Original Article

Post-partum weight change patterns in the WHO Multicentre Growth Reference Study

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Abstract

The interplay of factors that affect post-partum loss or retention of weight gained during pregnancy is not fully understood. The objective of this paper is to describe patterns of weight change in the six sites of the World Health Organization (WHO) Multicentre Growth Reference Study (MGRS) and explore variables that explain variation in weight change within and between sites. Mothers of 1743 breastfed children enrolled in the MGRS had weights measured at days 7, 14, 28 and 42 post-partum, monthly from 2 to 12 months and bimonthly thereafter until 24 months post-partum. Height, maternal age, parity and employment status were recorded and breastfeeding was monitored throughout the follow-up. Weight change patterns varied significantly among sites. Ghanaian and Omani mothers lost little or gained weight post-partum. In Brazil, India, Norway and USA, mothers on average lost weight during the first year followed by stabilization in the second year. Lactation intensity and duration explained little of the variation in weight change patterns. In most sites, obese mothers tended to lose less weight than normal-weight mothers. In Brazil and Oman, primiparous mothers lost about 1 kg more than multiparous mothers in the first 6 months. In India and Ghana, multiparous mothers lost about 0.6 kg more than primiparas in the second 6 months. Culturally defined mother-care practices probably play a role in weight change patterns among lactating women. This hypothesis should stimulate investigation into gestational weight gain and post-partum losses in different ethnocultural contexts.

Keywords: maternal post-partum weight loss, women of childbearing age, breastfeeding, maternal obesity, WHO, cultural context.

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Introduction

Enhanced post-partum weight loss is one of the putative maternal benefits of breastfeeding. In settings where food availability is not constrained, breastfeeding may lessen the risk of post-partum weight retention, which often contributes to overweight and obesity. The World Health Organization (WHO) recently published attained child growth and velocity standards based on the WHO Multicentre Growth

Reference Study (MGRS), a population-based study (1997–2003) in six countries: Brazil, Ghana, India, Norway, Oman and USA (WHO MGRS Group 2006a). The sample was drawn from populations with access to adequate and safe food, lactation support, health care and environments that did not constrain infant and young child growth. In addition to infant anthropometric variables, the MGRS monitored maternal weight longitudinally throughout the first 24 months post-partum (de Onis *et al.* 2004). Maternal

body weight was measured at each visit to describe patterns of weight change across study sites.

Weight gain during pregnancy has been found to be the most consistent predictor of post-partum weight loss (Schauberger *et al.* 1992; Parker & Abrams 1993; Boardley *et al.* 1995; Butte & Hopkinson 1998; Thorsdottir & Birgisdottir 1998; Baker *et al.* 2008). Maternal pre-pregnancy body mass index (BMI) also predicts risk of weight retention. For women with pre-pregnancy BMI values in the normal range, post-partum weight targets a return to pre-gravid weight (Butte & Hopkinson 1998; Thorsdottir & Birgisdottir 1998). Mixed findings have been reported for obese women. Retention of the weight gained in gestation was higher (at 6 weeks post-partum) among mothers who were obese compared with those with lower pre-conception BMI in a study of women who delivered between 1980 and 1990 in a San Francisco hospital (Gunderson *et al.* 2001). Conversely, obese mothers in a more recent Danish cohort retained (at 6 months post-partum) less of the weight gained in gestation, or lost more weight than did mothers who had entered pregnancy with normal-weight BMI (Nohr *et al.* 2008) as well as at 18 months (Baker *et al.* 2008).

Apart from breastfeeding, other variables shown to influence post-partum weight change are parity and behaviours which influence energy balance, such as physical activity level and diet (Brewer *et al.* 1989; Dewey *et al.* 1993; Boardley *et al.* 1995; Chou *et al.* 1999; Baker *et al.* 2008). Researchers in the USA report that black women, compared with white women of equivalent socio-economic status and prenatal weight gain, are at higher risk of gestational weight retention (Parker & Abrams 1993). This difference may be attributable to differences in energy

consumption and/or energy expenditure in the post-partum period (Boardley *et al.* 1995).

Many studies attempting to estimate the influence of the intensity, exclusivity and duration of breastfeeding on post-partum weight change using a variety of methodological approaches have reported mixed findings. Two related randomized controlled trials in Honduras examined post-partum weight loss from 4 to 6 months in association with continued exclusive vs. supplemented breastfeeding (with solid foods). In the first trial, mothers who continued exclusive breastfeeding lost 0.6 kg more than the supplementing group, while the second trial found no significant difference between the two groups (Dewey *et al.* 2001). Dewey (2004) reviewed 13 observational studies, in seven of which post-partum weight change was measured. The majority of the studies showed significant positive associations between breastfeeding and loss in weight or body fat, and this was most evident between 3 and 6 months post-partum. A large Danish study found similar negative association between breastfeeding intensity and post-partum weight retention at 6 months and 18 months (Baker *et al.* 2008).

