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Health Care Utilization in the First Month After Birth and Its Relationship to Newborn Weight Loss and Method of Feeding

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Abstract

Objective: Guidelines recommend closer outpatient follow-up for exclusively breastfed newborns, especially those with pronounced weight loss, because of increased risk of hyperbilirubinemia and dehydration that might require readmission. Our objective was to determine how feeding method and weight loss are associated with neonatal healthcare utilization.

Design: Retrospective cohort study.

Setting: Northern California Kaiser Permanente hospitals in 2009-2013

Patients: 143,889 neonates

Predictors: Inpatient method of feeding and inpatient and outpatient weights

Main outcome measures: Inpatient and outpatient utilization in the 30 days after birth

Results: Newborn weight loss and feeding method were each associated with utilization. Exclusively breastfed newborns had higher readmission rates than those exclusively formula fed for both vaginal (4.3% compared to 2.1%) (p<0.001) and Cesarean deliveries (2.1% compared to 1.5%) (p=0.025). Those exclusively breastfed also had more neonatal outpatient visits compared to those exclusively formula fed for both vaginal (means of 3.0 and 2.3, p<0.001) and Cesarean deliveries (means of 2.8 and 2.2, p<0.001). Among vaginally-delivered newborns of all feeding types, weight loss >10% at discharge was associated with a relative risk (RR) of readmission of 1.10 (1.00, 1.20) compared to those with <8% weight loss at discharge; among the subset weighed as inpatients or outpatients between 48-72 hours, the RR of readmission for those with >10% weight loss increased to 2.11 (1.95, 2.26).

Conclusions: Exclusive breastfeeding and weight loss are each associated with increased neonatal healthcare utilization. Improving clinical management of exclusively breastfed neonates with pronounced weight loss might reduce healthcare utilization.

Keywords: newborn; weight; nutrition

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Background

Weight loss is common in the newborn period for both breastfed and formula fed newborns, as newborns experience physiologic diuresis. Because enteral intake is low for exclusively breastfed newborns in the first few days after birth,[1-3] weight loss is more pronounced for exclusively breastfed newborns than for those exclusively formula fed.[4,5] While exclusively formula fed newborns lose about 3% of their birth weight prior to beginning weight gain, exclusively breastfed newborns lose 7-8% of their birth weight prior to beginning weight gain.[4,6,7].[5]

This differential between breastfed and formula fed infants with respect to early weight loss is usually well-tolerated but can have clinical consequences. For example, losing 10% or more of birth weight (sometimes called "excess weight loss")[8] is rare for formula-fed newborns but occurs for about 10% of exclusively breastfed newborns delivered vaginally and about 25% of those delivered by Cesarean.[4,5] Such weight loss of 10% or more has been associated with an increased risk of hypernatremia and hyperbilirubinemia.[9-12] The Academy of Breastfeeding Medicine protocol on supplementation recommends that newborns with >8-10% weight loss should be followed closely.[13] Early weight loss may thus be an important contributor to early health care utilization, but no previous studies have examined the association between early weight loss and health care utilization.

Our group had previously described how weight loss differs by feeding method using administrative data from a large cohort of healthy newborns.[4,5] In this paper, we examine data from the same cohort to report the association of feeding method and weight loss with health care utilization after discharge from the birth hospitalization and through 30 days of age. Because most newborns have not yet reached weight loss nadir at the time of discharge from the birth hospitalization, we examine health care utilization outcomes as they relate to both weight loss at discharge and weight loss occurring among the subset of newborns weighed between 48-72 hours, when nadir most commonly occurs.

Methods

Study design and participants

We used a retrospective cohort design to examine the effect of newborn weight loss on health care utilization after discharge from the birth hospitalization and through 30 days of age. Our cohort has been previously described.[4,5,14] Briefly, from a cohort of 161,471 neonates born at ≥36 weeks gestation at one of 14 Kaiser Permanente Northern California hospitals between January 1, 2009 and December 31, 2013, who survived to discharge home and who did not receive Level II or Level III care, we extracted data on all weights obtained during the first month and on the location where those weights were obtained (inpatient, outpatient or indeterminate) as well as on gestational age, method of delivery, length of stay, maternal race/ethnicity, and type (breast milk or formula) of all inpatient feedings. Our final cohort included 143,889 singleton newborns with birth weight 2000-5000 g and birth hospital length of stay <4 days (vaginal) or <5 days (Cesarean) who had complete data on method of delivery, birth weight and at least 1 weight documented between 6-72 hours of age for vaginally delivered newborns or between 6-96 hours of age for those delivered by Cesarean. Newborns with implausible weight loss or weight gain values (>10% loss in the first 24 hours, >15% loss at any time during the birth hospitalization, gain >5% during the birth hospitalization) were excluded.[4,5,15]

Variables

Neonates with only breast milk feedings documented during the birth hospitalization were defined as exclusively breastfed during the birth hospitalization; those with only formula feedings documented during the birth hospitalization were defined as exclusively formula fed during the birth hospitalization, and those who had documented feedings of both breast milk and formula were defined as mixed-fed. Weight change was defined as the difference between birth weight and each weight recorded subsequently, calculated as a percentage of birth weight as is typically done daily in clinical practice. Weight loss at discharge was defined based upon the most recent weight recorded prior to discharge. In the first month after birth, weights documented as obtained during an outpatient visit were defined as outpatient utilization, and a weight obtained during an inpatient visit at a time subsequent to discharge from the birth hospitalization was defined as having had inpatient utilization.

Analyses

We used a chi-squared test to compare exclusively breastfed and exclusively formula fed newborns with respect to the proportion with any inpatient utilization, and Student's t-test to compare these groups with respect to outpatient utilization. In unadjusted analysis, we used logistic regression models to estimate odds ratios (ORs) for inpatient utilization, and quasi-Poisson regression models to estimate incident ratios (IRs) for outpatient utilization. The quasi-Poisson was chosen because of under-dispersion in models that assumed a Poisson response. Additionally, we fitted models that adjusted for gestational age (36 weeks, 37-38 weeks, 39-40 weeks, and 41-43 weeks), birth weight (<2500 g, 2500 to <4000 g, and ≥4000 g), and race/ethnicity groups (Hispanic, Asian, Black non-Hispanic, White non-Hispanic, and other/unknown).

