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Volume marker inaccuracies: a cross sectional survey of infant feeding bottles

ABSTRACT

A cross sectional examination of the accuracy of volume markers on infant feeding bottles available for sale in NSW, Australia between December 2013 and February 2014 was carried out. Ninety-one bottles representing 28 different brands were examined. Volumes were marked in a combination of millilitres and ounces. Forty-two (46%) markings were embossed; 47 (52%) were printed on the bottle; 2 (2%) had both. Forty-seven (54%) bottles had no standard claim; 36 (41%) noted compliance with the European standard EN14350; 5 (6%) with non-existent Australian standards. Nineteen bottles (22%) had at least one measured marking outside the tolerance of EN14350. Markings both over and under-estimated true volume: mean tendency was to slightly over-estimate. Bottles claiming compliance with EN14350 were more likely to have inaccurate (10/36 versus 9/52). More expensive bottles did not have more accurate markings. Three bottles were disposable liner systems; these bottles had particularly large volume inaccuracies. Inaccurate volume markers on infant feeding bottles are a previously neglected but potentially important source of error in the reconstitution of infant formula. Over-concentrated and under-concentrated infant formula can cause serious illness or malnutrition. Over concentrated infant formula may contribute to obesity. Bottles with inaccurate volume markers are unfit for purpose; disposable liner bottles are particularly poor in this regard and should be prohibited from having volume markers on the bottle casing. To avoid individual or public harms, well-enforced standards are needed. Guidance for parents, carers and health professionals is needed to ensure infant formula is accurately reconstituted.

Key Words:

Infant; Infant Feeding; Bottle Feeding; Artificial Feeding; Standards

1 **INTRODUCTION**

2

3 Infants have special dietary needs. It is recommended that they be fed nothing
4 but breastmilk for the first 6 months of life and continue to be breastfed until
5 around 2 years of age (WHO and UNICEF, 2003). However, substantial
6 proportions of infants in developed nations, and increasingly in developing
7 nations, are exclusively or partially weaned from breastmilk in early infancy
8 (McAndrew et al., 2012; Australian Institute for Health and Welfare, 2011; Tang
9 et al., 2014; Lee Mendoza, 2010). When breastmilk is not available, infants
10 should be fed an infant formula that conforms to the relevant provisions of the
11 *Codex Alimentarius* (WHO and UNICEF, 2003; Fomon, 2001). Because infant
12 formula is a substitute for a human tissue and may be the sole source of nutrition
13 for infants for up to six months, strict regulation of its composition is necessary
14 (Cohen et al., 2010; Shaw, 2008). Variations in the nutritional profile of infant
15 formula can have significant implications for infant health (Fattal-Valevski et al.,
16 2005; Centers for Disease Control and Prevention, 1996; Skinner et al., 2010;
17 Taitz and Byers, 1972; Chambers and Steel, 1975; Keating et al., 1991).

18

19 Where infant formula is manufactured in powdered form, the provision of the
20 intended nutrition is dependent upon accurate reconstitution. Errors in the
21 measurement of powdered milk for reconstitution of infant formula, are
22 common in a variety of contexts (Wise, 1979; Jacob, 1985; Plaster and Bergman,
23 1995; Jeffs, 1989; Chambers and Steel, 1975; Paxson et al., 1977). However, the
24 measurement of an accurate volume of water is just as critical to the proper

25 reconstitution of infant formula. Parents using infant formula are routinely
26 instructed to reconstitute the product in infant feeding bottles using the volume
27 markers on the bottles to measure water (World Health Organization and Food
28 and Agriculture Organization, 2007). Such advice assumes that bottle volume
29 markers are accurate.

30

31 The only comprehensive standard for infant feeding bottles in the world is
32 EN14350 produced by the European Committee for Standardization (European
33 Committee for Standardization, 2004). In relation to accuracy of measurement,
34 EN14350 requires the validation of 3 volume markings. Where these volume
35 markers are less than 100mL they must be accurate to within 5mL of the
36 nominated value. Volume markers of 100mL or more must be accurate to within
37 5% of the nominated value. Although EN14350 is only enforceable within the
38 European Community, conformity with this standard used as a quality claim for
39 infant feeding bottles sold elsewhere. This study aimed to document the
40 accuracy of volume markings displayed on infant feeding bottles for sale in
41 Australia using the tolerance in the provisions of EN14350 as a benchmark.