The influence of parity on gestational and post-partum weight changes was reviewed by Walker *et al.* (2005) and Rasmussen & Yaktine (2009). They found no detectable association between parity and weight retention at 6 weeks (Walker *et al.* 2005) or 6 months (Rasmussen & Yaktine 2009) post-partum. Other studies that assessed weight change after 6 months post-partum, however, suggest that multiparous mothers lose less of the weight gained in pregnancy than do primiparas (Coitinho *et al.* 2001; Baker *et al.* 2008).

Post-partum weight change patterns published from diverse countries illustrate great inter-individual variability both within and among studies (Butte

Key messages

- Cultural mother-care practices probably influence post-partum weight change patterns.
- The observed patterns in Ghana and Oman suggest that affluent women of childbearing age are a risk group in the growing prevalence of overweight in developing countries.
- Daily frequencies and the median duration of breastfeeding in this study did not differ significantly among obese, overweight and normal BMI mothers.

& Hopkinson 1998; Winkvist & Rasmussen 1999). The MGRS is the largest study using a standardized protocol to assess post-partum weight change in culturally and ethnically diverse populations over an extended period. Our objective is to describe the patterns of maternal weight change observed in the six sites, and to explore what variables explain significant proportions of the variation in weight change within and among sites.

Materials and methods

The design and methods of the MGRS and its site-specific implementation are described elsewhere (de Onis *et al.* 2004). Briefly, the MGRS combined a longitudinal component that followed 1743 infants from birth to age 24 months and a cross-sectional component that enrolled children aged 18–71 months. This paper describes data from the MGRS longitudinal component. In addition to data obtained at the infant's birth, maternal data of interest were collected during the 21 home visits made at days 7, 14, 28 and 42, monthly from 2 to 12 months and every 2 months during the infant's second year.

Food frequency reports were used to describe the infant's consumption of breast milk, other fluids and milk, and solid and semi-solid foods in the intervals between home visits. More detailed data on typical daily feeding were collected by 24-h dietary recalls of what the child had eaten or drunk throughout the day. The recommendations for breastfeeding in the MGRS were that it be exclusive or predominant for at least 4 months and that it continue until at least age 12 months.

Maternal weight was measured on portable electronic scales with taring capability and 0.1 kg precision (UNICEF Electronic Scale 890, UNICEF, Copenhagen, Denmark). Maternal heights were measured with the Harpenden Portable Stadiometer (Chasmors, London, UK). For the weight change analysis, maternal weight at day 14 post-partum was chosen as the baseline, on the assumption that 14 days were reasonably adequate for maternal weight to stabilize with respect to fluid retention and fluctuations in body composition characteristic of the early post-partum period (Dewey 2004; Hatsu *et al.*

2008). For mothers who became pregnant during the follow-up, only the weights measured before they got pregnant were retained for the analysis.

We examined distributions of maternal characteristics (maternal age, parity, delivery mode, weight and BMI at baseline, and employment outside the home) and breastfeeding practices (exclusive or predominant breastfeeding in the first 6 months, breastfeeding frequency/day at 3, 6, 9 and 12 months, and breastfeeding duration) likely to influence maternal post-partum weight change patterns.

The volume of breast milk consumed was not measured directly in the MGRS. We therefore used the frequencies and volumes of fluids, likely consumed in inverse proportion to breast milk, to create inverse-proxy variables as potential estimators of lactation intensity. Average measures of intensity for the intervals 14 days–6 months and 6–12 months were time-weighted by the number of days between home visits corresponding to each interval and used to create four variables:

1. average ratio of breastfeeding frequency to the intake frequency of all milks (i.e. breast milk, animal milks or infant formula);
2. average ratio of breastfeeding frequency to the intake frequency of all milks and juices;
3. average of total intake volume of milks other than breast milk; and
4. average of total intake volume of juices and milks other than breast milk.

All four variables were highly skewed – for example, the inter-quartile limits for the first of these variables were 0.87 and 1 (range 0–1). Each was therefore recoded into three categories: <25th, 25–75th and >75th centile, for use in further analyses. From the information recorded in the MGRS on exclusivity and duration of breastfeeding, we also created a score similar to what has been used in other studies (Linné *et al.* 2002; Baker *et al.* 2008) for investigation as an alternative proxy measure of breastfeeding intensity.

The main outcome variable for the analyses presented in this paper is actual change in weight (kg). With weight at 14 days post-partum as the baseline,

weight change at 12 months, for example, is the difference between the mother's weight at 12 months and at 14 days post-partum. For some analyses, weight change over specific intervals (e.g. between 3 and 6 months) was considered, in which case, weight at the beginning of the specified interval served as the baseline.