We categorized maximum weight loss into 3 categories according to guideline thresholds for management[13] (<8% weight loss, 8-10% weight loss and >10% weight loss) and used the same tests, as appropriate, to compare inpatient and outpatient utilization by these groups. Additionally, in order to explore the statistical impact of weight loss on utilization without reference to thresholds established by clinical guidelines,[16] we also examined weight loss as a continuous measure using the same regression models as above. For these models, we used a restricted cubic spline with 4 degrees of freedom to allow for a non-linear relationship between weight loss and each outcome. Given the non-linear estimates, we reported model results for the 75th percentile of weight loss (more pronounced) versus the 25th percentile of weight loss (less pronounced) for the respective type of delivery. Estimates from unadjusted models were shown graphically as a function of all weight loss values using probabilities for logistic models and means for Poisson models, with respective 95% confidence intervals (CIs) also shown. We also reported model results adjusted for gestational age, birth weight and maternal race/ethnicity.

Additionally, we categorized newborn weight loss by centile of weight loss at discharge from the birth hospitalization, using our published nomograms depicting centiles of newborn weight loss.[15] We categorized newborn weights from less pronounced weight loss to more pronounced weight loss using the following centiles: <5th percentile, ≥5th to 10th percentile, ≥10th to 25th percentile, ≥25th to 50th percentile, ≥50th to 75th percentile, ≥75th to 90th percentile, ≥90th to 95th percentile and ≥95th percentile. Chi-squared and t-tests, as appropriate, were used to compare percentile groups. This study was approved by the University of California San Francisco Committee on Human Research and by the Institutional Review Boards of Penn State Medical College and Kaiser Permanente Northern California.

Results

In our final cohort, 108,745 delivered vaginally and 35,144 delivered via Cesarean (Figure 1). Table 1 shows demographic and clinical characteristics of the sample. Neonates were born at a median of 39 weeks gestational age for each type of delivery, but those delivered via Cesarean had a mean (SD) birth weight of 3495 grams (496 g), larger than the mean birth weight of 3415 grams (443 g) for vaginally delivered neonates. Median newborn hospital stays were 1.5 (interquartile range (IQR) 1.2-2.0) and 2.6 (IQR 2.1-3.1) days, respectively, for vaginal and Cesarean deliveries, with corresponding rates of exclusive breastfeeding during the maternity stay of 69% and 45%. Readmission occurred for 4397 (4.0%) vaginally-delivered infants and 757 (2.2%) of those delivered by Cesarean. Among the vaginally delivered infants, 3092 (70.3%) of the readmissions were secondary to hyperbilirubinemia and need for inpatient phototherapy. Among those delivered by Cesarean, 361 (47.7%) of the readmissions were for hyperbilirubinemia.

Utilization by type of feeding

We had data on inpatient feeding for 105,003 (96.6%) vaginally delivered newborns and 34,082 (97.0%) delivered by Cesarean. Among vaginally delivered newborns, readmission after discharge from the birth hospitalization occurred for 4.3% of those exclusively breastfed during their birth hospitalization and 2.1% of those exclusively formula fed during their birth hospitalization ($p<0.001$). (Table 2A) For vaginal births, the OR for readmission for exclusively formula fed infants compared to exclusively breastfed infants was 0.49 (0.39-0.61) in an unadjusted model and 0.44 (0.35-0.55) after adjusting for gestational age, birth weight and maternal race/ethnicity. (Supplementary Table 1A) For Cesarean births, readmission occurred for 2.4% of those exclusively breastfed during the birth hospitalization and 1.5% of those exclusively formula fed during the birth hospitalization ($p=0.025$). For Cesarean births, the OR of readmission for exclusively formula fed infants compared to exclusively breastfed infants was 0.62 (0.41-0.95) in an unadjusted model and 0.55 (0.36-0.84) after adjusting for gestational age, birth weight and maternal race/ethnicity.

Those exclusively breastfed during the birth hospitalization also had significantly more outpatient visits in the first 30 days after birth compared to those exclusively formula fed during the birth hospitalization for both vaginal (means of 3.0 and 2.3, p<0.001) and Cesarean deliveries (means of 2.8 and 2.2, p<0.001). In an unadjusted model, the incidence ratio (IR) for outpatient utilization among exclusively formula fed infants compared to those exclusively breastfed was 0.76 (0.75-0.77) and 0.77 (0.75-0.79), respectively, for infants delivered vaginally and by Cesarean. After adjusting for gestational age, race/ethnicity and birth weight, IRs changed little and were 0.76 (0.75-0.77) and 0.77 (0.75-0.80), respectively, for infants delivered vaginally and by Cesarean. (Supplementary Table 1B).

Utilization by weight loss at discharge

A total of 101,704 (93.5%) vaginally delivered and 34,197 (97.3%) Cesarean delivered newborns had at least 1 weight recorded during the birth hospitalization other than birth weight and were included in this portion of the analysis. For newborns delivered vaginally, weight loss >10% at discharge was rare (0.4%). For these vaginally delivered newborns, the unadjusted RR of readmission was 1.10 (1.00, 1.20) for those with >10% weight loss at discharge compared to those with <8% weight loss at discharge; rates of readmission, as estimated by logistic regression models, did not significantly differ by weight loss category either with or without adjusting for gestational age, birth weight and maternal race/ethnicity. However, the mean numbers of outpatient visits were significantly greater for those with more pronounced weight loss at discharge: 3.7 (SD=1.8) for those with weight loss >10% at discharge compared to 2.9 (SD=1.4) for those with weight loss <8% at discharge (p<0.001) (Table 2B). For newborns delivered by Cesarean, weight loss >10% at discharge occurred for 6% of newborns, and readmission rates were significantly higher for those with >10% weight loss compared to those with <8% weight loss at discharge: 2.7% vs. 2.0% (p=0.004). Outpatient utilization after Cesarean delivery was also significantly greater for newborns with more pronounced weight loss at discharge, with mean of 3.5 visits (SD=1.7) for those with >10% weight loss at discharge compared to mean of 2.6 visits (SD=1.3) for those with <8% weight loss (p<0.001). These findings are reflected in the estimates from unadjusted regression models shown in Figure 2.

