Hospital

Four studies reported on the length of stay in hospital for cup versus bottle or tube fed infants (Table 5). Four of the 5 studies on length of stay in hospital, including a large RCT, reported stays were similar or shorter for cup versus breastfeeding infants and none of the differences in length of stay were statistically significant (Table 5). One RCT in Australia reported extended hospital stays among cup fed infants relative to bottle fed infants [41], which has raised concern that cup-feeding increases cost and demand for limited resources [22, 23, 41]. However, the authors reported no difference in duration of hospital stay among those who complied with their assigned feeding method ($p = 0.27$), and found that length of stay after supplemental feeding by cup or bottle was started was similar for infants fed by cup versus bottle (12 vs 11 days, $p = 0.05$) [41].

Compliance and Acceptability

Non-compliance with cup feeding was the primary limitation of the RCT in Australia that examined cup versus bottle-feeding on breastfeeding outcomes; 56 % of participants assigned cup feeding group were given a bottle [41]. Problems reported included spillage, taking too much time, the infant not feeding well, and staff refusing to feed an

Table 3 Intake, duration and spillage of feeding by study design

References	Comparison	GA	Study design	Intake (ml/feed)			Duration of feeding (min/feed)			Spillage (%/feed)		
				Cup	Comparison	*p*	Cup	Comparison	*p*	Cup	Comparison	*p*
Yilmaz et al. [24]	Cup versus bottle	PT	RCT	–	–	–	13.7	13.6	0.32	–	–	–
Marinelli et al. [25]	Cup versus bottle	PT	RCT	20.9	27.2	0.001	20.1	16.3	0.002	–	–	–
Rocha et al. [33]	Cup versus bottle	PT	RCT	–	–	–	11.8	13.4	ns	–	–	–
Aloysius and Hickson [26]	Paladai versus bottle	PT	RCT	23.1	29.6	0.20	17.8	13.1	0.06	12.1[a]	3.6[a]	0.004
Howard et al. [43]	Cup versus bottle	FT	RCT	29.1	35.3	>0.05	5.3	5.9	<0.05	–	–	–
Howard et al. [44]	Cup versus bottle	FT	RCT	67	121	–	–	–	–	–	–	–
Huang et al. [20]	Cup versus bottle	FT	Interv.	363[b]	438[b]	0.06	–	–	–	–	–	–
Malhotra et al. [21]	Cup versus bottle	All	Interv.	–	–	–	–	–	–	25.9	1.5	<0.001
	Cup versus paladai	All	Interv.	–	–	–	–	–	–	25.9	6.0	<0.001
	Paladai versus bottle	All	Interv.	–	–	–	–	–	–	6.0	1.5	<0.001
Freer [27]	Cup versus breast	PT	Interv.	–	–	–	11.1	12.4	–	–	–	–
Dowling et al. [16]	Cup versus bottle	PT	Observ.	4.6	–	–	15.2	–	–	38.5	–	–
Brown et al. [30]	Cup versus bottle	FT	Observ.	28.4	33.9	0.15	–	–	–	–	–	–
Dalal et al. [42]	Paladai	PT	Observ.	91–100	–	–	2.3–2.6	–	–	–	–	–

GA gestational age, *PT* preterm, *FT* fullterm, *Observ.* observational study, *RCT* randomized clinical trial, *Interv.* intervention study, *ml* milliliters, *min* minutes % percentage

[a] Calculated based on raw data provided in original source paper

[b] Average amount consumed during the entire hospital stay (duration of hospitalization not provided)

infant with a cup [41]. In the United Kingdom, mothers assigned cup feeding were 3.6 times more likely to withdraw from the trial than mothers assigned bottle feeding ($p = 0.01$) [36]. In contrast, an RCT in Switzerland found 9.5 % assigned to a cup feeding protocol requested a bottle or had trouble cup feeding [39]. In an RCT in Turkey, 8.7 % were non-compliant with the cup compared to 6.8 % non-compliant with a bottle ($p = 0.39$) [24]. A study in the US reported similar levels of compliance with 89 % and 93 % using the assigned cup or bottle respectively [44]. These studies suggest >90 % compliance with cup feeding in certain settings may be feasible.