42

43 **MATERIALS AND METHODS**

44

45 **Study design and setting**

46 A cross sectional examination of infant feeding bottles available for sale in NSW,
47 Australia between December 2013 and February 2014.

48

49 **Inclusion and exclusions criteria**

50 Purposive sampling: one sample of each and every bottle found available for sale
51 was purchased. All brands, volumes and shapes of infant feeding bottles were
52 eligible for inclusion. The search for bottles ceased when saturation was reached
53 and no additional bottle types could be found.

54

55 **Variables**

56 Deionised water was used to fill each bottle to its graduated markings so that the
57 base of the meniscus was level with the midpoint of markings at 50 mL, 60 mL,
58 90 mL, 100 mL, 120 mL and 150 mL. These volumes were chosen because they
59 are specified in instructions for reconstitution for infant formula in Australia for
60 infants 2 months of age and less (those most vulnerable in the event of
61 reconstitution error). The mass of the water to 0.1g was measured at each
62 individual graduation mark at 25°C. Bottles and water were weighed using an
63 A&D FX-400 balance (calibrated a week prior) and each measurement was
64 checked by two investigators and recorded. Duplicate measurements were made
65 for disposable liner bottles (bottle systems that had a rigid outer casing with a
66 disposable liner for holding liquid). Notes were made about the ease of
67 measurement and anomalies in markings.

68

69 **Data and statistical methods**

70 Data were entered in Excel 2013 (Microsoft, USA). Basic calculations of visually
71 observed volume vs volume by mass and percent difference between the two
72 measurements were also carried out in Excel. Data were then transferred to

73 Stata using StatTransfer v.13 (Circle Systems, USA). Data for results tables and
 74 the figures were produced in Stata Intercooled v.13.1 (StataCorp LP, USA). Sub-
 75 group analysis of bottles that claimed vs those that did not claim compliance
 76 with the existing regulatory standard was made. Since this was a descriptive
 77 study rather than one testing an a-priori hypothesis, a formal sample size
 78 calculation was not needed.

79

80 RESULTS

81

82 A total of 91 different infant feeding bottles were purchased, representing 28
 83 brands (mode 3 bottles per brand). These came from 19 different outlets
 84 including department stores, discount stores, chemists, supermarkets, hospital
 85 supply stores, online stores and convenience stores. Ninety-one of these bottles
 86 were hard-sided and 3 were disposable liner bottles. Table 1 summarizes the key
 87 characteristics of the 88 hard-sided bottles explored in the main analysis.

88

89 **Table 1** Main characteristics of hard-sided bottles included in study (n=88)
 90

Variable	N	%
Brands (n=27)	mode 3 per brand (min 1, max 10)	
Volume		
250 mL	25	28%
240 mL	13	15%
150 mL	11	13%
125 mL	12	13%
other <250mL	11	14%
other >250mL	16	18%
Price (\$, USD)*	median \$4.83 (IQR 2.23 to 8.90), min \$0.89, max \$26.71	
Marked in		
mL only	8	9%

mL and unspecified ounce	54	61%
mL and unspecified fluid ounce (fl. oz)	18	20%
mL and US fl. oz. †	2	2%
mL and UK fl. oz. †	3	3%
mL US AND UK oz	3	3%
Printed or embossed		
Embossed	40	45%
Printed	45	51%
Both (not aligned)	3	3%
Standards claim		
None	47	54%
European standards label	36	40%
“Australian approved safety standards”	5	6%

91 *Purchased in Australian Dollars between Dec 2013 and Feb 2014. US Dollar
92 price calculated at midpoint exchange rate, 15th Jan 2014. US\$1=AUS\$1.123
93 †UK (Imperial) fluid oz = 28mL; US fluid oz = 30mL

94

95 The commonest total volume of hard-sided bottles was 250mL (25 bottles, 28%
96 of sample); 47 (53%) were <250mL; and 16 (18%) were >250mL in volume.
97 Median price was \$4.83 USD per bottle, though there was a wide range (\$0.89-
98 \$26.71). Markings on some bottles were hard to read or ambiguous; for example,
99 one had a marking that was not horizontal but angled. Observers noted that
100 measuring water was easier in narrow bottles than in wide bottles. Most bottles
101 displayed markings in both millilitres and ounces, though often (54 bottles, 61%
102 of sample) the type of ounce was not specified. Forty bottles (45%) had
103 embossed markings, some of which were difficult to read; 45 (51%) had printed
104 markings. Three bottles (3%) had both printed and embossed markings but
105 these markings were not aligned with one another. The manufacturers of 36
106 (41%) bottles claimed that their product met EN14350.(European Committee for
107 Standardization, 2004) Five (6%) of bottles claimed adherence to “Australian