Categorizing weight loss at discharge as above (<8%, 8-10% or >10% of birth weight) was more highly associated with inpatient and outpatient utilization than categorizing weight loss at discharge by quartile for hour of age. For vaginally delivered infants, the unadjusted and adjusted ORs for readmission for the 75th percentile of weight loss compared to the 25th percentile were 1.09 (1.01-1.17) and 1.00 (0.93-1.08) respectively, while the unadjusted and adjusted IRs for outpatient visits were 1.10 (1.09-1.11) and 1.09 (1.08-1.10), respectively, for the same percentiles. Results from analyses for infants delivered by Cesarean were similar (Supplementary Table 2).

Utilization by maximum weight loss 48-72 hours

A total of 55,398 (50.9%) vaginally delivered and 22,198 (63.2%) Cesarean delivered newborns had a weight recorded in either an inpatient or an outpatient setting at 48-72 hours of age and were included in this portion of the analysis. Of those delivered vaginally and by Cesarean, respectively, 9.3% and 14.0% had weight loss >10% at 48-72 hours of age. Among all newborns with weights recorded at 48-72 hours of age, maximum weight loss during 48-72 hours of age was highly associated with subsequent inpatient and outpatient utilization (Table 2C). For vaginally delivered newborns, a readmission occurred for 9.9% of those with >10% weight loss compared with 4.7% of those with <8% weight loss (p<0.001), leading to an unadjusted RR of 2.11 (1.95, 2.26). Vaginally-delivered newborns with >10% weight loss at 48-72 hours had mean of 4.2 (SD=1.7) outpatient visits in the first month, compared with mean of 2.9 (SD=1.3) among vaginally-delivered newborns with <8% weight loss at 48-72 hours (p<0.001). For newborns delivered via Cesarean, readmission rates were 3.5% and 2.0%

(p<0.001), and the mean number of outpatient visits were 3.5 (SD=1.7) and 2.6 (SD=1.2) (p<0.001) for newborns with >10% and <8% maximum weight loss at 48-72 hours, respectively. Estimates from unadjusted regression models for readmissions and outpatient utilization are shown as a function of weight loss in Figure 3 for each type of delivery.

In analysis of the impact of weight loss at 48-72 hours of age on outpatient and inpatient utilization, categorizing weight loss as <8%, 8-10% or >10% of birth weight was more highly associated with inpatient and outpatient utilization than categorizing weight loss by quartile. At 48-72 hours of age, unadjusted logistic regression models indicated that infants with weight loss at the 75^{th} percentile had ORs for readmission of 1.76 (1.59-1.95) and 1.66 (1.35-2.03) for infants delivered vaginally and by Cesarean, respectively when compared to those with weight loss at the 25^{th} percentile; after adjusting for gestational age, birth weight and maternal race/ethnicity ORs for readmission were 1.79 (1.63-1.96) and 1.72 (1.40-2.11) for infants delivered vaginally and by Cesarean, respectively, for the same percentiles. At 48-72 hours of age, infants with weight loss at the 75^{th} percentile had unadjusted IRs for outpatient utilization of 1.22 (1.21-1.23) and 1.20 (1.18-1.22) for infants delivered vaginally and by Cesarean, respectively, when compared to infants with weight loss at the 25^{th} percentile; after adjusting for gestational age, birth weight and maternal race/ethnicity, IRs for the outcome of outpatient utilization were 1.27 (1.26-1.28) and 1.20 (1.18-1.22) for infants delivered vaginally and by Cesarean, respectively, for the same percentiles. (Supplementary Table 3)

Utilization by centile of weight loss at discharge

When using centile of weight loss as a predictor of utilization, more pronounced centile of weight loss was associated with a decrease in both rates of readmission and frequency of outpatient visits. For vaginally delivered newborns, readmission rates varied by centile of weight loss from 4.5% for those with ≥5^{th} to 10^{th} percentile of weight loss to 3.0% for those with ≥95^{th} percentile of weight loss, while outpatient utilization also varied by centile of weight loss from 3.3 visits (SD=1.6) for those with ≥5th to 10th percentile of weight loss to 2.6 visits (SD=1.2) for those with ≥95th percentile of weight loss. For those delivered by Cesarean, readmission rates were 3.4% for those with <5th percentile of weight loss and 1.0% for those with ≥95th percentile of weight loss, and mean outpatient utilization was 3.5 visits (SD=1.7) for those with <5th percentile of weight loss and 2.3 visits (SD=1.1) for those with ≥90th to 95th percentile of weight loss. (Table 3)

Discussion

Our study found that newborns breastfed exclusively during the birth hospitalization had increased inpatient and outpatient utilization in the first month after birth. Readmission occurred twice as frequently for newborns exclusively breastfed during the birth hospitalization as compared to those receiving only formula, and exclusively breastfed newborns had about 30% more outpatient visits. Although gestational age, birth weight and maternal race/ethnicity were strong predictors both of feeding method and of utilization, adjusting for these variables had little impact on the relationship between feeding method and utilization. Weight loss was also associated with heath care utilization, with newborns who had lost >10% of their birth weight having greater inpatient and outpatient utilization than those who lost <8% of their birth weight; the association between weight loss and utilization remained strong even after adjusting for other variables which had strong association with feeding method, weight loss and utilization.

Two considerations may be relevant for understanding these observed relationships between method of feeding, weight loss and inpatient and outpatient utilization. First, some or all of the observed increase in utilization may be medically necessary. The two most common causes of neonatal readmission are hyperbilirubinemia and feeding difficulty, both of which are associated with exclusive breastfeeding and are also associated with excess weight loss.[17-20] In the first few days after birth, the low enteral intake of the exclusively breastfed newborn can cause both weight loss and hyperbilirubinemia,.[21] Such short-term adverse consequences of exclusive breastfeeding may be viewed as representing an acceptable tradeoff given the magnitude of its reported benefits. The second consideration is that some of the observed increase in utilization may not be medically necessary. Clinicians and parents may worry about weight loss, even in the absence of hyperbilirubinemia and dehydration.[22,23] Our finding that losing more than 10% of birth weight is a stronger predictor of inpatient and outpatient utilization than weight loss centile for hour of age suggests that some proportion of excess utilization for newborns with pronounced weight loss may be attributable to clinician adherence to guideline weight loss thresholds.