Five studies reported on provider opinions about cup feeding [21, 26, 29, 31, 32]. The largest study (N = 103) in Canada found beliefs about 'nipple confusion' and safety and utility of cup feeding varied by provider type [32]. A study in the UK found that nurses found cup feeding more difficult than bottle feeding [26]. More than 50 % of nurses in Sweden reported difficulties with a new cup feeding protocol; hygiene rules were not followed and nurses thought cup feeding may not meet intake requirements [31]. An ethnographic study in the UK reported nurses thought the cup could be messy, though the majority liked the cup because it allowed the infant to 'control the rate at which they [were] fed'. Most thought cup feeding should be given by a clinical provider—not the mother [29]. A study in India reported nurses unanimously preferred the paladai over the bottle and cup without a pour spout and thought it took less time and effort of the infant to feed than the other methods [21]. The primary disadvantage of the

Table 4 Breastfeeding in cup versus bottle fed infants by study design and time point measured

	Time point	GA	Study design	References	Cup	Bottle	*p*	Estimate	95 % CI
Any breastfeeding and/or breast milk									
Any breastfeeding versus none (%)—at hospital discharge	Discharge	PT	RCT	Yilmaz et al. [24]	99	91	***<0.001***	***1.08***	***1.05, 1.13***
	Discharge	PT	RCT	Gilks [36]	52	44	***0.59***	***1.2***	***0.7, 2.0***
	Discharge	PT	RCT	Collins et al. [41][a]	74	68	0.27	***1.1***	
	Discharge	PT	RCT	Rocha et al. [33]	81.8	79.4	***0.79***	***1.0***	***0.8, 1.3***
	Discharge	FT	Observ.	Brown et al. [30]	70	55	0.30	1.9	0.6, 6.3
	Discharge	All	Observ.	Lang [8]	***92.1***				
	Discharge	PT	Observ.	Gupta et al. [45]	***89.8***				
Any breastfeeding versus none (%)—after discharge	Day 5	FT	RCT	Schubiger et al. [39]	100	99.3	ns		
	5–19 days post discharge	PT	RCT	Rocha et al. [33]	43.2	44.1	***0.93***	***1.0***	***0.6, 1.6***
	2 months	FT	RCT	Schubiger et al. [39]	88.0	87.7	ns	–	–
	3 months post discharge	PT	RCT	Yilmaz et al. [24]	88	82	0.09	***1.06***	***0.99, 1.14***
	3 months post discharge	PT	RCT	Collins et al. [41][a]	42	36	0.33	***1.2***	
	3 months post discharge	PT	RCT	Rocha et al. [33]	29.5	14.7	***0.12***	***2.0***	***0.8, 5.1***
	4 months	FT	RCT	Schubiger et al. [39]	75.4	70.5	ns	–	–
	6 months	PT	RCT	Yilmaz et al. [24]	69	59	0.02	***1.2***	***1.03, 1.3***
	6 months	FT	RCT	Schubiger et al. [39]	57.0	55.3	ns	–	–
	6 months post discharge	PT	RCT	Collins et al. [41][a]	31	24	0.22	***1.3***	
Any breastfeeding (days)	Duration, in days	FT	RCT	Howard et al. [44][b]	105	140	0.50	0.9	0.8, 1.1
Subgroups									
Any breastfeeding (days), those who had >2 supplemental feedings	Duration	FT	RCT	Howard et al. [44]	–	–	ns	–	–
Any breastfeeding (days), those who had a cesarean section	Duration	FT	RCT	Howard et al. [44]	161	90	0.04	–	–
Any breastfeeding versus none (%), those who complied with assigned method	Not specified	PT	RCT	Collins et al. [41]	–	–	0.004	21.1	2.6, 169.8
Any breastfeeding versus none (%), those breastfeeding 5–19 days post discharge	3 months post discharge	PT	RCT	Rocha et al. [33]	68.4	33.3	0.04	***2.0***	***0.9, 4.5***
Exclusive or full breastfeeding or received only breast milk									
Exclusively breastfeeding versus not (%)	Prior to discharge	PT	RCT	Mosley et al. [38]	***66.7***	***75.0***	***0.88***	***0.9***	***0.4, 2.5***
Exclusively breastfeeding versus not (%)	Discharge	PT	RCT	Yilmaz et al. [24]	72	46	<0.0001	1.6	1.4, 1.8
Exclusive breastfeeding versus not (%)	Discharge	PT	RCT	Gilks [36]	37.0	14.8	***0.06***	***2.5***	***0.9, 7.0***
Fully breastfed versus not (%)	Discharge	PT	RCT	Collins et al. [41][a]	61	47	0.03	***1.3***	

