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Temporal changes in transcutaneous hemoglobin levels and their influencing factors in postpartum women: a longitudinal study

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ABSTRACT

This study aimed to clarify the temporal changes in transcutaneous hemoglobin levels up to 1 month postpartum and the influencing factors in postpartum women using a noninvasive transcutaneous hemoglobin measuring device. The study participants were pregnant women recruited at an outpatient clinic. We collected information on their dietary history using a concise self-administered questionnaire and an agreement document when they were hospitalized for delivery. Transcutaneous hemoglobin levels of the mothers were measured using Pronto (Masimo) at 1 day, 4 days, 2 weeks, and 1 month postpartum. We included 135 mothers (mean age, 31.7 years) who delivered at full term. The mean transcutaneous hemoglobin levels decreased slightly from day 1 (11.9 ± 1.6 g/dL) to day 4 postpartum (11.8 ± 1.7 g/dL), followed by a significant increase from day 4 to 2 weeks postpartum (13.8 ± 1.0 g/dL; $p < 0.01$), and no change from 2 weeks to 1 month postpartum (13.8 ± 0.9 g/dL). Iron intake in the third trimester of pregnancy affected transcutaneous hemoglobin levels from day 4 postpartum to recovery by 2 weeks postpartum. The rapid increase in hemoglobin levels from day 4 to 2 weeks postpartum was a novel finding. Evaluation of hemoglobin levels in women at 2 weeks postpartum is important for postpartum recovery. Furthermore, health guidance regarding iron intake in the third trimester of pregnancy has been suggested to be effective in restoring postpartum hemoglobin levels.

Keywords: diet, female, hemoglobin, iron, postpartum period

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INTRODUCTION

Anemia in postpartum women causes depression[1-3] and fatigue.[4,5] Moreover, postpartum depression is associated with suicide and child abuse.[6-9] Postpartum fatigue delays physical recovery associated with pregnancy and delivery in mothers.[4,10] Thus, postpartum depression and fatigue can be prevented by checking for postpartum anemia to reduce the rates of suicide, child abuse, and delayed physical recovery in postpartum women.

Despite the importance of recovering from postpartum anemia, there are few studies on the

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recovery of hemoglobin levels after birth, and the duration required for recovery is not clear. Previous studies have shown that hemoglobin levels are the lowest at approximately 1–5 days postpartum, gradually increasing thereafter and returning to the pre-pregnant state 1 month postpartum.[11,12] However, as these studies did not measure hemoglobin levels between 9 days and 1 month postpartum, the fluctuations during this period are unknown. If hemoglobin levels return to pre-pregnancy levels within this timeframe, assessing them at 1 month postpartum is too late. For these reasons, there is a need to define the more detailed temporal changes in hemoglobin levels from 9 days to 3 weeks postpartum and to identify the time of recovery to pre-pregnancy levels. We believe that this information would allow for accurate assessment of the physical recovery of postpartum women without delay.

Furthermore, the above-described data were obtained only for individuals over 40 years of age. Changes in dietary habits over many years can affect iron intake in postpartum women, and alterations in diet may lead to fluctuations in hemoglobin levels up to approximately 1 month postpartum.

The measurement of transcutaneous hemoglobin level, which replaces blood hemoglobin level as an indicator of anemia, is beneficial for postpartum women. Blood hemoglobin level testing requires blood sampling, which is painful and carries the risk of infection. Meanwhile, transcutaneous hemoglobin levels can be easily measured by simply placing a special sensor on the fingertip, providing results on the spot, and allowing frequent measurements. It is useful for rapid monitoring of large fluctuations in hemoglobin levels in postpartum women and provides quick results during outpatient visits. In a previous systematic review and meta-analysis of transcutaneous hemoglobin measuring devices, Hiscock et al[13] found that the overall mean difference between blood and transcutaneous hemoglobin levels was –0.03 g/dL (95% prediction interval, –0.30 to 0.23), with 95% limits of agreement of –3.0 to 2.9 g/dL. Kim et al[14] found the overall mean difference and standard deviation to be 0.10 ± 1.37 g/dL (95% prediction interval, –2.59 to 2.80). These results are more reliable than the overall mean difference of 1.0 g/dL published by Masimo Co, Ltd[15] and suggest that blood hemoglobin levels can be substituted for transcutaneous hemoglobin levels in clinical practice.