Our study found that weight loss measured at 48-72 hours of age, the time of weight nadir for most infants, had the strongest association with the likelihood of readmission and outpatient utilization. This is consistent with the possibility that increased enteral intake, which often occurs for exclusively breastfed newborns at 48-72 hours of age when maternal milk becomes copious, may lead to reduced utilization, perhaps by increasing fecal excretion of bilirubin[15] and thereby reducing the risk of hyperbilirubinemia. The generalizability of our findings is enhanced by the diverse racial-ethnic composition of our cohort. However, in our study population, only 53% of newborns were weighed at 48-72 hours. This may introduce bias into our findings because it is likely that these newborns differ in many respects from newborns not weighed at 48-72 hours. In order to examine the effect of weight loss at 48-72 hours on utilization with less risk of bias, future research should identify a cohort of newborns that can be weighed at 48-72 hours of age and then followed for inpatient and outpatient utilization.

Our study has several important limitations. First, we had limited data on the reasons for outpatient or inpatient utilization, and cannot report whether an inpatient or outpatient visit was medically necessary. However, our study's data show that readmission for phototherapy accounted for the large majority of inpatient utilization, and in Northern California Kaiser Permanente populations a very high proportion of such readmissions are medically indicated. Second, due to the retrospective study design, we did not have access to data to adjust for parity, income and education, characteristics that are associated both with breastfeeding and with utilization. However, since younger maternal age, lower income and lower educational attainment are all associated both with less likelihood of breastfeeding and with greater health care utilization, it is unlikely that the findings in our study are attributable to confounding from these sources.[24,25] Third, we characterized newborn feeding using data from the entire birth hospitalization. If some infants initiated exclusive breastfeeding but received formula later during the birth hospitalization to preclude the need for additional utilization, our study may underestimate the effect of exclusive breastfeeding on health care utilization.

While our results demonstrate increased health care utilization for exclusively breastfed newborns and for those with pronounced weight loss, future studies are needed to determine how this increase should be addressed. Improved clinician and parent education regarding normal newborn weight patterns may be helpful in reducing unnecessary utilization, while strategies such as banked donor milk to support early breastfeeding may ameliorate the low enteral intake that can lead to hyperbilirubinemia and dehydration. If exclusively breastfed newborns in our cohort had had readmission rates similar to those of exclusively formula fed newborns, the cohort would have had 1706 fewer readmissions. Neonatal readmission is a significant source of parental anxiety,[26] so reducing its frequency might improve family experiences surrounding the neonatal period. In addition, since the cost of a neonatal readmission has been estimated at $4548,[27] a potential savings of $7.8 million might be realized for a cohort similar to ours if the readmission rate of exclusively breastfed newborns approximated that of newborns exclusively formula fed. Since close to 4 million infants are born in the U.S. each year, strategies to reduce excess utilization in the neonatal period have the potential to bring substantial cost savings and public health benefit.

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Figure 1: Cohort derivation

Figure 2: Results of fitted regression models for outpatient utilization (Poisson regression) and inpatient utilization (logistic regression) by maximum weight loss at discharge from birth hospitalisation. (Top row) Estimated mean numbers of outpatient visits with 95% CI (gray), which tracks very close to the mean. (Bottom row) Estimated probabilities of an inpatient visit with 95% CI (gray).

Figure 3: Results of fitted regression models for outpatient utilization (Poisson regression) and inpatient utilization (logistic regression) by maximum weight loss at 48-72 hours after birth. (Top row) Estimated mean numbers of outpatient visits with 95% CI (gray), which tracks very close to the mean. (Bottom row) Estimated probabilities of an inpatient visit with 95% CI (gray).

Table 1. Demographic and clinical characteristics of included newborns by type of delivery

	Vaginal (N=108,745)	Cesarean (N=35,144)	Total (N=143,889)
Birth weight (grams)			
Mean (SD)	3415 (442.8)	3495 (496.2)	3435 (457.7)
Gestational age (weeks)			
Median (interquartile range)	39 (38-40)	39 (38-40)	39 (38-40)
Maternal race/ethnicity			
Hispanic	27551 (25.3%)	8619 (24.5%)	36170 (25.1%)
American Indian/Eskimo	444 (0.4%)	144 (0.4%)	588 (0.4%)
Asian	26436 (24.3%)	8734 (24.9%)	35170 (24.4%)
Black, non-Hispanic	7368 (6.8%)	2830 (8.1%)	10198 (7.1%)
White, non-Hispanic	44056 (40.5%)	13832 (39.4%)	57888 (40.2%)
Other/unknown	2890 (2.7%)	985 (2.8%)	3875 (2.7%)
Newborn hospital length of stay (days)			
Median (interquartile range)	1.5 (1.2-2.0)	2.6 (2.1-3.1)	1.8 (1.3-2.3)
Type of feeding during birth hospital			
Missing	3742 (.%)	1062 (.%)	4804 (.%)
Exclusive breastfeeding	72098 (68.7%)	15399 (45.2%)	87497 (62.9%)
Exclusive formula fed	4027 (3.8%)	1568 (4.6%)	5595 (4%)
Mixed feeding	28878 (27.5%)	17115 (50.2%)	45993 (33.1%)

Table 2. Outpatient and inpatient utilization after discharge from the birth hospitalization and through 30 days of age by type of feeding during the birth hospitalization, by weight loss 48-72 hours, and by weight loss at discharge.

Group	N	Mean (SD) number of outpatient weights	N (%) with inpatient visit
A. Outpatient and inpatient utilization by feeding type during birth hospitalization			
Vaginal	105003		
Exclusive breastfed	72098 (68.7%)	3.0 (1.4)	3077 (4.3%)
Exclusive formula fed	4027 (3.8%)	2.3 (1.0)	86 (2.1%)
Mixed feeding	28878 (27.5%)	2.8 (1.4)	1144 (4.0%)
Cesarean	34082		
Exclusive breastfed	15399 (45.2%)	2.8 (1.4)	374 (2.4%)
Exclusive formula fed	1568 (4.6%)	2.2 (0.9)	24 (1.5%)
Mixed feeding	17115 (50.2%)	2.8 (1.3)	345 (2.0%)
B. Outpatient and inpatient utilization by weight loss at discharge			
Vaginal	101704		
<8% weight loss	97827 (96.2%)	2.9 (1.4)	3986 (4.1%)
8-10% weight loss	3480 (3.4%)	3.5 (1.7)	165 (4.7%)
>10% weight loss	397 (0.4%)	3.7 (1.8)	18 (4.5%)
Cesarean	34197		
<8% weight loss	24937 (72.9%)	2.6 (1.3)	500 (2.0%)
8-10% weight loss	7204 (21.1%)	3.1 (1.5)	184 (2.6%)
>10% weight loss	2056 (6.0%)	3.5 (1.7)	56 (2.7%)
C. Outpatient and inpatient utilization by weight loss from 48-72 hours			
Vaginal	55398		
<8% weight loss	38562 (69.6%)	2.9 (1.32)	1802 (4.7%)
8-10% weight loss	11696 (21.1%)	3.6 (1.57)	890 (7.6%)
>10% weight loss	5140 (9.3%)	4.2 (1.65)	509 (9.9%)
Cesarean	22198		
<8% weight loss	12957 (58.4%)	2.6 (1.2)	255 (2.0%)
8-10% weight loss	6134 (27.6%)	3.1 (1.5)	171 (2.8%)
>10% weight loss	3107 (14.0%)	3.5 (1.7)	108 (3.5%)