Table 4 continued

	Time point	GA	Study design	References	Cup	Bottle	*p*	Estimate	95 % CI
Exclusively breastfed (%)	Discharge	All	Observ.	Lang [8]	90	–	–	–	–
Exclusively breastfed versus not (%)	Discharge	PT	Observ.	Gupta et al. [45]	***55.9***				
Exclusive, high breastfeeding versus medium/low breastfeeding (%)	1-week after discharge	PT	Interv.	Abouelfettoh et al. [35]	***67.0***	***40.0***	***0.04***	***1.7***	***1.0, 2.8***
Almost exclusively breastfeeding or fed with expressed breast milk versus not (%)	1-week after discharge	PT	Interv.	Abouelfettoh et al. [35]	47	33	***0.29***	***1.4***	***0.7, 2.6***
Exclusively breastfeeding versus not (%)	3 months	PT	RCT	Yilmaz et al. [24]	77	47	<0.001	1.6	1.4, 1.9
Exclusively breastfeeding versus not (%)	6 months	PT	RCT	Yilmaz et al. [24]	57	42	<0.001	1.4	1.1, 1.6
Exclusive breastfeeding (median, days)	Duration	FT	RCT	Howard et al. [44][b]	21	14	0.29	1.1	0.9, 1.3
Full breastfeeding (median, days)	Duration	FT	RCT	Howard et al. [44][b]	45	37	0.74	1.0	0.8, 1.2
Subgroups									
Exclusive breastfeeding versus not (%), those that roomed-in	In hospital	PT	RCT	Gilks [36]	***91.0***	***36.4***	***0.01***	***2.5***	***1.1, 5.6***
Exclusively breastfed versus not (%), those that intended to breastfeed	Discharge	All	Observ.	Lang [8][c]	81	63	***<0.01***	***1.3***	***1.1, 1.5***
Exclusive breastfeeding, those who had >2 supplemental feedings	Duration	FT	RCT	Howard et al. [44]	–	–	<0.01	–	–
Full breastfeeding, those who had >2 supplemental feedings	Duration	FT	RCT	Howard et al. [44]	–	–	<0.01	–	–
Exclusive breastfeeding (median, days) those who had a Cesearan section	Duration	FT	RCT	Howard et al. [44]	21	11	0.04	–	–
Full breastfeeding (median, days), those who had a Cesearan section	Duration	FT	RCT	Howard et al. [44]	56	21	0.02	–	–

Bolded, italicized estimates were calculated based on data provided in the paper

GA gestational age, *PT* preterm, *FT* fullterm, *RCT* randomized clinical trial

[a] No confidence interval was reported nor calculated since there were a substantial number of twins that could not be accounted for in a post hoc analysis

[b] Hazard ratios were adjusted for predictors that were statistically significant at the $p < 0.10$ level

[c] Comparison was 'not cup fed' rather than bottle-fed

paladai is that, because it is made of steel, it sometimes cuts an infant's lip [21].

Discussion

We identified 28 original research articles on cup feeding in newborn infants. All studies were initiated after birth in a hospital setting. Neonatal cup feeding appears to be physiologically safe though intake may be less and spillage greater relative to bottle or tube feeding. Similar proportions of cup and bottle fed infants were breastfed at hospital discharge but cup fed infants appear more likely to be exclusively breastfed. Among certain subgroups, cup versus bottle feeding was statistically significantly associated with an increase in any and exclusive breastfeeding. Compliance and acceptability varied and may be problematic in certain settings.