Analyses done included the estimation of summary statistical measures (e.g. means and respective confidence intervals, medians and ranges), *t*-tests and multiple linear regressions. The statistical package S-Plus was used for these analyses (S-PLUS® 8.0 for Windows, 2007, Insightful Corp., Seattle, WA, USA). Comparisons were also made using graphs and tables.

Results

The starting sample was the full MGRS longitudinal sample, comprising 1743 mothers, with one measurement of height and 21 follow up assessments of weight. Table 1 presents a summary description of the sample by site, showing that 1542 (88.5%) mothers completed the study and contributed a total of 29 311 observations that have been used for the analyses presented in this paper [excluding 1529 (5%) pregnancy weights of mothers who became pregnant during the follow-up, but retaining their pre-pregnancy weights]. The BMI distributions (at 14 days, 3 months, 6 months, 9 months and 12 months post-partum) for mothers who dropped out of the study were no different from those of the group that completed the follow-up (data not shown).

Table 2 presents, by site, maternal characteristics potentially relevant to post-partum weight change in the final sample. Mean ages ranged from 27.7 years in Oman to 31.5 years in the USA. The majority of mothers in Brazil, India, Norway and the USA were primiparous compared with 37.0% in Ghana (median parity 2; range 1–8) and 25.8% in Oman (median parity 3; range 1–12). Employment outside the home was common overall, but ranged from minority proportions in India (35.7%) and Oman (44.2%) to majorities of between 77.5% (Norway) and 84.9% (Ghana).

Summary information related to the birth and infancy of the index child is also presented in Table 2. Norway had the largest percentage of vaginal deliveries (91.2%), followed by Oman and the USA with over 80%. The only site with majority Caesarean sections was Brazil (54%). Ghanaian mothers were the heaviest with a median BMI above 27 kg m⁻² at 14 days post-partum, while the Norwegians had the lowest BMI (median, 24.0 kg m⁻²). Over 90% of Ghanaian mothers complied with the study criteria for exclusive/predominant breastfeeding compared with 49% in Brazil. Just over 86% complied in Norway and the USA, while India and Oman had compliance rates of 76.6% and 66.4%, respectively. All sites but Brazil (with 32.6%) had well over half the mothers (64.4–83.6%) breastfeeding throughout the first year post-partum. The median duration of breastfeeding was longest in Oman (22 months) and shortest in Brazil (8 months). The duration of breastfeeding was

Table 1. Sample description (composition)

	Brazil	Ghana	India	Norway	Oman	USA	Total
Individuals							
Full sample	310	329	301	300	295	208	1743
Study completed (mothers who got pregnant during study)*	287 (23)	292 (77)	269 (19)	262 (59)	260 (94)	172 (56)	1542 (328)
Study not completed	23	37	32	38	35	36	201
Observations							
Study completed	5740	5840	5380	5240	5200	3440	30 840
Observations of pregnant mothers	114	367	91	224	485	248	1529
Final sample†	5626	5473	5289	5016	4715	3192	29 311

*Subset of mothers who completed the study. †Excluding observations from the visit when a mother reported pregnancy and subsequent visits.

Table 2. Maternal characteristics and BF practices by site

	Brazil	Ghana	India	Norway	Oman	USA	All
Maternal age (y)*	28.3 (6.3)	30.8 (3.9)	29.0 (3.5)	30.8 (4.3)	27.7 (5.0)	31.5 (4.5)	29.6 (4.9)
Primiparous (%)	50.2	37.0	53.5	54.6	25.8	51.7	45.1
Maternal employment (%)	70.0	84.9	35.7	77.5	44.2	85.5	63.0
Vaginal delivery (%)	46.0	75.7	59.5	91.2	86.9	85.5	73.0
Maternal BMI at 14 days†	25.0 (18.4; 37.1)	27.1 (18.5; 41.8)	25.1 (17.9; 43.0)	24.0 (17.2; 36.9)	25.6 (16.0; 47.7)	24.9 (18.7; 40.9)	25.2 (16.0; 47.7)
Exclusive/predominant BF‡ (%)	49.0	90.4	76.6	86.4	66.4	86.5	75.1
BF up to 12 months (%)	32.6	83.6	74.4	64.4	82.2	77.1	68.3
BF duration (months)†	8.3 (0.5; 24)	15.5 (2; 24)	14.9 (2; 24)	13.1 (1; 24)	22 (1.5; 24)	15.6 (1.4; 24)	14.5 (0.5; 24)
BF frequency per day at selected ages*							
3 months	7.2 (4.0)	12.8 (3.9)	10.0 (2.5)	8.0 (2.1)	11.4 (3.1)	8.6 (2.4)	9.7 (3.7)
6 months	4.4 (4.0)	9.3 (4.4)	6.5 (3.1)	7.0 (2.5)	9.3 (3.9)	7.6 (3.2)	7.3 (4.0)
9 months	2.7 (3.4)	7.7 (4.8)	4.9 (3.1)	4.4 (2.7)	8.3 (3.9)	5.9 (3.0)	5.6 (4.1)
12 months	1.8 (3.0)	6.4 (5.0)	3.5 (2.9)	2.3 (2.2)	7.0 (4.2)	4.3 (3.2)	4.2 (4.1)