Table 3: Outpatient and inpatient utilization after discharge from the birth hospitalization and through 30 days of age by centile of weight loss at discharge from the birth hospitalization

Group	N	Mean (SD) number of outpatient visits	N (%) with inpatient visit
Vaginal	101704		
<5th percentile	4001 (3.9%)	3.2 (1.5)	145 (3.6%)
≥5th to 10th percentile	4163 (4.1%)	3.3 (1.6)	187 (4.5%)
≥10th to 25th percentile	13983 (13.7%)	3.2 (1.6)	576 (4.1%)
≥25th to 50th percentile	25985 (25.5%)	3.0 (1.4)	1140 (4.4%)
≥50th to 75th percentile	26834 (26.4%)	2.9 (1.4)	1152 (4.3%)
≥75th to 90th percentile	16079 (15.8%)	2.7 (1.2)	617 (3.8%)
≥90th to 95th percentile	5278 (5.2%)	2.7 (1.2)	191 (3.6%)
≥95th percentile	5381 (5.3%)	2.6 (1.2)	161 (3.0%)
Cesarean	34197		
<5th percentile	1162 (3.4%)	3.5 (1.7)	39 (3.4%)
≥5th to 10th percentile	1680 (4.9%)	3.2 (1.6)	38 (2.3%)
≥10th to 25th percentile	5804 (17.0%)	3.1 (1.5)	157 (2.7%)
≥25th to 50th percentile	9390 (27.5%)	2.8 (1.4)	251 (2.7%)
≥50th to 75th percentile	8601 (25.2%)	2.6 (1.2)	144 (1.7%)
≥75th to 90th percentile	4694 (13.7%)	2.5 (1.2)	71 (1.5%)
≥90th to 95th percentile	1535 (4.5%)	2.3 (1.1)	27 (1.8%)
≥95th percentile	1331 (3.9%)	2.4 (1.1)	13 (1.0%)

Supplementary Table 1: Adjusted estimates of the effect of type of feeding on inpatient and outpatient utilization, for infants delivered vaginally and by Cesarean. (A) Adjusted odds ratios for the effect on readmission (B) Adjusted incidence ratios for the effect on outpatient utilization

A. Odds ratios (OR) for the outcome of readmission

	Vaginal		Cesarean	
Parameter	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Feeding type				
Exclusive breastfeeding (ref)	1		1	
Exclusive formula	0.44 (0.35-0.55)	<0.001	0.55 (0.36-0.84)	0.005
Mixed	0.76 (0.70-0.81)	<0.001	0.71 (0.61-0.83)	<0.001
Gestational age				
Late preterm, 36 weeks	4.56 (3.99-5.23)	<0.001	3.76 (2.77-5.09)	<0.001
Early term, 37-38 weeks	2.18 (2.04-2.33)	<0.001	2.02 (1.72-2.38)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	0.71 (0.62-0.82)	<0.001	0.75 (0.56-1.00)	0.046
Birth weight				
<2500 g	1.02 (0.84-1.24)	0.83	1.11 (0.72-1.72)	0.64
2500 g to <4000 g (ref)	1		1	
≥4000 g	1.12 (0.99-1.26)	0.06	1.60 (1.32-1.95)	<0.001
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	
Hispanic	1.28 (1.18-1.39)	<0.001	1.12 (0.93-1.36)	0.24
Asian	1.75 (1.62-1.89)	<0.001	1.36 (1.14-1.64)	0.001
Black, non-Hispanic	0.91 (0.78-1.05)	0.20	0.83 (0.60-1.14)	0.25
Other/unknown	1.11 (0.92-1.34)	0.29	0.87 (0.54-1.39)	0.56

B. Estimated incidence ratios for Poisson models of outpatient visits

Parameter	**IR (95% CI)**	**p-value**	**IR (95% CI)**	**p-value**
Feeding type				
Exclusive breastfeeding (ref)	1		1	
Exclusive formula	0.76 (0.75-0.77)	<0.001	0.77 (0.75-0.80)	<0.001
Mixed	0.94 (0.93-0.95)	<0.001	0.97 (0.96-0.98)	<0.001
Gestational age				
Late preterm, 36 weeks	1.19 (1.17-1.21)	<0.001	1.16 (1.12-1.19)	<0.001
Early term, 37-38 weeks	1.07 (1.06-1.08)	<0.001	1.04 (1.03-1.05)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	1.00 (0.99-1.01)	0.68	1.03 (1.01-1.05)	0.001
Birth weight				
<2500 g	1.07 (1.05-1.10)	<0.001	1.07 (1.03-1.11)	<0.001
2500 g to <4000 g (ref)	1		1	
≥4000 g	1.00 (0.99-1.01)	0.78	1.04 (1.02-1.05)	<0.001
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	
Hispanic	0.99 (0.98-0.99)	0.001	0.95 (0.94-0.97)	<0.001
Asian	1.08 (1.07-1.09)	<0.001	1.00 (0.98-1.01)	0.53
Black, non-Hispanic	0.91 (0.90-0.92)	<0.001	0.87 (0.85-0.89)	<0.001
Other/unknown	0.98 (0.97-1.00)	0.07	0.98 (0.95-1.01)	0.16

Supplementary Table 2: Adjusted estimates of the effect of discharge weight loss on readmissions and outpatient utilization, for infants delivered vaginally and by Cesarean. (A) Adjusted odds ratios for the effect on readmission (B) Adjusted incidence ratios for the effect on outpatient utilization