108 Approved Safety Standards” despite the absence of any Australian standard for
109 infant feeding bottles.

110

111 We found markings on nineteen bottles (22%) (range 1-5) that were outside the
112 accuracy requirement of EN14350. Thirty-nine bottles (44%) had at least one
113 missing marking (range 1- 3) for volumes specified in instructions for
114 reconstitution of infant formula available in Australia for infants 2 months of age
115 and younger (range 1-6). In total, 50 (57%) had either inaccurate or missing
116 markings. A summary of the frequency of inaccurate and missing markings is
117 presented in Table 2.

118

119 **Table 2** Frequency of inaccurate and missing volume markings on bottles
120

Volume	Inaccurate*		Missing	
	N	%	N	%
50	9	11	11	13
60	6	9	26	30
90	7	10	22	25
100	9	12	5	6
120	3	5	27	31
150	3	4	1	1
Total	37	9	92	

121 *Inaccurate is defined as being outside the tolerance levels provided by standard
122 EN14350 of plus or minus 5mls for volumes under 100mL and plus or minus 5%
123 for volumes over 100mL.
124

125 Bottles with inaccurate markings were produced or distributed by companies
126 based in Australia, China, New Zealand, UK and the USA and manufactured in
127 Bulgaria, China, Germany, New Zealand, Thailand, and the UK. Bottles with
128 missing markings were produced or distributed by companies based in Australia,

129 China, Malaysia, New Zealand, Singapore, UK and the USA and manufactured in
 130 Australia, Austria, China, Hungary, Germany, Thailand, UK, and the USA.

131

132 As shown in Figure 1 histograms and Table 3, markings slightly overestimated
 133 the actual volume of water present in the bottle: on average by 0.43mL at the
 134 50mL mark; 0.50mL at the 60mL mark; 0.57mL at the 90mL mark; 0.77mL at the
 135 100mL mark; 0.93mL at the 120mL mark; and 0.94mL at the 150mL mark. As
 136 illustrated by similar discrepancies and overlapping confidence intervals, mean
 137 accuracy was similar for embossed and printed markings. Mean volumes on
 138 bottles that claimed compliance with EN14350 were similar to those that did
 139 not. However, markings that were outside the tolerance requirements of
 140 EN14350 were more commonly found in bottles that claimed to meet this
 141 standard (10/36; 28%) compared with those that did not (9/52; 17%). There
 142 was no relationship between bottle price and overall accuracy of volume
 143 markings (Figure 2).

144

145 **Table 3** Volume differences according to key characteristics

146

Mean mL "off" (95% CI)	All bottles	Standard claim		Marking type	
		None	European standard	Embossed	Printed
At 50mL mark (n=80)	-0.43 (-1.1, 0.3)	-0.42 (-1.3, 0.4)	-0.31 (-1.6, 1.0)	-0.53 (-1.5, 0.4)	-0.7 (-1.6, 0.1)
At 60mL mark (n=65)	-0.50 (-1.2, 0.2)	-0.60 (-1.5, 0.3)	-0.17 (-1.3, 1.0)	-0.73 (-1.8, 0.4)	-0.34 (-1.2, 0.5)
At 90mL mark (n=68)	-0.57 (-1.4, 0.2)	-0.69 (-1.47, 0.1)	-0.34 (-1.8, 1.2)	-1.05 (-2.2, 0.1)	-0.67 (-1.6, 0.2)
At 100mL	-0.77	-1.11	-0.23	-1.28	

mark (n=84)	(-1.5, -0.1)	(-2.0, -0.2)	(-1.4, 1.1)	(-2.3, -0.2)	-0.35 (-1.3, 0.6)
At 120 mL mark (n=62)	-0.93 (-1.6, -0.3)	-0.99 (-1.7, 0.2)	-0.81 (-2.0, 0.4)	-1.23 (-2.1, -0.3)	-0.70 (-1.6-0.2)
At 150 mL mark (n=72)	-0.94 (-1.8, -0.1)	-1.42 (-2.6, -0.3)	-0.38 (-1.9, 1.2)	-1.67 (-2.8, -0.5)	-0.76 (-1.8, 0.3)