BF, breastfeeding; BMI, body mass index. *Mean [standard deviation (SD)]; †Median (minimum; maximum); ‡Exclusive or predominant breastfeeding at 4 months.

truncated at 24 months when the MGRS follow-up ended, with 11.2% of the children still breastfeeding. Based on 24-hour dietary recalls, Ghana and Oman had consistently higher average breastfeeding frequencies than the other four sites. As expected, the median frequencies were highest at age 3 months, ranging between seven (Brazil) and 13 times (Ghana), and by age 12 months, they had dropped to between two (Brazil and Norway) and seven times (Oman).

Bivariate associations between weight change and age, delivery mode or employment status were not statistically or clinically significant (data not shown). To examine associations between breastfeeding and the outcomes of interest, weight change between 14 days and 6 months was regressed on each of the four inverse-proxy estimators of lactation intensity, adjusted for maternal age, BMI at 14 days, parity, delivery mode, and infant birthweight and sex. From all four models, the highest coefficient of determination was around 5%, indicating that 95% of the variability in maternal weight change remained unexplained. Analogous results were obtained when the weight change between 6 and 12 months was used as a dependent variable with the same set of covariates, and site-specific models were even less informative. Similar analyses using the breastfeeding intensity score calculated on the basis of exclusivity and duration of breastfeeding also yielded non-significant results. For subsequent analysis, therefore, we reverted to the use of breastfeeding frequency as the proxy estimator of lactation intensity.

The patterns of change in BMI are summarized in Fig. 1. Median BMI values in all sites declined sharply between 7 days and 14 days post-partum. The BMI of Indian, Omani and US mothers stabilized for the next 2 weeks, while in the remaining sites, the downward trend continued for longer periods. Mothers in Ghana began to regain weight at 2 months and maintained a gently rising trend that kept the site's median BMI above 27 kg m⁻² through to the end of the second year. The overall pattern in Oman was very similar to that seen in Ghana, but the median BMI remained below 26 kg m⁻² throughout the observation period. The other four sites experienced downward trends throughout the first year followed by plateaus in the

Fig. 1. Median post-partum maternal body mass index (BMI) patterns by site.

Fig. 2. Median post-partum maternal weight change relative to day 14 by site.

second year. Norwegian mothers' median BMI stood apart at the bottom, beginning at 24 kg m^{-2} and finishing below 23 kg m^{-2} .

Figure 2 depicts median weight change relative to individuals' own weights at 14 days post-partum. Weights in Ghana again stood apart and above the other sites: after a drop of 500 g from day 14 to the end of the first month, the change in weight took on an overall positive trend ending at 24 months with a net gain of about 800 g. The rest of the sites experienced cumulated weight losses up to 12 months with stabili-

zation in the second year. Aside from Ghana and Oman, the relative positions of the weight change curves for the other four sites are quite different from what was observed in the BMI graph. On average, Indian mothers lost no weight between day 14 and 2 months, but thereafter, their weight change curve followed a steady downward trend, dropping below Oman and eventually, Brazil and Norway, by 24 months. The USA experienced the largest weight change, registering a median loss in excess of 4 kg by 24 months.

Looking at individual weight change, almost 60% of mothers ($n=909$) experienced both gains and losses (relative to day 14) at various points post-partum, compared with 129 (8.5%) who experienced only gains and 484 (31.8%) who experienced only losses during the 2-year follow-up (Table 3). In the distribution of individual mothers' maximum weight losses, the site medians ranged from 2.7 kg in Ghana to 6.5 kg in the USA. The magnitude of gains was a lot smaller than that of losses, medians here ranging between zero in the USA (51% of US mothers experienced only losses) and 3.8 kg in Ghana. In absolute terms, the maximum observed loss (27.2 kg) was in the same range as the maximum observed gain (28.4 kg). Looking at the overall picture of losses vs. gains, the mothers in all sites except Ghana had a greater propensity to lose rather than to gain weight.

The possible influence of parity on weight loss was examined by comparing primiparous and multiparous mothers in respective trimesters of the first year. The *t*-test results showed a few significant differences between the two groups' maternal weight changes, but there was no systematic pattern in these across the sites (data not shown). However, where the significant differences fell in the first half of infancy, primiparas had higher weight losses than multiparas [Brazil in the first trimester (900 g), and Oman in both the first (1150 g) and second (1110 g) trimesters]. The opposite applied in the trimesters 6–9 months and 9–12 months where, respectively, Indian and Ghanaian multiparas lost about 600 g more than their primiparous counterparts. In Norway and the USA, none of the differences were significant at the 5% level.