A. Estimated odds ratios for logistic regression models of readmission

	Vaginal		Cesarean	
Parameter	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Weight loss at discharge*				
5.5% vs. 2.5%	1.00 (0.93-1.08)	0.91	-	-
8.0% vs. 5.0%	-	-	1.10 (0.92-1.31)	0.29
Gestational age				
Late preterm, 36 weeks	4.10 (3.59-4.69)	<0.001	3.53 (2.62-4.77)	<0.001
Early term, 37-38 weeks	2.19 (2.05-2.35)	<0.001	2.01 (1.70-2.37)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	0.72 (0.63-0.83)	<0.001	0.75 (0.57-1.00)	0.05
Birth weight				
<2500 g	0.95 (0.79-1.16)	0.64	1.14 (0.74-1.76)	0.56
2500 g to <4000 g (ref)	1		1	
≥4000 g	1.11 (0.98-1.25)	0.10	1.54 (1.27-1.88)	<0.001
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	
Hispanic	1.23 (1.13-1.34)	<0.001	1.08 (0.90-1.31)	0.41
Asian	1.68 (1.55-1.81)	<0.001	1.30 (1.09-1.56)	0.004
Black, non-Hispanic	0.86 (0.74-1.00)	0.047	0.86 (0.62-1.19)	0.36
Other/unknown	1.10 (0.91-1.33)	0.33	0.87 (0.54-1.39)	0.55

B. Estimated incidence ratios for Poisson models of outpatient visits

	Vaginal		Cesarean	
Parameter	**IR (95% CI)**	**p-value**	**IR (95% CI)**	**p-value**
Weight loss at discharge**				
5.5% vs. 2.5%	1.09 (1.08-1.10)	<0.001	-	-
8.0% vs. 5.0%	-	-	1.13 (1.12-1.14)	<0.001
Gestational age				
Late preterm, 36 weeks	1.12 (1.10-1.14)	<0.001	1.15 (1.12-1.19)	<0.001
Early term, 37-38 weeks	1.06 (1.05-1.07)	<0.001	1.04 (1.02-1.05)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	1.00 (0.99-1.01)	0.62	1.03 (1.01-1.05)	<0.001
Birth weight				
<2500 g	1.06 (1.04-1.08)	<0.001	1.11 (1.07-1.15)	<0.001
2500 g to <4000 g (ref)	1		1	
≥4000 g	0.99 (0.98-1.00)	0.13	1.03 (1.01-1.04)	<0.001
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	

Hispanic	0.98 (0.97-0.99)	<0.001	0.95 (0.94-0.97)	<0.001
Asian	1.06 (1.05-1.07)	<0.001	0.99 (0.98-1.00)	0.21
Black, non-Hispanic	0.90 (0.89-0.91)	<0.001	0.88 (0.87-0.90)	<0.001
Other/unknown	0.98 (0.96-0.99)	0.005	0.98 (0.95-1.01)	0.19

*OR shown for 75th vs. 25th percentiles of weight loss because weight loss was modeled non-linearly

**IR shown for 75th vs. 25th percentiles of weight loss because weight loss was modeled non-linearly

Supplementary Table 3: Adjusted estimates of the effect of weight loss at 48-72 hours of age on readmissions and outpatient utilization, for infants delivered vaginally and by Cesarean. (A) Adjusted odds ratios for the effect on readmission (B) Adjusted incidence ratios for the effect on outpatient utilization

A. Estimated odds ratios for logistic regression models of outpatient visits

	Vaginal		**Cesarean**	
Parameter	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Weight loss 48-72 hours*				
8.5% vs. 4.5%	1.79 (1.63-1.96)	<0.001	-	-
9.0% vs. 5.5%	-	-	1.72 (1.40-2.11)	<0.001
Gestational age				
Late preterm, 36 weeks	3.44 (2.95-4.02)	<0.001	3.40 (2.41-4.81)	<0.001
Early term, 37-38 weeks	2.00 (1.84-2.16)	<0.001	2.00 (1.65-2.43)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	0.73 (0.62-0.85)	<0.001	0.84 (0.61-1.15)	0.27
Birth weight				
<2500 g	1.05 (0.84-1.31)	0.67	1.02 (0.62-1.68)	0.95
2500 g to <4000 g (ref)	1		1	
≥4000 g	1.04 (0.90-1.20)	0.59	1.47 (1.16-1.85)	0.001
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	
Hispanic	1.23 (1.11-1.35)	<0.001	0.96 (0.76-1.21)	0.73
Asian	1.69 (1.55-1.85)	<0.001	1.16 (0.94-1.43)	0.17
Black, non-Hispanic	1.02 (0.85-1.22)	0.86	0.93 (0.65-1.33)	0.68
Other/unknown	1.15 (0.92-1.43)	0.23	0.73 (0.41-1.29)	0.28

B. Estimated incidence ratios for Poisson models of outpatient visits

	Vaginal		**Cesarean**	
Parameter	**IR (95% CI)**	**p-value**	**IR (95% CI)**	**p-value**
Weight loss 48-72 hours**				
8.5% vs. 4.5%	1.27 (1.26-1.28)	<0.001	-	-
9.0% vs. 5.5%	-	-	1.20 (1.18-1.22)	<0.001
Gestational age				
Late preterm, 36 weeks	1.14 (1.12-1.16)	<0.001	1.17 (1.13-1.21)	<0.001
Early term, 37-38 weeks	1.06 (1.05-1.07)	<0.001	1.04 (1.02-1.05)	<0.001
Full term, 39-40 weeks (ref)	1		1	
Post term, 41-43 weeks	0.99 (0.98-1.00)	0.21	1.03 (1.01-1.05)	<0.001
Birth weight				
<2500 g	1.12 (1.10-1.15)	<0.001	1.10 (1.06-1.15)	<0.001
2500 g to <4000 g (ref)	1		1	
≥4000 g	0.99 (0.97-1.00)	0.027	1.02 (1.01-1.04)	0.006
Maternal race/ethnicity				
White, non-Hispanic (ref)	1		1	
Hispanic	0.99 (0.98-1.00)	0.24	0.95 (0.93-0.96)	<0.001

Asian	1.06 (1.05-1.07)	<0.001	0.98 (0.97-1.00)	0.029
Black, non-Hispanic	0.95 (0.94-0.97)	<0.001	0.89 (0.86-0.91)	<0.001
Other/unknown	0.98 (0.96-1.00)	0.08	0.97 (0.94-1.01)	0.11