Postpartum hemoglobin levels are dependent on the body's absorption of iron from external sources such as diet. Hemoglobin is found in red blood cells and is composed of "heme" (an iron-containing blood pigment) and "globin" (a protein). Therefore, iron deficiency results in low hemoglobin levels. However, because the body cannot synthesize iron, all the iron present in the body must be derived from dietary sources, except for that acquired through pharmacotherapy. Consequently, if iron absorption is normal, iron reserves stored in the body are directly proportional to the quantity of iron consumed in the diet. It takes approximately 7 days for red blood cells to be synthesized from proerythroblasts using iron, indicating that the benefits of an iron-rich diet will not manifest until at least 7 days after ingesting iron. Therefore, hemoglobin levels in women up to approximately 1 week postpartum are dependent on their dietary habits during the third trimester of pregnancy.[16] Bambo et al[17] also reported that iron intake in the third trimester of pregnancy is a factor in postpartum anemia. Accordingly, we suggest that dietary intake during the third trimester of pregnancy influences hemoglobin levels in the postpartum period.

Approximately 1 week postpartum, breast milk changes from transitional to mature milk, with an increase in the volume of milk produced. Simultaneously, this is a period of increased iron transfer into breast milk, which might explain the slower rate of increase in hemoglobin levels during this period. In addition, previous studies have reported a higher prevalence of postpartum anemia in mothers who exclusively breastfeed than in those who use infant formula or mixed feeding.[18-20] Therefore, we propose that assessing the effect of iron transfer to infants through breast milk on postpartum anemia is necessary.

This study aimed to clarify the temporal changes in transcutaneous hemoglobin levels from 1 day to 1 month after delivery and explore the factors influencing these changes by using a noninvasive and safe transcutaneous hemoglobin measurement device.

Hypothesis

Based on the findings of Miller et al[12] on temporal changes in blood hemoglobin levels in women from 1 day to 1 month postpartum, we hypothesized that transcutaneous hemoglobin levels are lower on day 4 than on day 1 postpartum and then increase at a consistent rate until 1 month postpartum.

METHODS

Definition

The World Health Organization defines anemia as a blood hemoglobin level of less than 11.0 g/dL. Based on this definition, we defined anemia as a transcutaneous hemoglobin level of less than 11.0 g/dL.

Research design

This longitudinal study was conducted between December 2021 and October 2022.

Participants

Eligibility criteria. Participants were women who were deemed ready for the study by their attending physicians. Inclusion criteria were (a) over 20 years of age, (b) at least 33 weeks of gestation, (c) no pregnancy complications (including preeclampsia, hypertensive disorders of pregnancy, gestational diabetes), (d) no other iron deficiency anemia, (e) no kidney, autoimmune, psychiatric, thyroid, or digestive system diseases, (f) intention to have 2-week or 1-month postpartum checkups at the collaborating institution participating in the study, and (g) understanding the research description in Japanese.

Exclusion criteria. We excluded women who (a) delivered a non-live-born infant, (b) delivered before 37 weeks or after 42 weeks of gestation, (c) received a blood transfusion at delivery, (d) experienced postpartum hemorrhage, (e) breastfed or formula-fed their infants less than three times a day at 2 weeks and 1 month postpartum, (f) could not have their transcutaneous hemoglobin measured due to injuries on their fingers, and (g) exhibited a special pattern of absorbance for which the numerical level could not be calculated using the principle of transcutaneous hemoglobin measurement.

Data collection

This study was conducted at a secondary emergency hospital with a neonatal intensive care unit located in an urban area of central Japan. Participants were recruited during prenatal checkups. They were provided with an explanation of this study, an agreement form, and a brief self-administered diet history questionnaire (BDHQ). The researcher received these materials when the participants were hospitalized for delivery. Transcutaneous hemoglobin levels were measured on days 1 and 4 postpartum during the hospital stay and at 2 weeks and 1 month postpartum in the outpatient clinic.

Informed consent

We explained the study to the participants using written instructions regarding the waiting time for prenatal care checkups. A set of documents (explanation document, consent form, consent withdrawal form, and questionnaires) were distributed to the women. Informed consent was obtained from all the enrolled participants.

Data collection procedure

We visited the women 1 day after their deliveries in their hospital rooms. The transcutaneous hemoglobin levels were measured thrice for approximately 1 min each time by attaching the dedicated Pronto (Masimo Japan) sensor to the ring finger of the non-dominant hand while the women were in a sitting position. Four days postpartum, the researcher visited the hospitalized mothers again and measured the transcutaneous hemoglobin levels thrice using the same procedure. At health examinations 2 weeks and 1 month postpartum, transcutaneous hemoglobin levels were again measured thrice by the researcher while the participants were in the waiting room. The researcher obtained data on the sociodemographic characteristics and blood hemoglobin levels of the participants from their electronic medical records.