Comparative analyses were then carried out to investigate associations between weight change and BMI grouping at 14 days post-partum ($<25 \text{ kg m}^{-2}$ as normal, 25 to 29.9 kg m^{-2} as overweight and $\geq 30 \text{ kg m}^{-2}$ as obese). The fewer than 1% of mothers in the final sample who had BMI below 18.5 were merged with the normal BMI group. Brazil, India, Norway and the USA each had fewer than 30 mothers in the obese category.

We explored breastfeeding frequency in the different BMI groups in each site. If maternal BMI

Table 3. Estimates of maximum weight losses and gains (kg)

Site	<i>n</i>	Median of nadirs in weight loss (kg)	Observed maximum weight losses (kg)	Mothers with only losses (<i>n</i>)	Median of peaks in weight gain (kg)	Observed maximum weight gains (kg)	Mothers with only gains (<i>n</i>)
Brazil	281	-5.1	-20.8	99	0.6	16.5	22
Ghana	287	-2.7	-18.4	54	3.8	21.7	44
India	267	-5.0	-24.8	62	1.6	12.2	18
Norway	258	-5.5	-19.6	116	0.2	25.5	6
Oman	260	-3.9	-27.2	66	1.8	25.0	33
USA	169	-6.5	-23.0	87	0.0	28.4	6
Total*	1522	-4.7	-27.2	484	1.2	28.4	129

*Twenty mothers have missing weights at baseline (day 14).

Fig. 3. Means and 95% confidence intervals of average frequency of breastfeeding by interval, by body mass index group.

covaried systematically with breastfeeding intensity (insofar as this could be estimated by breastfeeding frequency), patterns confirming such associations might be evident in Fig. 3. The figure presents average breastfeeding frequency in each of the four trimesters of the first year post-partum. In all sites, and regardless of the trimester considered, the 95% confidence intervals around the mean frequencies of breastfeeding by BMI groups overlapped. Patterns in Ghana, Norway and Brazil suggested that between 3 and 12 months, normal BMI mothers had the highest breastfeeding frequencies and obese mothers consistently had the lowest. No such patterns were evident in the other sites.

Figure 4 presents the patterns, by site, of mothers' median weight change (relative to weight at 14 days) by maternal BMI grouping. The three BMI groups

followed similar within-site patterns in Ghana, India and Oman. In Brazil and Norway, the obese groups' weight curves stood out above the normal and overweight groups. For Brazil, the obese group had a definite positive trend in weight that was also observed, although to a lesser degree, in Norway. The figure also displays the median ages at breastfeeding termination. The greatest distinctions among BMI groups were observed in Brazil and the USA. Obese mothers in Brazil had a median weaning age of less than 6 months vs. almost 9 months in the normal BMI group. Conversely, in the USA, median weaning age in the obese group was 21 months compared with the normal BMI group's 15 months. For the other sites, there was no clear distinction in median weaning ages for the different groups. Overall, there is nothing in the curves to suggest that cessation of breastfeeding

Fig. 4. Median weight change by maternal body mass index group (symbols indicate the median weaning age).

had any influence on the pattern of maternal weight change in any site or BMI grouping.

We also looked at cumulative changes over varying intervals: 14 days–6 months, 14 days–12 months, 14 days–18 months and 14 days–24 months (Table 4). In Brazil, regardless of the reference time frame, both normal BMI and overweight mothers experienced net losses, although these were more pronounced in the latter group. Conversely, the obese group had a net gain of 5.1 kg from baseline to 24 months. In Ghana, on average, all groups gained weight. The overall tendency was for the normal BMI group to gain double or triple the weight gained by the other two groups. In India, the highest net losses were observed in the obese group and the lowest usually in the normal BMI group. The alignment of the BMI groups was the same in Norway as in the USA; regardless of the

interval considered, the greatest losses were observed among the overweight, followed by the normal BMI group. In both sites, the obese groups experienced the least losses; in fact, this group in Norway experienced net gains in the 12-, 18- and 24-month intervals. In Oman, the normal BMI and overweight groups were closely comparable except in the first semester where the median loss in the overweight group was 200 g compared with 1.8 kg in the normal BMI group. The obese group experienced the least average losses (and net gains from 0 to 12 months).