In terms of safety, evidence on respiratory stability suggests that cup feeding is as or more stable than bottle-

Table 5 Hospital stay according to feeding method by gestational age and study design

References	Measure	GA	Study design	Duration of hospital stay	Cup	Bottle/tube	Difference	*p*
Yilmaz et al. [24]	Cup versus bottle	PT	RCT	Duration of hospital stay (days, mean, SD)	25.7 (2.2)	25.9 (2.2)	0.2	0.15
Collins et al. [41]	Cup versus bottle	PT	RCT	Duration of hospital stay (days, median, IQR)	59 (37–85)	48 (33–65)	11	0.01
Abouelfettoh et al. [35]	Cup versus bottle	PT	Interv.	Duration of hospital stay (days, mean, SD)	15.5 (8.1)	19.4 (9.8)	−3.9	0.09
Rekha and Rao [40]	Paladai versus tube	PT	Interv.	Duration of hospital stay (days, mean)	10.5	10	0.5	
Brown et al. [30]	Cup versus bottle	FT	Observ.	Median difference in maternity unit stay after supplement started (days)			1	0.09
Subgroups								
Collins et al. [41]	Cup versus bottle	PT	RCT	Duration of hospital stay after supplemental feeding started (days)	12	11	1	0.46
				Duration of hospital stay among those <28 weeks gestational age (days, IQR)	93 (86–113)	93 (72, 100)	0	0.03
				Duration of hospital stay among those 28 to 34 weeks gestational age (days, IQR)	45 (32–66)	40 (32–55)	5	0.01
				Among the subgroup who complied with assigned method	–	–	–	0.27

GA gestational age, *PT* preterm, *FT* full term, *Observ.* observational study, *RCT* randomized clinical trial, *Interv.* intervention study, *SD* standard deviation, *IQR* interquartile range

feeding in pre- and full term neonates that are generally healthy. A greater proportion of preterm and normal term infants with oxygen desaturation were bottle-fed suggesting infants cup feeding may be more physiologically stable [25, 33, 43]. Future studies that evaluate strategies to optimize physiologic stability while cup feeding may be informative and have particular relevance for infants with respiratory or cardiac problems. Cup size and shape may influence physiologic stability of cup feeding and may benefit from investigation.

Studies reporting on intake and spillage consistently demonstrate that cup fed infants may take in less and spill more than bottle-fed infants. Though cup fed infants may have lower intake, most studies did not report a statistically significant difference in weight loss. Differences in weight loss measures make it difficult to compare studies. Standardization of this measure would benefit future studies. Bottle fed infants having greater intake and greater oxygen desaturation is consistent with our hypothesis of a faster feeding pace with bottle-feeding. Future research could test this theory by comparing cup to bottles with different flow rates. Most studies that examined intake and spillage did not report on weight loss and vice versa. Future research that comprehensively evaluates intake, spillage, weight loss, and weight gain over time in a single RCT of cup versus bottle feeding could address whether lower intake translates into poorer weight gain.

Although most studies reported no difference in 'any breastfeeding' at or after hospital discharge, cup fed infants were more likely to be exclusively breastfed than bottle-fed infants. Our findings on 'any breastfeeding' are consistent with two Cochrane reviews [22, 23]. These reviews examined the same four RCTs on cup feeding (one also included a study on nasogastric tubes) [33, 36, 38, 41]. Although not as rigorous as those in the Cochrane series, our findings included many additional studies may provide insight for future research [3, 30, 35, 39, 44]. The conclusion by one review that 'cup feeding confers no significant benefit in maintaining breastfeeding beyond hospital discharge' may be premature. The recent RCT from Turkey found exclusive breastfeeding was statistically significant higher at 6 months post discharge in cup fed infants [24]. Exclusive breastfeeding for the first 6 months of life has wide ranging, well-established benefits to mother and infant. Future RCTs should consider examining exclusive breastfeeding through 6 months post-hospital discharge. Several studies identified subgroups for whom cup feeding may be helpful (e.g. mothers who delivered via cesarean section or roomed-in). Since the cesarean rate is relatively high in high- and middle-income countries and is increasing in low-incomes countries this may be an important consideration in breastfeeding promotion globally [46, 47]. Although post hoc findings from subgroup analyses should be viewed with caution, they do provide directions for future research.