147
148

149 The disposable liner bottles were made by two manufacturers. Total volumes of
150 the liners were 300mL, 120mL and an unspecified maximum >150mL. Volume
151 markers printed on the rigid casings of these products underestimated water
152 volume to the extent that they were outside the requirements of EN14350 in all
153 but one case. Wide variations were observed when repeat measurements were
154 taken; expansion of the plastic liners with the addition of water was observed to
155 influence volume. Thus, second measurements in the same plastic liner resulted
156 in smaller discrepancies (not reported). Markings were both printed on the
157 bottle casing and embossed on the liners however, measurements could only be
158 made using the markings on bottle casings as the observers were unable to read
159 those printed on the plastic liners once they were filled with water. Table 4
160 shows volume discrepancies for the three disposable bottle systems in the
161 sample.

162

163 **Table 4** Volume discrepancies of the disposable liner bottles

Disposable bottle	Actual Volume at					
	50mL (% off stated volume)	60mL (% off)	90mL (% off)	100mL (%off)	120mL (% off)	150mL (%off)
Brand A	31.4 (-37%)	38.8 (-21%)	51.3 (43%)	70.1 (-30%)	86.8 (-28%)	138.5 (-8%)
Brand B – 300mls	56.6 (13%)	-	-	120.9 (21%)	-	184.0 (23%)

Brand B – 120mls	45.3 (9%)	-	-	93.7 (6%)	-
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164 - No mark at this volume
165

166 **DISCUSSION**

167

168 This study reveals volume markings on infant feeding bottles are commonly
169 inaccurate and may make it difficult for infant formula to be properly
170 reconstituted. An appreciable proportion of volume markings on the bottles
171 purchased were outside tolerances required by standard EN13450. Factors that
172 consumers might consider to indicate quality, such as claims of compliance with
173 EN13450 or price, were not associated with greater accuracy.

174

175 The “bottle marker” problem adds to an already long list of factors responsible
176 for error in infant formula reconstitution, including variation in composition of
177 powdered milk(Paxson et al., 1977); errors in measurement of powdered infant
178 formula due to addition of too few or too many scoops of powder(Lilburne et al.,
179 1988); under-filling, packing or using heaped scoops of infant formula(Lilburne
180 et al., 1988); and adding water or powdered infant formula in the incorrect
181 order.(Daly et al., 1998) Errors in infant formula reconstitution may neutralise
182 one another. However, it has been found that the parents, caregivers and health
183 professionals tend to add more powdered infant formula than is instructed,
184 resulting in over-concentration.(Lilburne et al., 1988; Chambers and Steel, 1975;
185 Jacob, 1985; McJunkin et al., 1987; Jeffs, 1989; Daly et al., 1998) The risk of over-
186 concentration is likely to be compounded by the tendency identified in this
187 study, of bottles to over-represent volumes.

188

189 Over-concentrated infant formula has implications for infant health. The most
190 extreme of these is hypernatraemia, a life threatening form of dehydration.(Taitz
191 and Byers, 1972; Chambers and Steel, 1975; Lilburne et al., 1988) Risks are
192 greatest in very small/premature infants whose renal function has least capacity
193 to deal with over-concentration and in young infants with diarrhoea. (Khuffash
194 and Majeed, 1984; Rhodin et al., 2009)

195

196 Less dramatic, but more significant for public health, over-concentrated infant
197 formula may contribute to excessive weight gain in infancy. Lucas et al (Lucas et
198 al., 1992) found that infants fed a powdered infant formula gained more weight
199 and were more likely to be overweight at 6 months of age than infants fed the
200 same volume of a comparable ready-to-use liquid infant formula. Over-
201 concentration of powdered infant formula resulted in consumption of an
202 additional 209 kJ/day.(Lucas et al., 1992) Other research indicates that infants
203 can self regulate energy intake, suggesting growth may not be affected by errors
204 in formula concentration. (Fomon et al., 1975; Adair, 1984) However, carer-
205 driven feeding may override compensatory mechanisms. (Bartok and Ventura,
206 2009)