Discussion

The MGRS design was ideal for assessing post-partum maternal weight change, with baseline weight measured in the first weeks and mothers followed

Table 4. Estimates of maternal weight change – median (minimum, maximum) – by 6, 12, 18 and 24 months

Site	BMI group (n)	Median weight change 14 days–6 mo (kg)	Median weight change 14 days–12 months (kg)	Median weight change 14 days–18 months (kg)	Median weight change 14 days–24 months (kg)
Brazil	Normal (141)	–2.1 (–8.6, 9.6)	–3.0 (–11.2, 7.4)	–2.3 (–10.8, 7.5)	–1.9 (–10.1, 15.4)
	Overweight (111)	–2.3 (–12.3, 8.9)	–4.2 (–19.5, 9.5)	–3.8 (–20.7, 12.7)	–3.8 (–17.5, 12.6)
	Obese (29)	0.3 (–9.1, 10.8)	–0.1 (–15.6, 14.8)	2.6 (–16.9, 15.5)	5.1 (–20.8, 15.0)
Ghana	Normal (83)	1.8 (–8.1, 12.8)	0.3 (–10.2, 12.4)	1.0 (–11.6, 14.0)	1.5 (–9.6, 13.3)
	Overweight (141)	0.9 (–11.1, 18.0)	0.9 (–12.5, 19.2)	0.6 (–12.1, 16.7)	0.3 (–12.8, 16.6)
	Obese (60)	0.7 (–9.6, 12.0)	0.6 (–13.7, 15.6)	0.5 (–17.7, 16.0)	0.4 (–15.7, 15.0)
India	Normal (132)	–1.1 (–9.7, 10.5)	–2.4 (–12.4, 8.2)	–2.2 (–10.3, 9.1)	–1.9 (–12.4, 10.2)
	Overweight (109)	–1.0 (–10.7, 7.7)	–3.4 (–15.4, 9.4)	–3.1 (–15.7, 12.2)	–4.2 (–14.2, 9.8)
	Obese (26)	–1.4 (–10.3, 6.1)	–5.5 (–18.2, 4.6)	–4.7 (–24.8, 8.5)	–4.1 (–21.8, 5.7)
Norway	Normal (163)	–3.0 (–11.4, 6.0)	–3.1 (–15.3, 7.7)	–2.6 (–12.4, 9.9)	–2.8 (–13.6, 13.0)
	Overweight (78)	–3.1 (–14.2, 13.1)	–4.3 (–16.5, 14.3)	–5.0 (–19.6, 14.8)	–3.6 (–13.1, 16.8)
	Obese (16)	–0.8 (–14.9, 8.5)	0.4 (–12.5, 17.5)	1.2 (–13.5, 10.5)	3.1 (–11.8, 25.5)
Oman	Normal (119)	–1.8 (–10.6, 8.7)	–2.0 (–12.8, 7.7)	–2.4 (–10.8, 9.0)	–0.9 (–10.0, 12.1)
	Overweight (85)	–0.2 (–13.3, 10.3)	–1.8 (–14.5, 8.5)	–2.4 (–18.4, 9.4)	–1.1 (–16.1, 10.2)
	Obese (56)	0.8 (–11.3, 13.8)	0.1 (–12.7, 16.7)	–1.0 (–11.9, 22.2)	–0.2 (–11.9, 25.0)
USA	Normal (85)	–3.2 (–9.4, 6.2)	–4.6 (–11.3, 7.7)	–4.4 (–11.3, 6.1)	–3.7 (–11.8, 8.7)
	Overweight (63)	–3.6 (–11.0, 6.7)	–5.6 (–14.2, 11.8)	–5.1 (–18.2, 12.3)	–6.4 (–17.2, 4.4)
	Obese (21)	–2.7 (–9.3, 9.4)	–2.4 (–23.0, 7.6)	–1.0 (–18.7, 11.6)	–3.2 (–19.3, 14.2)

BMI, body mass index.

longitudinally for 24 months. The weight change patterns observed in Brazil, India, Norway and the USA followed the expected trend of sustained loss in the first year, with plateaus or slight upward shifts in the second year, as observed in an earlier US study (Dewey *et al.* 1993). Net losses at 24 months averaged 2–4 kg. The situation was different in Ghana where mothers on average gained weight, and to a lesser extent in Oman with very little net loss. Individually, mothers were more likely to lose than to gain weight (except in Ghana), and the overall magnitude of losses experienced was higher than the magnitude of gains. Nonetheless, inter-subject variation was extremely high even within sites.

Previous studies suggest that ethnicity may be a contributing factor to variations in post-partum weight loss (Walker *et al.* 2006). In a study by Parker & Abrams (1993), black mothers were more likely to retain a larger proportion of weight gained in gestation or to gain new weight in the post-partum period than white mothers. A similar risk of weight retention was observed by Boardley *et al.* (1995), but it was associated with higher consumption of total and fat calories among black mothers, who also exercised less than their white counterparts. Maternal food intake

and physical activity data were not collected in the MGRS, but cultural practices in the different sites might explain the patterns observed in Ghana, India and Oman.