Existing research indicates non-compliance with cup feeding is multifactorial and may involve nursing staff training and compliance, mother's intention, and an infant's ability to breastfeed. Nurses and parents do not always find cup feeding acceptable [29, 36, 41]. That those who complied with cup-feeding in one RCT were 21 times more likely to breastfeed than those who complied with bottle-feeding [41] suggests that cup feeding, when used as prescribed, could be a potent solution to transitioning preterm infants to breastfeeding. The mechanism by which cup feeding may enhances breastfeeding remains unclear. One explanation is that cup feeding avoids the 'nipple confusion' introduced by a bottle [4]. Another possibility we posit is that cup feeding is inconvenient or inefficient enough to motivate mothers to do everything possible to breastfeed. Lower intake and greater spillage with cup feeding likely affects compliance and acceptability. Clinical staff and parent acceptance may vary by context. For example, cup feeding is acceptable and even preferable to bottles in India and Kenya [21, 48]. In Europe and other high-resource settings, hospitals that routinely use and train providers on cup feeding may have greater compliance than hospitals that do not prescribe cup feeding [8, 24, 48]. In middle-income countries (e.g. Turkey) cup feeding occurs (Table 1), however there is little information on the acceptability of cup feeding in these settings. It is known that some report poor compliance even with extensive training [41]. Reasons for non-compliance and methods to improve cup feeding compliance should be investigated further.

Extended hospital stay was the primary reason the Cochrane reviews did not recommend cup feeding. The recommendation is based on a single RCT conducted in Australia [41]. Given there was no difference in length of stay in those who complied with their assigned feeding method in this study, length of hospital stay may not be due to cup feeding per se, but dissatisfaction with the method that led to a transition to another feeding method [41]. That the four other studies, including a recent large RCT from Turkey not in the Cochrane review found minimal differences in length of hospital stay suggests this recommendation may need to be reconsidered [24, 30, 35, 40].

UNICEF and WHO programs and guidelines recommend hand expression of breast milk and cup feeding for infants unable to breastfeed in low-resource and emergency settings [12, 49–52]. Cup feeding may reduce intake and increase spillage however this needs to be carefully weighed against alternatives such as the availability of nasogastric tubes or the risks of bottle feeding in low-resource settings [53, 54]. Certain cup shapes or sizes may improve outcomes. For example, the paladai compared to a generic cup minimizes spillage [21]. A cup feeder's training and skill may also influence intake and spillage. In low-resource settings, cup feeders are often mothers rather than nurses. Ensuring caregivers have the skill to optimally feed their infant may have a large impact on outcomes and infant survival. Current practices, compliance, and acceptability of cup feeding should be assessed in low-resource settings. Research on cup feeding is needed in low-resource settings such as Sub-Saharan Africa where cup feeding is the standard of care for infants unable to breastfeed, particularly since there is little existing research from these settings and it is the WHO and UNICEF recommendation.

There are limitations to the existing evidence. Few studies report on comparable outcomes. Within each domain, there was substantial variation in measures, making it difficult to compare studies. Several studies had methodological limitations. Some did not employ a comparison group [16, 42, 45] and many had small sample sizes [10, 16, 26–28, 38, 42]. Because most studies did not describe the cup or bottle used, it was impossible to evaluate the impact of cup design on outcomes. Shape, material, and ergonomics of feeding tools may influence intake, spillage, and feeding efficiency. Only one RCT analyzed their data using the gold standard intent-to-treat analysis [41]. Most non-randomized studies conducted unadjusted analysis [3, 20, 30, 40]. Not adjusting for confounding factors in observational studies (e.g. gestational age) could result in incorrect inference. Our search was limited to studies published in English and so we may have missed some information.

Given the wide reaching and well-established benefits of breast milk and long-term breastfeeding, perhaps the most important area of investigation is to evaluate exclusive long-term breastfeeding outcomes (e.g. 3 and 6 months), and breastfeeding outcomes in subgroups such as mothers who intend to breastfeed or had a Cesarean section. Additional research in low-resource settings is needed to optimize cup feeding in these settings. Lastly, research in infants with anomalies (cleft palate) that interfere with breastfeeding, particularly in low-resource settings, is needed to establish whether or not cup feeding is superior to other options (especially bottle) in these infants. Innovative approaches to cup feeding that optimize physiologic stability, milk intake, weight gain, and improve acceptability could potentially have a large impact on the long term health of infants with breastfeeding difficulties globally.

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Compliance with Ethical Standards

Conflict of Interest The authors declare they have no conflicts of interest.

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