207

208 Over-concentrated infant formula can also exacerbate constipation in formula
209 fed infants (Vandenplas et al., 2013; Nevo et al., 2007) and increase the severity
210 of gastro-oesophageal reflux disease.(Vandenplas et al., 2013; Salvia et al., 2001;
211 Carroll et al., 2002)

212

213 Under-concentrated infant formula also has health implications. Sustained
214 suboptimal nutrient intake could result in poor growth and development. (David
215 and David, 1984)

216

217 **Regulatory Framework**

218 Greater attention to the regulation of the manufacture of infant feeding bottles is
219 necessary to ensure that volume markers are accurate and adequate.
220 Comprehensive standards should require testing of all volume markers as
221 bottles can have a mixture of accurate and inaccurate volume markers. In
222 addition, standards should require that markings are present for the volumes of
223 water specified for infant formula reconstitution on the packaging of infant
224 formula products sold in corresponding markets. Missing markings are
225 potentially just as problematic as inaccurate ones as caregivers may seek to
226 estimate water volume using the available markers. Consideration might be
227 given to standardising the volumes of water required for reconstitution of infant
228 formula products.

229

230 This study suggests that volume markers on disposable liner bottles are grossly
231 inaccurate and that this problem is inherent to the design of these bottles. Thus,
232 disposable liner bottles should be prohibited from displaying volume markers so
233 that they cannot be used for measuring water. Although the study included only
234 bottles for sale within Australia, inaccurate bottles originated in a large number
235 of countries. This suggests that the problem of inaccurate volume markers is

236 unlikely to be limited to Australia and that international standards should be
237 developed.

238

239 This study also identified that active external monitoring and enforcement of
240 compliance with standards of manufacture is required. A number of bottles
241 claiming compliance with EN14350 had volume markers that were outside the
242 tolerance of the standard. As it currently stands, manufacturers are responsible
243 for monitoring compliance with EN14350 and there is no provision for testing
244 frequency within the standard.

245

246 **Advising on choice of infant feeding bottle**

247 Caregivers should be encouraged to choose infant feeding bottles that display
248 clear volume markings commensurate with the instructions printed on the infant
249 formula product they are using and to test the volume markers of purchased
250 bottles using a scale accurate to 1g. These are generally available in pharmacies
251 (where many parents purchase infant formula and bottles) and hospitals. In the
252 process of measuring water in bottles for the study it was noted that
253 measurement of water was easier in tall, thin bottles rather than squat and wide
254 ones. It is known that the narrower the container within which liquid is
255 measured, the more accurate the measurement. Hence, measuring cylinders and
256 pipettes are the instruments of choice in laboratories, and for applications where
257 accurate measurement of liquid volumes is crucial.(Ansel, 2012) Caregivers
258 should therefore be advised that narrow bottles will make accurate
259 measurement of water easier.

260

261 Those using powdered infant formula require instruction in the accurate
262 measurement of water. Providing parents with education can reduce adverse
263 consequences associated with dilution errors.(Sunderland and Emery, 1979)
264 However, despite requirements for individualised instruction for parents using
265 infant formula in schemes such as the Baby Friendly Hospital Initiative, there is
266 evidence that many parents do not receive such education.(Tarrant et al., 2012;
267 Wirihana and Barnard, 2012) Given the vulnerability of formula fed infants to a
268 variety of avoidable risks, including those associated with reconstitution errors
269 but also poor hygiene, cleaning and over feeding, this is alarming. Education and
270 support of parents and caregivers who are using infant formula by health
271 providers should be considered essential.

272

273 **Limitations**

274 There are a number of limitations to this research. One of each bottle type was
275 sampled. It may be that different production batches, or even different bottles
276 within the same batch, have greater or fewer accurate markings and that
277 accuracy would vary over time. It is also possible that that bottles for sale in
278 countries other than Australia may be less or more accurate. Indeed an
279 investigation by the New Zealand Ministry of Consumer Affairs found that even
280 when only a single volume marking was measured on bottles purchase in New
281 Zealand, 42% of bottles measured were inaccurately marked.(Ministry of Health,
282 2013)

283

284 The consequences of the inaccuracies we observed in “real life” settings, at
285 individual or population levels have not been studied. Further research is
286 necessary to ascertain how common the problems identified are and to
287 determine how inaccurate volume markers impact infant formula reconstitution
288 in practice.