Transcutaneous hemoglobin measurement. Transcutaneous hemoglobin measurement was performed using the Pronto device. This innovative equipment assesses transcutaneous hemoglobin in under a minute by affixing a specialized sensor to the fingertip. The Pronto employs a multi-wavelength sensor, utilizing at least seven wavelengths, to differentiate between oxyhemoglobin, deoxyhemoglobin, carboxyhemoglobin, methemoglobin, and plasma. Furthermore, the device integrates sensors equipped with various light-emitting diodes. Signal data are collected through the transmission of visible and infrared light (range, 500–1,300 nm) across the capillary bed of the fingertip, capturing changes in absorbance throughout the blood pulsation cycle. Based on the signal from the sensor, the device calculates the total hemoglobin level using a proprietary algorithm. In terms of device reliability, findings from Masimo Japan[15] involving 3,519 participants revealed a correlation coefficient between transcutaneous and blood hemoglobin levels of $r = 0.91$, with a standard deviation for transcutaneous hemoglobin levels (±SD) of ±0.8.

Blood hemoglobin measurement. Blood was drawn from the participants by the ward staff on day 1 postpartum. Blood hemoglobin was analyzed using three device types from Beckman Coulter (LH750/LH780/HNK) and ADVIA120 from Siemens Healthcare Diagnostics.

Anemia treatment. Anemia treatment included intravenous or oral iron preparations.

Dietary habits in the third trimester of pregnancy. Dietary habits in the third trimester of pregnancy were surveyed using the BDHQ developed by Kobayashi et al,[21] which assessed nutrient intake in the past month.

Sociodemographic characteristics and blood hemoglobin levels. We collected data on participants' age, height, weight, medical history, delivery history, working status, hemoglobin levels during pregnancy and the postpartum period, number of gestation weeks, delivery style, intrapartum hemorrhage, birth weight, and types of feeding from the electronic medical records.

Analysis

For sociodemographic characteristics, ordinal and nominal variables were presented as percentages. Furthermore, continuous variables were presented as means and standard deviations for normally distributed items and as medians and interquartile ranges for non-normally distributed items. The concordance between the transcutaneous hemoglobin and blood hemoglobin levels on day 1 postpartum was assessed by Bland-Altman analysis.

Transcutaneous hemoglobin levels were measured on day 1, day 4, 2 weeks, and 1 month to clarify the time of significant change in transcutaneous hemoglobin levels from day 1 to day 4, from day 4 to 2 weeks, and from 2 weeks to 1 month. In addition, the transcutaneous hemoglobin level at two-time points, which had the largest amount of change, was examined using a paired t-test. To investigate the effects of iron intake in the third trimester of pregnancy and types of feeding on transcutaneous hemoglobin level changes, factors associated with postpartum anemia in previous studies[19,22-29] were analyzed by adjusted logistic regression.

Statistical analyses were conducted using SPSS 28.0 J (IBM Corp), and a significance level of $p < 0.05$ was established.

Ethical considerations

We explained the research objective, methods, protection of personal information, voluntary nature of participation, absence of penalties for non-participation in this study, and liberty to withdraw consent at any point to the participants orally and in writing while patients were waiting for perinatal care checkups. Furthermore, written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Nagoya University Graduate School of Medicine and Hospital (approval number: 21-133).

RESULTS

Questionnaires were distributed to the 142 women who participated in this study. After seven women withdrew their consent due to poor physical condition during delivery or the early postpartum period, we finally analyzed data from 135 participants.

Sociodemographic characteristics of the participants

Table 1 summarizes the participants' sociodemographic characteristics. The mean (SD) age was 31.7 (5.4) years. The mean (SD) pre-pregnancy body mass index was 21.6 (3.2). A total of 19 (14.1%) women took oral pharmacotherapy for anemia during the third trimester of pregnancy, 89 (65.9%) were multiparous, and 86 (63.7%) underwent vaginal deliveries. The median intrapartum hemorrhage was 690.8 mL, with an interquartile range of 396.0–871.5 mL. The mean (SD) birth weight was 3,019 (33.6) g, with three infants having low birth weight (<2,500 g) and one infant having macrosomia (≥4,000 g).

Table 1 Sociodemographic characteristics of study participants (n = 135)

		Mean ± standard deviation	**N (%)**	**Median (interquartile range)**
Age (years)		31.7 ± 5.4		
Height (cm)		157.5 ± 5.5		
Pre-pregnancy weight (kg)				54.1 (48.0–60.0)
Pre-pregnancy BMI (kg/m^2)		21.6 ± 3.2		
Oral pharmacotherapy for anemia during third trimester of pregnancy	Positive		19 (14.1)	
	Negative		115 (85.2)	
	Unclear		1 (0.7)	