*OR shown for 75th vs. 25th percentiles of weight loss because weight loss was modeled non-linearly

**IR shown for 75th vs. 25th percentiles of weight loss because weight loss was modeled non-linearly

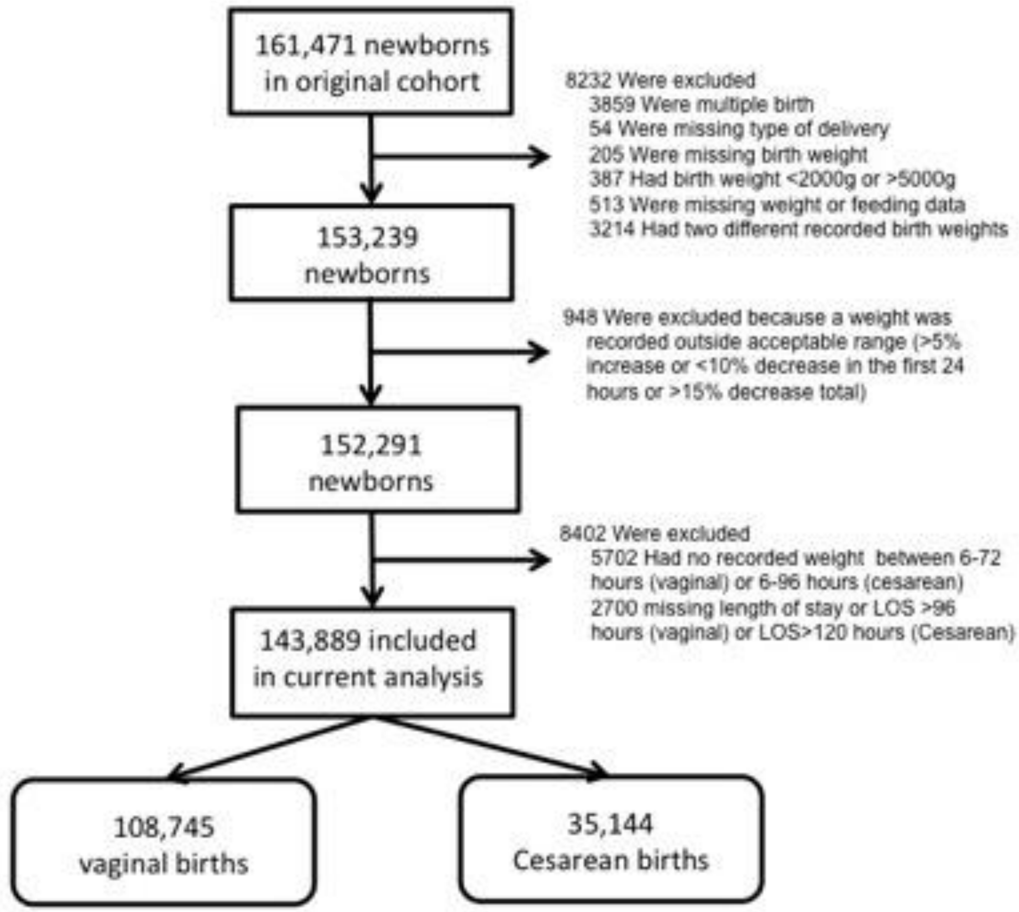

161,471 newborns in original cohort
8232 Were excluded
3859 Were multiple birth
54 Were missing type of delivery
205 Were missing birth weight
387 Had birth weight <2000g or >5000g
513 Were missing weight or feeding data
3214 Had two different recorded birth weights
153,239 newborns
948 Were excluded because a weight was recorded outside acceptable range (>5% increase or <10% decrease in the first 24 hours or >15% decrease total)
152,291 newborns
8402 Were excluded
5702 Had no recorded weight between 6-72 hours (vaginal) or 6-96 hours (cesarean)
2700 missing length of stay or LOS >96 hours (vaginal) or LOS>120 hours (Cesarean)
143,889 included in current analysis
108,745 vaginal births
35,144 Cesarean births