289

290 **CONCLUSIONS**

291

292 Inaccurate volume markers on infant feeding bottles are a previously neglected
293 but potentially important source of error in the reconstitution of infant formula.

294 This study found a tendency of volume markers to over-estimate actual volume
295 of water: this predisposes to over-concentrated infant formula and potential
296 problems like hypernatremia, obesity and constipation. Other markers under-
297 estimate actual volumes and thus over-dilute the end product, predisposing to
298 under-nutrition. Infant feeding bottles with inaccurate volume markers should
299 be considered unfit for purpose: disposable bottle systems are particularly poor
300 in this regard. To avoid either individual or public harms, well-enforced
301 standards are needed, as is better guidance to both carers and health
302 professionals to accurately measure water volume when reconstituting
303 powdered infant formula.

304

305 **Key messages**

- 306 • Volume marker on infant feeding bottles can be inaccurate even where
307 compliance the European Standard EN14350 is claimed.

- 308 • Disposable liner bottle systems are particularly inaccurate and volume
309 markings on them should be prohibited to prevent them being used to
310 measure water.
- 311 • The health of formula fed infants is likely to adversely impacted by
312 inaccurate volume markers on infant feeding bottles leading to infant
313 formula reconstitution errors.

REFERENCES

- Adair LS. (1984) The infant's ability to self-regulate caloric intake: a case study. *Journal of the American Dietetic Association* 84: 543-546.
- Ansel HC. (2012) *Pharmaceutical Calculations* Philadelphia: Wolters Kluwer/ Lippincott Williams and Wilkins.
- Australian Institute for Health and Welfare. (2011) *2010 Australian National Infant Feeding Survey*, Canberra: AIHW.
- Bartok CJ and Ventura AK. (2009) Mechanisms underlying the association between breastfeeding and obesity. *International Journal of Pediatric Obesity* 4: 196-204.
- Carroll AE, Garrison MM and Christakis DA. (2002) A systematic review of nonpharmacological and nonsurgical therapies for gastroesophageal reflux in infants. *Archives of Pediatrics and Adolescent Medicine* 156: 109-113.
- Centers for Disease Control and Prevention. (1996) Infant metabolic alkalosis and soy-based formula- United States. *Morbidity and Mortality Weekly Report* 45: 985-988.
- Chambers TL and Steel AE. (1975) Concentrated milk feeds and their relation to hypernatraemic dehydration in infants. *Archives of Diseases in Children* 50: 610-615.
- Cohen RS, Xiong SC and Sakamoto P. (2010) Retrospective review of serological testing of potential human milk donors. *Archives of Disease in Childhood Fetal and Neonatal Edition* 95: F118-120.
- Daly A, MacDonald A and Booth IW. (1998) Diet and disadvantage: Observations on infant feeding from an inner city. *Journal of Human Nutrition and Dietetics* 11: 381-389.
- David CB and David PH. (1984) Bottle-feeding and malnutrition in a developing country: The 'bottle-starved' baby. *Journal of Tropical Pediatrics* 30: 159-164.
- European Committee for Standardization. (2004) Child use and care articles- Drinking equipment. *Part 1: General and mechanical requirements and tests EN 14350-1*.
- Fattal-Valevski A, Kesler A, Sela B-A, et al. (2005) Outbreak of life-threatening thiamine deficiency in infants in Israel caused by a defective soy-based formula. *Pediatrics* 115: e233-238.
- Fomon S. (2001) Infant feeding in the 20th century: Formula and beikost. *Journal of Nutrition* 131: 409S-420S.
- Fomon SJ, Filmer LJ, Jr., Thomas LN, et al. (1975) Influence of formula concentration on caloric intake and growth of normal infants. *Acta Paediatr Scand* 64: 172-181.
- Jacob F. (1985) Infant care: Getting it right. *Community Outlook*: 20-21.
- Jeffs SG. (1989) Hazards of scoop measurements in infant feeding. *Journal of the Royal College of General Practitioners* 39: 113.
- Keating JP, Schears GJ and Dodge PR. (1991) Oral water intoxication in infants: An American epidemic. *American Journal of Diseases of Children* 145: 985-990.
- Khuffash FA and Majeed HA. (1984) Hypernatremic dehydration in infants with gastroenteritis. *Clin Pediatr (Phila)* 23: 255-258.