Intake during third trimester of pregnancy	Iron (mg/day)	7.9 ± 0.6		
	Energy (kcal/day)			1693.8 (1286.6–2333.2)
	Protein (g/day)	62.1 ± 20.8		
	Fat (g/day)			57.1 (41.9–75.5)
	Carbohydrate (g/day)			233.6 (171.4–310.0)
Marital status	Married		130 (96.3)	
	Unmarried		2 (1.5)	
	Unclear		3 (2.2)	
Delivery history	Primiparous		46 (34.1)	
	Multiparous		89 (65.9)	
Delivery style	Vaginal delivery		86 (63.7)	
	Caesarean section		49 (36.3)	
Intrapartum hemorrhage (mL)				690.8 (396.0–871.5)
Birth weight (g)		3019 ± 33.6		

BMI: body mass index

Relationship between transcutaneous and blood hemoglobin levels on day 1 postpartum

Figure 1 shows the Bland–Altman plots for transcutaneous hemoglobin level comparisons with blood hemoglobin levels. This comparison showed a bias (SD) of 2.4 (1.11) g/dL (95% confidence interval, 2.18–2.58), with limits of agreement 0.19–4.55 g/dL and an agreement range of 4.37

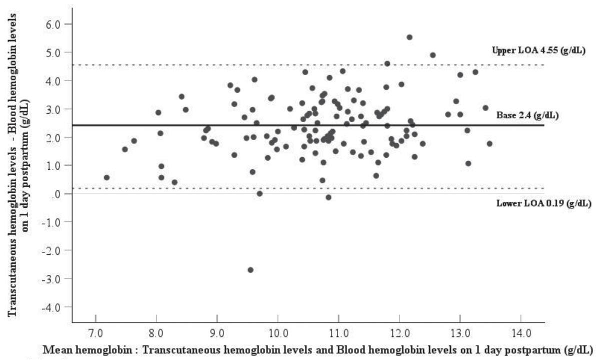

Fig. 1 Differences in blood hemoglobin levels and transcutaneous hemoglobin levels (Bland–Altman plots; n = 135)

The y-axis shows the accuracy and variability of transcutaneous hemoglobin levels with blood hemoglobin levels. Bias, limits of agreement (LOA), and range for the comparison between blood hemoglobin levels and transcutaneous hemoglobin levels samples are shown. Bias represents the mean difference between the two hemoglobin levels. Lower LOA = mean difference – 1.96SD × mean difference, and upper LOA = mean difference + 1.96SD × mean difference. Agreement range = Lower LOA + Upper LOA.

g/dL. The sensitivity and specificity of the presence or absence of anemia in transcutaneous hemoglobin and blood hemoglobin levels were 30.0% and 100.0%, respectively. The sensitivity and specificity of the presence or absence of anemia in transcutaneous hemoglobin levels and blood hemoglobin levels corrected by subtracting 2.4 g/dL with reference to Bland–Altman plots were 93.5% and 45.0%, respectively.

The mean transcutaneous hemoglobin levels (mean ± SD, 11.9 ± 1.6 g/dL) were significantly higher than the blood hemoglobin levels (mean ± SD, 9.5 ± 1.3 g/dL; $p<0.01$). Based on Pearson's correlation coefficient, a strong correlation was observed between blood and transcutaneous hemoglobin levels on day 1 postpartum ($r = 0.71$).

Change in transcutaneous hemoglobin levels from 1 day to 1 month postpartum

Figure 2 shows transcutaneous hemoglobin levels on day 1, day 4, 2 weeks, and 1 month postpartum. The mean transcutaneous hemoglobin level decreased slightly from day 1 (mean ± SD, 11.9 ± 1.6 g/dL) to day 4 postpartum (mean ± SD, 11.8 ± 1.7 g/dL), followed by a significant increase from day 4 to 2 weeks postpartum (mean ± SD, 13.8 ± 1.0 g/dL; $p<0.01$). The mean transcutaneous hemoglobin levels from 2 weeks to 1 month postpartum (mean ± SD, 13.8 ± 0.9 g/dL) were unchanged.

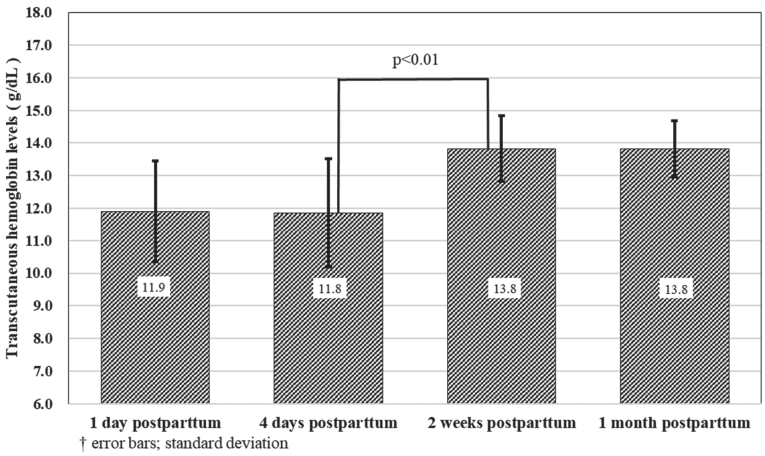

Fig. 2 Temporal changes in transcutaneous hemoglobin levels of the postpartum women included in this study (n = 135)