Figure 1.jpg

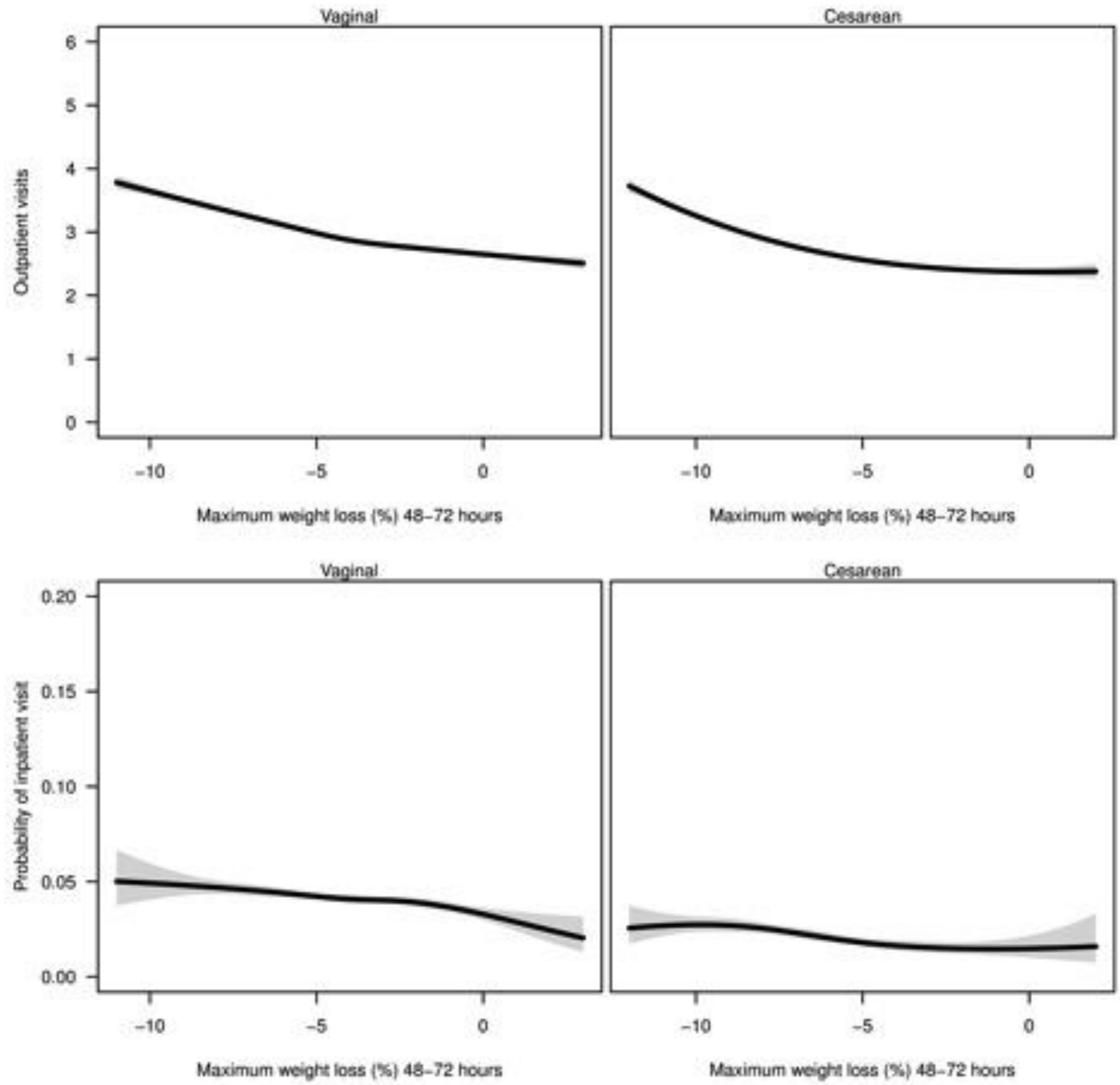
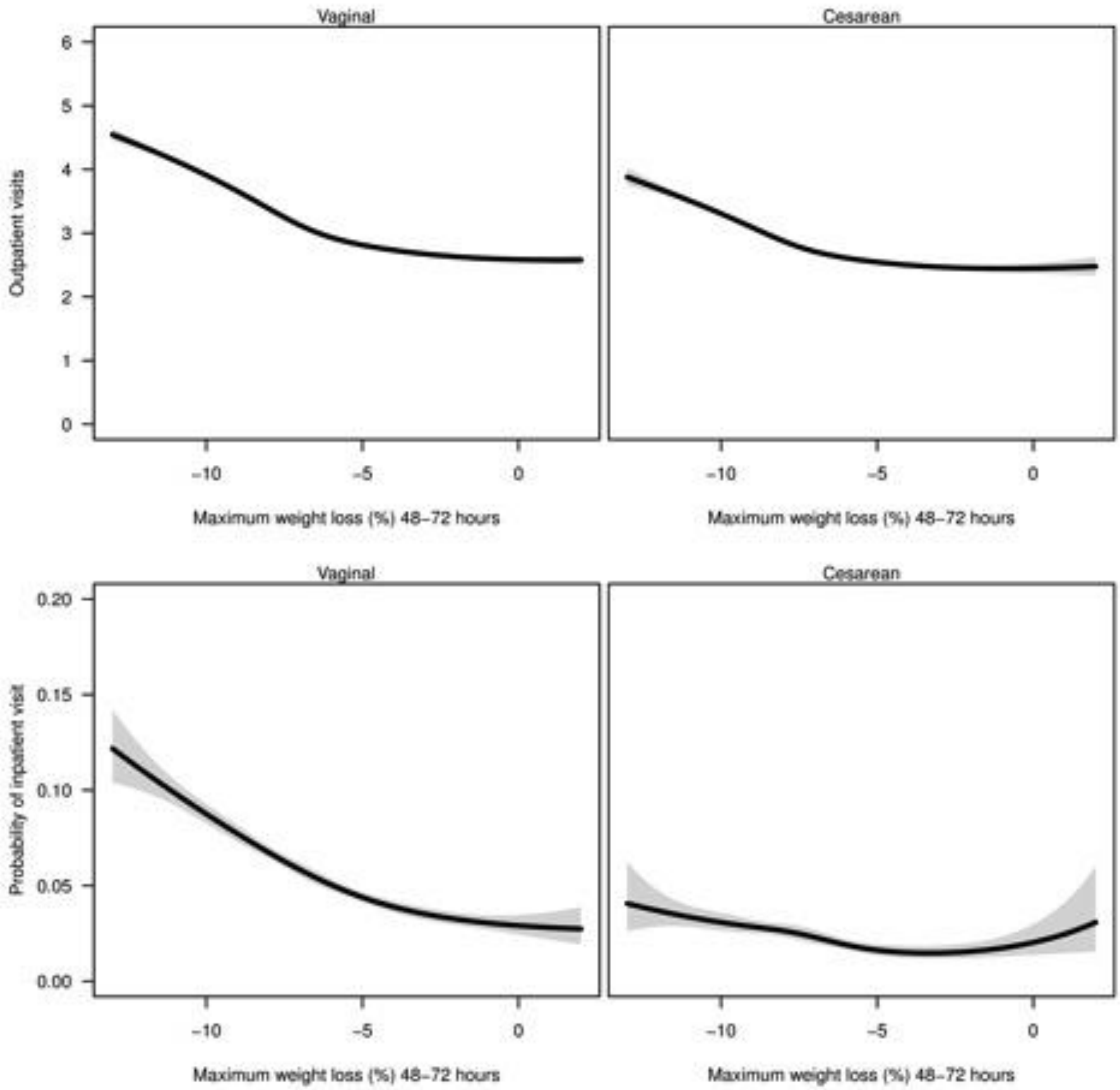

Vaginal
Cesarean
Outpatient visits
Maximum weight loss (%) 48–72 hours
Maximum weight loss (%) 48–72 hours
Vaginal
Cesarean
Probability of inpatient visit
Maximum weight loss (%) 48–72 hours
Maximum weight loss (%) 48–72 hours

Figure 2.jpg



Vaginal
Cesarean
Outpatient visits
6
5
4
3
2
1
0
−10
−5
0
Maximum weight loss (%) 48−72 hours
Maximum weight loss (%) 48−72 hours
Vaginal
Cesarean
Probability of inpatient visit
0.20
0.15
0.10
0.05
0.00
−10
−5
0
Maximum weight loss (%) 48−72 hours
Maximum weight loss (%) 48−72 hours

Figure 3.jpg