In Ghana, a close relative – usually the mother – takes over the household chores of the newly delivered woman. The new mother receives a markedly improved diet of rich soups and sauces with lactation-enhancing herbs and the best portion of the family pot. In this period, mothers do not make any conscious effort to lose weight, and engaging in physical activity for this purpose happens only rarely in Ghana (AL, unpublished observations).

Similarly, newly delivered Indian mothers are surrounded by their mothers, grandmothers and other relatives, and may be totally confined for 40 days, particularly if the baby is a boy or a firstborn. It is a period of celebration and many religious rituals invariably accompanied by elaborate meals. Moreover, the mothers receive special diets and high-calorie preparations (from cereals, ghee and sugar) that are meant to overcome the fatigue of delivery, increase breast milk production and promote early involution of the uterus (NB, unpublished observations). This might explain why Indian

mothers began to lose weight only after 2 months post-partum.

Cultural practices in Oman also do little to enhance post-partum weight loss. A newly delivered mother and her child are accorded special care, rich with celebration and feasting by the extended family and community (Hammad *et al.* 1999). Most Omani households in the MGRS sample (83%) extended beyond the nuclear family, all including one or more house maids. These living arrangements and cultural observances afforded the mothers much rest and few opportunities to actively lose weight.

Earlier studies in Denmark and Brazil found that higher parity (adjusted for age) was positively associated with overweight and obesity, and that it attenuated lactation-attributable weight loss (Coitinho *et al.* 2001; Baker *et al.* 2008). This overall pattern appears to be reflected in Ghana and Oman where mothers had highest parity and baseline BMI, and experienced the least weight loss despite having the highest reported frequency and overall duration of breastfeeding.

Typically, studies that have found no association between breastfeeding and weight loss reported very low rates of breastfeeding (Schauberg *et al.* 1992; Boardley *et al.* 1995). In contrast, the MGRS fostered a 'pro-lactation culture' resulting in very high overall rates of breastfeeding (WHO MGRS Group 2006b), especially in the period of 3–6 months, where breastfeeding is reported to have the strongest association with post-partum weight loss (Dewey 2004). In the absence of any direct measurement of breastfeeding intensity, the variables used in this analysis as proxies do not appear to have been precise enough to capture variation in caloric output through lactation. Alternatively, as breastfeeding stimulates appetite, lactating mothers, particularly in Ghana and Oman, may have failed to mobilize the fat stores accumulated during pregnancy and/or gained new weight in the post-partum period.

Looking at the weight change in three BMI strata, while no clear-cut difference was detectable in Ghana, other sites showed distinctive patterns: in India, obese mothers experienced the biggest weight losses, while in Brazil, Norway, Oman and the USA, they had lower weight losses than the normal BMI

and overweight groups. The pattern in these latter four sites is similar to those reported by Gunderson *et al.* (2001) among mothers in California. A review by Lederman (2004) concluded that breastfeeding alone could not be expected to prevent permanent weight retention after pregnancy in overweight women, yet among Danish mothers, this failure to lose gestational weight with breastfeeding was observed in only the very obese mothers (Baker *et al.* 2008).

The eligibility criteria for enrolment into the MGRS were child-centred and focused on selecting children in environments most likely to promote healthy growth. The selection criteria relating to mothers resulted in a sample of non-smoker mothers who were highly motivated to breastfeed. At the global level, culturally defined mother-care practices in the post-partum period are the most likely explanation of the observed site differences in weight change patterns in the MGRS. Future research should look in greater depth at post-partum weight change in relation to gestational weight gain and post-delivery energy consumption and expenditure in different ethnocultural contexts.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

AS and EB analysed the data and participated in preparation of the first draft; AWO coordinated the data analysis plan, writing and review of the manuscript and completed the final version; LN-R, MdO and CG, participated in the analysis plan and revision of the manuscript; and AL, AB, NB, KGD, CLA, AJM, JVdB reviewed and contributed to later versions of the manuscript.