Factors associated with the change in transcutaneous hemoglobin levels between day 4 and 2 weeks postpartum

Table 2 reports the factors associated with changes in transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. Women were divided into two groups using the median change in transcutaneous hemoglobin levels between day 4 and 2 weeks postpartum (1.8 g/dL) as the cutoff: 49 women had a change greater than 1.8 g/dL, and 45 women had a change of less than 1.8 g/dL. Hemoglobin levels decreased in five participants and increased in 89 participants between day 4 and 2 weeks postpartum. All five participants who showed a decrease in hemoglobin levels had a magnitude of change of less than 1.8 g/dL. Multivariate analysis revealed that mothers with higher iron intake in the third trimester of pregnancy experienced significantly greater changes of 1.8 g/dL or more than those with lower iron intake.

Table 2 Factors influencing the amount of changes in transcutaneous hemoglobin levels between 4 days postpartum and 2 weeks postpartum (n = 94)

Independent variables	Large increase in transcutaneous hemoglobin[a]			
	Univariate		Multivariate	
	COR	95% CI	AOR	95% CI
Age	1.079	1.004 – 1.159	1.051	0.973 – 1.134
Pre-pregnant BMI	0.985	0.890 – 1.090		
Iron intake during third trimester of pregnancy (mg/day)	1.223	1.038 – 1.439	**1.197**	**1.006 – 1.425**
Intrapartum hemorrhage (/10 mL)	1.011	1.001 – 1.022	1.011	0.999 – 1.022
Birth weight (g)	1.001	1.000 – 1.002		
Employment status				
Not working	1.000			
Working	0.895	0.395 – 2.026		
Delivery history				
Primipara	1.000			
Multipara	1.087	0.487 – 2.425		
Delivery style				
Vaginal	1.000			
Caesarean section	0.524	0.234 – 1.168		
One day postpartum pharmacotherapy				
No pharmacotherapy	1.000			
Pharmacotherapy	0.698	0.305 – 1.597		
Types of feeding (2 weeks postpartum)				
Infant formula	1.000			
Exclusive breastfeeding	1.979	0.441 – 8.873		
Mixed	1.107	0.273 – 4.493		

[a] <1.8 g/dL (n = 49): changes in hemoglobin levels between 4 days postpartum and 2 weeks postpartum group = 0
≥1.8 g/dL (n = 45): changes in hemoglobin levels between 4 days postpartum and 2 weeks postpartum group = 1
BMI: body mass index
COR: crude odds ratio
AOR: adjusted odds ratio
95% CI: 95% confidence interval

Relationship between iron intake and presence or absence of anemia oral treatment in the third trimester of pregnancy

The mean (SD) iron intake in the third trimester of pregnancy, according to the BDHQ, was 7.9 (2.7) mg/day. The mean (SD) iron intake in the third trimester of pregnancy for the 19 women who took oral treatment for anemia and the 115 women who did not take treatment was 7.78 (2.1) mg/dL and 7.92 (2.7) mg/dL, respectively. The unpaired t-test performed on the mean values of the two groups revealed no significant differences. In addition, logistic regression analysis was performed with the dependent variable being the presence of oral treatment for anemia in the third trimester of pregnancy and the independent variable being iron intake in the third trimester of pregnancy, with the following results: reference = no treatment, crude odds ratio = 1.021, 95% confidence interval = 0.842–1.239; no significant difference existed. Despite concerns that low iron intake in the third trimester of pregnancy might increase the likelihood of receiving oral treatment for anemia, these results showed no significant association between iron intake and the use of oral treatment for anemia during this period. Therefore, we did not exclude participants who were on oral treatment for anemia in the third trimester of pregnancy.

DISCUSSION

In this study, for the first time, we found a more rapid increase in mean transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum.

The mean transcutaneous hemoglobin levels decreased from day 1 to day 4, supporting our hypothesis. However, the change in transcutaneous hemoglobin levels from day 4 to 1 month postpartum did not increase by a constant amount, undermining this hypothesis.

The factor affecting changes in transcutaneous hemoglobin levels at day 4 and 2 weeks postpartum for participants was iron intake in the third trimester of pregnancy.