- Lee Mendoza R. (2010) Breast Milk Versus Formula. *ICAN: Infant, Child, & Adolescent Nutrition* 2: 7-15.
- Lilburne AM, Oates RK, Thompson S, et al. (1988) Infant feeding in Sydney: A survey of mothers who bottle feed. *Journal of Paediatrics and Child Health* 24: 49-54.
- Lucas A, Lockton S and Davies PS. (1992) Randomised trial of a ready-to-feed compared with powdered formula. *Archives of Disease in Childhood* 67: 935-939.
- McAndrew F, Thompson J, Fellows L, et al. (2012) Infant Feeding Survey 2010. Leeds: Health and Social Care Information Centre.
- McJunkin JE, Bithoney WG and McCormick MC. (1987) Errors in formula concentration in an outpatient population. *Journal of Pediatrics* 111: 848-850.
- Ministry of Health. (2013) *Inaccurate volumen markings on baby feeding bottles*. Available at: <http://www.health.govt.nz/our-work/preventative-health-wellness/nutrition/inaccurate-volume-markings-baby-feeding-bottles>.
- Nevo N, Rubin L, Tamir A, et al. (2007) Infant feeding patterns in the first 6 months: an assessment in full-term infants. *J Pediatr Gastroenterol Nutr* 45: 234-239.
- Paxson CL, Adcock EW and Morris FH. (1977) Osmolalities of infant formulas. *American Journal of Diseases of Children* 131: 139-141.
- Plaster SE and Bergman EA. (1995) Variability of infant formula scoop weights. *Journal of the American Dietetic Association* 96: A64.
- Rhodin MM, Anderson BJ, Peters AM, et al. (2009) Human renal function maturation: a quantitative description using weight and postmenstrual age. *Pediatric Nephrology* 24: 67-76.
- Salvia G, De Vizia B, Manguso F, et al. (2001) Effect of intragastric volume and osmolality on mechanisms of gastroesophageal reflux in children with gastroesophageal reflux disease. *Am J Gastroenterol* 96: 1725-1732.
- Shaw R. (2008) The notion of the gift in the donation of body tissues. *Sociological Research Online* 13: 4.
- Skinner CG, Thomas JD and Osterloh JD. (2010) Melamine toxicity. *Journal of Medical Toxicology* 6: 50-55.
- Sunderland R and Emery JL. (1979) Apparent disappearance of hypernatraemic dehydration from infant deaths in Sheffield. *Br Med J* 2: 575-576.
- Taitz LS and Byers HD. (1972) High calorie/osmolar feeding and hypertonic dehydration. *Archives of Disease in Childhood* 47: 257-260.
- Tang L, Lee AH, Binns CW, et al. (2014) Widespread usage of infant formula in China: A major public health problem. *Birth* 41: 339-343.
- Tarrant RC, Sheridan-Pereira M, McCarthy RA, et al. (2012) Mothers who Formula Feed: Their Practices, Support Needs and Factors Influencing their Infant Feeding Decision. *Child Care in Practice* 19: 78-94.
- Vandenplas Y, Gutierrez-Castrellon P, Velasco-Benitez C, et al. (2013) Practical algorithms for managing common gastrointestinal symptoms in infants. *Nutrition* 29: 184-194.
- WHO and UNICEF. (2003) *Global Strategy for Infant and Young Child Feeding*, Geneva: WHO.

- Wirihana LA and Barnard A. (2012) Women's perceptions of their healthcare experience when they choose not to breastfeed. *Women Birth* 25: 135-141.
- Wise A. (1979) Errors in preparation of infant feeds. *Nutrition and Food Science* 79: 17-18.
- World Health Organization and Food and Agriculture Organization. (2007) *How to prepare formula for bottle-feeding at home*, Geneva: World Health Organization.

Figure 1 Histograms of mL difference between stated volume and measured volume at 50, 60, 90, 100, 120 and 150mL markings (if present, n=80, 65, 68, 84, 62, 72)

Figure 2 Scatterplot of bottle price in USD (x-axis) vs mL difference at 50mL marking

Table 1 Main characteristics of hard-sided bottles included in study (n=88)

Table 2 Frequency of inaccurate and missing volume markings on bottles

Table 3 Volume differences according to key characteristics

Table 4 Volume discrepancies of the disposable liner bottles