References

- Baker J.L., Gamborg M., Heitmann B.L., Lissner L., Sørensen T.I.A. & Rasmussen K.M. (2008) Breastfeeding reduces postpartum weight retention. *American Journal of Clinical Nutrition* **88**, 1543–1551.
- Boardley D.J., Sargent R.G., Coker A.L., Hussey J.R. & Sharpe P.A. (1995) The relationship between diet, activity, and other factors, and postpartum weight change by race. *Obstetrics and Gynecology* **86**, 834–838.
- Brewer M.M., Bates M.R. & Vannoy L.P. (1989) Postpartum changes in maternal weight and body fat depots in lactating vs nonlactating women. *American Journal of Clinical Nutrition* **49**, 259–265.
- Butte N.F. & Hopkins J. (1998) Body composition changes during lactation are highly variable among women. *Journal of Nutrition* **128** (Suppl. 2), 381S–385S.
- Chou T.W., Chan G.M. & Moyer-Mileur L. (1999) Postpartum body composition changes in lactating and nonlactating primiparas. *Nutrition* **15**, 481–484.
- Coitinho D.C., Sichieri R. & D'Aquino Benício M.H. (2001) Obesity and weight change related to parity and breast-feeding among parous women in Brazil. *Public Health Nutrition* **4**, 865–870.
- de Onis M., Garza C., Victora C.G., Onyango A.W., Frongillo E.A. & Martines J. for the WHO Multicentre Growth Reference Study Group (2004) The WHO Multicentre Growth Reference Study: planning, study design, and methodology. *Food and Nutrition Bulletin* **25** (Suppl. 1), S15–S26.
- Dewey K.G. (2004) Impact of breastfeeding on maternal nutritional status. In: *Protecting Infants through Human Milk: Advancing the Scientific Evidence Base* (eds L.K. Pickering, A.L. Morrow, G.M. Ruiz-Palacios & R.J. Schanler), pp 91–100. Kluwer Academic/Plenum Publishers: New York.
- Dewey K.G., Cohen R.J., Brown K.H. & Rivera L.L. (2001) Effects of exclusive breastfeeding for four versus six months on maternal nutritional status and infant motor development: results of two randomized trials in Honduras. *Journal of Nutrition* **131**, 262–267.
- Dewey K.G., Heinig M.J. & Nommsen L.A. (1993) Maternal weight-loss patterns during prolonged lactation. *American Journal of Clinical Nutrition* **58**, 162–166.
- Gunderson E.P., Abrams B. & Selvin S. (2001) Does the pattern of postpartum weight change differ according to pregravid body size? *International Journal of Obesity* **25**, 853–862.
- Hammad A., Kysia R., Rabah R., Hassoun R. & Connelly M. (1999) *Guide to Arab culture: Health care delivery to the Arab American community*. Community Health and Research Center. Public Health Education and Research Department. Series of Research Report No. 7. Arab Community Center for Economic and Social Services (ACCESS): Dearborn, MI.
- Hatsu I.E., McDougald D.M. & Anderson A.K. (2008) Effect of infant feeding on maternal body composition. *International Breastfeeding Journal* **3**, 1–8.
- Lederman S.A. (2004) Influence of lactation on body weight regulation. *Nutrition Reviews* **62** (Pt. 2), S112–S119.
- Linné Y., Barkeling B. & Rössner S. (2002) Long-term weight development after pregnancy. *Obesity Reviews* **3**, 75–83.
- Nohr E.A., Vaeth M., Baker J.L., Sorensen T.I.A., Olsen J. & Rasmussen K.M. (2008) Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. *American Journal of Clinical Nutrition* **87**, 1750–1759.
- Parker J.D. & Abrams B. (1993) Differences in postpartum weight retention between black and white mothers. *Obstetrics Gynecology* **81**, 768–774.
- Rasmussen K.M. & Yaktine A.L. (eds) (2009) *Weight Gain During Pregnancy: Reexamining the Guideline*. Institute of Medicine (Committee to Reexamine IOM Pregnancy Weight Guidelines, Food and Nutrition Board and Board on Children, Youth, and Families), National Research Council: Washington, DC.
- Schauberger C.W., Rooney B.L. & Brimer L.M. (1992) Factors that influence weight loss in the puerperium. *Obstetrics Gynecology* **79**, 424–429.
- Thorsdottir I. & Birgisdottir B.E. (1998) Different weight gain in women of normal weight before pregnancy:

- post-partum weight and birth weight. *Obstetrics Gynecology* **92**, 377–383.
- Walker L.O., Sterling B.S., Kim M., Arheart K.L. & Timmerman G.M. (2006) Trajectory of weight changes in the first 6 weeks postpartum. *Journal of Obstetric, Gynecological, and Neonatal Nursing* **35**, 472–481.
- Walker L.O., Sterling B.S. & Timmerman G.M. (2005) Retention of pregnancy-related weight in the early post-partum period: implications for women's health services. *Journal of Obstetric, Gynecological, and Neonatal Nursing* **34**, 418–427.
- WHO Multicentre Growth Reference Study Group (2006a) Enrolment and baseline characteristics in the WHO Multicentre Growth Reference Study. *Acta Paediatrica* **95** (Suppl. 450), 7–15.
- WHO Multicentre Growth Reference Study Group (2006b) Breastfeeding in the WHO Multicentre Growth Reference Study. *Acta Paediatrica* **95** (Suppl. 450), 16–26.
- Winkvist A. & Rasmussen K.M. (1999) Impact of lactation on maternal body weight and body composition. *Journal of Mammary Gland Biology and Neoplasia* **4**, 309–318.