The mean transcutaneous hemoglobin level at 2 weeks postpartum increased sharply from day 4 postpartum in this study. No previous studies have measured blood hemoglobin levels around 2 weeks postpartum, and most results were based on a line graph connecting levels at day 4 and 1 month postpartum, which was interpreted as a gradual increase during this period. Hence, we did not predict a rapid increase, as observed in this study. The increase from day 4 to 2 weeks postpartum has not been fully elucidated, yet the restoration of transcutaneous hemoglobin to normal levels by at least 2 weeks postpartum is a novel and significant finding. We believe that this rapid increase is due to the production of blood cells. During the production of erythrocytes, hematopoietic stem cells in the bone marrow become pre-erythroblasts, which then undergo a maturation process that takes approximately 7 days.[16] Therefore, replacing erythrocytes lost through intrapartum hemorrhage and lochia takes at least 7 days postpartum. We consider that because erythrocytes lost during labor are produced 7 days postpartum, the hemoglobin levels in this study increased rapidly from day 4 to 2 weeks postpartum.

Factors associated with the change in transcutaneous hemoglobin levels between day 4 and 2 weeks postpartum

Iron intake during the third trimester of pregnancy was identified as a factor influencing the amount of change in transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. It takes approximately 1 week to produce new red blood cells to replace those lost during intrapartum hemorrhage and other events. Therefore, iron intake in the third trimester of pregnancy is not directly related to the production of red blood cells immediately after delivery until day 1 or day 4 postpartum. Further, this iron intake is not directly involved in the change in the transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. Women with higher iron intake in the third trimester of pregnancy have greater iron stores than those with lower intake. When the body has excess iron, it binds to a protein called ferritin in the liver and spleen and is stored.[30,31] This stored iron is then used when new red blood cells are produced. Thus, women with higher iron intake in the third trimester of pregnancy may have more iron stores than women with lower iron intake, suggesting that iron stores are used to produce red blood cells lost during labor and that red blood cells are produced more rapidly. This may have contributed to the rapid increase in transcutaneous hemoglobin levels from 4 days to 2 weeks postpartum. From these results, we believe that iron intake in the third trimester of pregnancy, while not directly affecting the change in hemoglobin levels, influences this change indirectly through the women's stored iron and daily diet. This suggests that, to promote recovery from day 4 to 2 weeks postpartum, it is effective to encourage iron intake by informing pregnant women during health guidance in the third trimester that dietary iron intake affects the recovery of postpartum hemoglobin levels.

The type of feeding until 2 weeks postpartum did not affect the amount of change in transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. Exclusive breastfeeding was expected to result in lesser changes in transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum due to greater iron transfer to the infant through breast milk compared to women who were mixed feeding or using infant formula, but no effect was noted. Although anemia in breastfeeding women is a common concern,[18-20] in this study, the type of feeding until 2 weeks postpartum did not affect the change in transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. Therefore, we recommend assisting mothers who wish to breastfeed their infants for up to 2 weeks postpartum, regardless of changes in transcutaneous hemoglobin levels.

Study limitations

This study has four main limitations. First, the results of this study cannot be generalized because the study participants were relatively healthy women without underlying diseases or abnormalities during pregnancy, delivery, or the postpartum period. Therefore, the study findings are applicable only to healthy women without complications.

Second, accurately determining the extent to which the body absorbs iron intake during the third trimester of pregnancy is challenging. Transcutaneous hemoglobin levels rely on the body's iron stores to produce hemoglobin; therefore, these levels reflect how much ingested iron is absorbed and utilized by the body. Food combinations can influence the absorption rate of ingested iron. For example, consuming caffeine alongside iron-containing foods can inhibit iron absorption. Conversely, the absorption of iron is enhanced when foods rich in vitamin C and animal proteins are consumed with iron-containing foods. A limitation of the BDHQ used in this study is that it did not allow for an accurate assessment of the actual amount of iron absorbed, as the specific food combinations were not recorded.

Third, the degree of correction for transcutaneous hemoglobin levels is a consideration. In this study, correcting for the 2.4 g/dL difference between the mean hemoglobin and blood hemoglobin levels resulted in a sensitivity of over 90.0%, indicating a high level of reliability that does not significantly affect the reliability of transcutaneous hemoglobin measurements. However, Butwick et al[32] and Mills et al[33] reported mean differences of 1.36 and 2.4 g/dL, respectively, between transcutaneous and blood hemoglobin levels on postpartum day 1 following cesarean section or vaginal delivery. Therefore, future investigations should focus on determining the appropriate degree of correction needed to increase the reliability of transcutaneous hemoglobin levels.

Fourth, the sample size of this study was small. Although small sample sizes may render substantively meaningful differences statistically insignificant, the data analysis in this study yielded significant p-values.

Conclusion

This study found that transcutaneous hemoglobin levels decreased slightly from day 1 to day 4 postpartum, followed by a sharp increase from day 4 to 2 weeks, remaining unchanged until 1 month postpartum. These findings highlight the importance of assessing hemoglobin recovery in women at 2 weeks postpartum. Furthermore, iron intake in the third trimester of pregnancy was identified as a key factor influencing the recovery of transcutaneous hemoglobin levels from day 4 to 2 weeks postpartum. Based on these results, providing health guidance on iron intake during the third trimester is recommended to effectively restore postpartum hemoglobin levels.

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Author contributions

M.S. contributed to the conception and design of this study, collected data, performed the statistical analysis, and drafted the manuscript. S.I. critically reviewed the manuscript and supervised the whole study process. Both authors read and approved the final manuscript.

Conflict of interest disclosure

The authors have no conflict of interest to declare.

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REFERENCES

1 Lin CY, Li CK, Liu JM, Hsu RJ, Chuang HC, Chang FW. Postpartum Depression and Subsequent Autoimmune Diseases in Taiwan. *Int J Environ Res Public Health*. 2018;15(8):1783. doi:10.3390/ijerph15081783

2 Maeda Y, Ogawa K, Morisaki N, Tachibana Y, Horikawa R, Sago H. Association between perinatal anemia and postpartum depression: A prospective cohort study of Japanese women. *Int J Gynaecol Obstet*. 2020;148(1):48–52. doi:10.1002/ijgo.12982

3 Kang SY, Kim HB, Sunwoo S. Association between anemia and maternal depression: A systematic review and meta-analysis. *J Psychiatr Res*. 2020;122:88–96. doi:10.1016/j.jpsychires.2020.01.001

4 Corwin EJ, Arbour M. Postpartum Fatigue and Evidence-Based Interventions. *MCN Am J Matern Child Nurs*. 2007;32(4):215–220. doi:10.1097/01.NMC.0000281959.71454.e5

5 Holm C, Thomsen LL, Langhoff-Roos J. Intravenous iron isomaltoside treatment of women suffering from severe fatigue after postpartum hemorrhage. *J Matern Fetal Neonatal Med*. 2019;32(17):2797–2804. doi:10.1080/14767058.2018.1449205

6 Choi H, Yamashita T, Wada Y, et al. Factors associated with postpartum depression and abusive behavior in mothers with infants. *Psychiatry Clin Neurosci*. 2010;64(2):120–127. doi:10.1111/j.1440-1819.2010.02063.x

7 Earls MF; Committee on Psychosocial Aspects of Child and Family Health American Academy of Pediatrics. Incorporating recognition and management of perinatal and postpartum depression into pediatric practice. *Pediatrics*. 2010;126(5):1032–1039. doi:10.1542/peds.2010-2348

8 Lee YL, Tien Y, Bai YS, et al. Association of Postpartum Depression with Maternal Suicide: A Nationwide Population-Based Study. *Int J Environ Res Public Health*. 2022;19(9):5118. doi:10.3390/ijerph19095118

9 Scott D. Early identification of maternal depression as a strategy in the prevention of child abuse. *Child Abuse Negl*. 1992;16(3):345–358. doi:10.1016/0145-2134(92)90044-r

10 Pugh LC, Milligan R. A framework for the study of childbearing fatigue. *ANS Adv Nurs Sci*. 1993;15(4):60–70. doi:10.1097/00012272-199306000-00007

11 Furuya H, Kurabayashi M, Hasegawa S. Changes in blood composition, water, electrolytes, metabolism of glucose. Published in Japanese. In: Okada H, ed. *Puerperium*. Kanehara Publication; 1979:44–54. *Obstetrics and Gynecology MOOK*; 7.

12 Miller J, Williams HB, Macarthur JL. Hemoglobin changes in labor and the puerperium; a study of 102 patients. *Am J Obstet Gynecol*. 1959;78(2):303–312. doi:10.1016/0002-9378(59)90179-6

13 Hiscock R, Kumar D, Simmons SW. Systematic review and meta-analysis of method comparison studies of Masimo pulse co-oximeters (Radical-7™ or Pronto-7™) and HemoCue® absorption spectrometers (B-Hemoglobin or 201+) with laboratory haemoglobin estimation. *Anaesth Intensive Care*. 2015;43(3):341–350. doi:10.1177/0310057x1504300310

14 Kim SH, Lilot M, Murphy LS, et al. Accuracy of continuous noninvasive hemoglobin monitoring: a systematic review and meta-analysis. *Anesth Analg*. 2014;119(2):332–346. doi:10.1213/ane.0000000000000272

15 Masimo. Total Hemoglobin (SpHb). Accessed October 3, 2024. https://professional.masimo.com/technology/co-oximetry/sphb/#references-list

16 Mescher AL. Hemopoisis. In: Mescher AL ed. *Junqueira's Basic Histology*. 16th edition. McGraw-Hill; 2021:Chapter 13.

17 Bambo GM, Kebede SS, Sitotaw C, Shiferaw E, Melku M. Postpartum anemia and its determinant factors among postnatal women in two selected health institutes in Gondar, Northwest Ethiopia: A facility-based, cross-sectional study. *Front Med (Lausanne)*. 2023;10:1105307. doi:10.3389/fmed.2023.1105307

18 Basrowi RW, Zulfiqqar A, Sitorus NL. Anemia in Breastfeeding Women and Its Impact on Offspring's Health in Indonesia: A Narrative Review. *Nutrients*. 2024;16(9):1285. doi:10.3390/nu16091285

19 Teixeira Mde L, Lira PI, Coutinho SB, Eickmann SH, Lima MC. Influence of breastfeeding type and maternal anemia on hemoglobin concentration in 6-month-old infants. *J Pediatr (Rio J)*. 2010;86(1):65–72. doi:10.1590/S0021-75572010000100012

20 Amano I, Murakami A. Prevalence of infant and maternal anemia during the lactation period in Japan. *Pediatr Int*. 2019;61(5):495–503. doi:10.1111/ped.13833

21 Kobayashi S, Honda S, Murakami K, et al. Both comprehensive and brief self-administered diet history questionnaires satisfactorily rank nutrient intakes in Japanese adults. *J Epidemiol*. 2012;22(2):151–159. doi:10.2188/jea.je20110075

22 Aguree S, Owora A, Hawkins M, Reddy MB. Iron Deficiency and Iron Deficiency Anemia in Women with and without Obesity: NHANES 2001–2006. *Nutrients*. 2023;15(10):2272. doi:10.3390/nu15102272

23 Başkiran Y, Uçkan K, Çeleğen I. Effect of grand multiparity on maternal, obstetric, fetal and neonatal results. *Eur Rev Med Pharmacol Sci*. 2023;27(22):10979–10984. doi:10.26355/eurrev_202311_34466

24 Young MF, Oaks BM, Tandon S, Martorell R, Dewey KG, Wendt AS. Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. *Ann N Y Acad Sci*. 2019;1450(1):47–68. doi:10.1111/nyas.14093

25 Rudzinski P, Lopuszynska I, Pieniak K, Stelmach D, Kacperczyk-Bartnik J, Romejko-Wolniewicz E. Feeding Practices, Maternal and Neonatal Outcomes in Vaginal Birth after Cesarean and Elective Repeat Cesarean Delivery. *Int J Environ Res Public Health*. 2022;19(13):7696. doi:10.3390/ijerph19137696

26 Kamruzzaman M. Is BMI associated with anemia and hemoglobin level of women and children in Bangladesh: A study with multiple statistical approaches. *PLoS One*. 2021;16(10):e0259116. doi:10.1371/journal.pone.0259116

27 Baş EK, Bülbül A, Uslu S, Baş V, Elitok GK, Zubarioğlu U. Maternal Characteristics and Obstetric and Neonatal Outcomes of Singleton Pregnancies Among Adolescents. *Med Sci Monit*. 2020;26:e919922. doi:10.12659/msm.919922

28 Huang CC, Huang YT, Wu MP. A nationwide population analysis of antenatal and perinatal complications among nurses and nonmedical working women. *Taiwan J Obstet Gynecol*. 2016;55(5):635–640. doi:10.1016/j.tjog.2015.06.015

29 Basu S, Sidh SN. Work status and health of women: a comparative study of northern and southern states of rural India. *World Health Popul*. 2008;10(2):40–52. doi:10.12927/whp.2008.19930

30 World Health Organization. WHO guideline on use of ferritin concentrations to assess iron status in individuals and populations. Published April 21, 2020. Accessed October 1, 2024. https://www.who.int/publications/i/item/9789240000124#:~:text=This%20guideline%20provides%20global,%20evidence-informed

31 Mei Z, Addo OY, Jefferds ME, Sharma AJ, Flores-Ayala RC, Brittenham GM. Physiologically based serum ferritin thresholds for iron deficiency in children and non-pregnant women: a US National Health and Nutrition Examination Surveys (NHANES) serial cross-sectional study. *Lancet Haematol*. 2021;8(8):e572–e582. doi:10.1016/s2352-3026(21)00168-x

32 Butwick AJ, Walsh EM, Kuzniewicz M, Li SX, Escobar GJ. Patterns and predictors of severe postpartum anemia after Cesarean section. *Transfusion*. 2017;57(1):36–44. doi:10.1111/trf.13815

33 Mills K, Vermeer JM, Berry WE, Karreman E, Lett CD. Determining the validity of non-invasive spot-check hemoglobin co-oximetry testing to detect anemia in postpartum women at a tertiary care centre, a prospective cohort study. *BMC Pregnancy Childbirth*. 2023;23(1):479. doi:10.1186/s12884-023-05783-3