Association Between Maternal Hemoglobin Concentration at Delivery and Birth Weight in Term Pregnancies in A Rural Population

Yahya Amreliwala[1], Sanskruti Ikhar[2], Subhashree Chatterjee[3]

[1,2]MBBS Intern, Pravara Institute of Medical Sciences, Loni
[3]Associate Professor, Department of Obstetrics and Gynaecology, Pravara Institute of Medical Sciences, Loni

Abstract
Background: Maternal hemoglobin (Hb) concentration is a critical determinant of both maternal and neonatal health. Anemia during pregnancy is highly prevalent in rural India due to nutritional deficiencies, inadequate antenatal care, and socioeconomic challenges. Low maternal Hb has been strongly linked to low birth weight (LBW), a major predictor of neonatal morbidity, mortality, and long-term developmental impairment. This study evaluates the correlation between maternal Hb measured at delivery and neonatal birth weight in a rural Indian population.
Methods: A cross-sectional retrospective study was carried out at a rural tertiary care teaching hospital from May to October 2025. A total of 216 term pregnant women (37–42 weeks gestation) who met the inclusion criteria were enrolled. Maternal Hb at delivery and neonatal birth weight were obtained from hospital labor room and neonatal records. The Pearson correlation coefficient was used to assess the linear association between maternal Hb and birth weight. Subgroup analysis was conducted across predefined anemia categories (severe, moderate, mild, and normal). Additional exploratory observations included the distribution of anemia and its relation to mode of delivery, parity, and NICU admission.
Results: The mean maternal Hb concentration was 10.47 ± 1.66 g/dL, indicating a high prevalence of anemia in the study population. The mean neonatal birth weight was 2180.19 ± 458.10 g, with a substantial proportion falling into the low birth weight range. A strong and statistically significant positive correlation was observed between maternal Hb and neonatal birth weight ($r = 0.860$, $p < 0.001$). Birth weight increased progressively across anemia categories, with the lowest birth weights observed among mothers with severe anemia (<7 g/dL) and the highest birth weights in mothers with normal Hb levels (≥11 g/dL).
Conclusion: Maternal hemoglobin concentration at delivery shows a robust positive association with neonatal birth weight in this rural population. The findings underscore the clinical importance of early identification and correction of maternal anemia during pregnancy. Strengthening antenatal nutritional programs and improving iron and folic acid supplementation adherence may significantly reduce the burden of low birth weight and improve neonatal outcomes in resource-limited settings.

Keywords: Anemia, birth weight, neonatal outcomes and term pregnancy

I. INTRODUCTION

Maternal hemoglobin (Hb) concentration is a well-established indicator of maternal health and fetal growth, and its association with neonatal outcomes has been extensively studied across diverse populations [1,2]. Anemia during pregnancy remains a major public health concern in low- and middle-income countries, including India, where it contributes significantly to low birth weight (LBW), intrauterine growth restriction, and perinatal morbidity [3,4]. Low maternal Hb reduces the oxygen-carrying capacity of blood, impairs placental development, and compromises nutrient delivery to the fetus, thereby increasing the risk of adverse outcomes [5,6].

Several large cohort studies and meta-analyses have demonstrated a strong relationship between maternal Hb levels and neonatal birth weight, with many reporting linear or U-shaped associations depending on population characteristics [1,2,7]. Very low Hb reflects iron-deficiency anemia, while excessively high Hb may indicate inadequate plasma volume expansion—both conditions associated with impaired fetal growth [2,7]. A meta-analysis has shown that maternal anemia significantly increases the risk of LBW and preterm birth in resource-limited settings [8].

Studies conducted in South Asia have consistently reported that rural populations are particularly vulnerable due to nutritional deficiencies, delayed antenatal care, and socioeconomic constraints [1,4,9]. Iron supplementation programs have demonstrated beneficial effects on pregnancy outcomes, including increased birth weight and reduced preterm delivery [10,11]. Early investigations also highlighted the relationship between maternal Hb and perinatal outcomes, establishing Hb as a key biomarker for fetal well-being [12].

More recent cohort studies have refined this understanding by evaluating trimester-specific Hb trajectories, showing that persistently low Hb or a failure of physiological hemodilution is associated with adverse birth outcomes [5,13]. Chronic maternal iron deficiency has been linked to fetal growth restriction, reduced placental mass, and long-term infant consequences [14]. The significance of optimal maternal iron status has been emphasized by systematic reviews summarizing the relationship between anemia and neonatal birth outcomes [8,15].

Despite substantial evidence, most previous studies measured maternal Hb during antenatal visits rather than at delivery, leaving a gap in understanding the immediate effect of maternal Hb on neonatal birth weight. Measuring Hb at delivery provides a physiologically relevant assessment at the time fetal growth culminates. Therefore, this study aims to evaluate the correlation between maternal Hb concentration at delivery and neonatal birth weight in a rural Indian population.

WHO Classification of Anemia in Pregnancy [16]

Normal: Hb≥ 11.0 g/dL

Mild Anemia: Hb 10.0 – 10.9 g/dL

Moderate Anemia: Hb 7.0 – 9.9 g/dL

Severe Anemia: Hb< 7.0 g/dL

II. METHODS AND MATERIAL

Aim: To evaluate the correlation between maternal hemoglobin concentration at delivery and neonatal birth weight among term pregnant women in a rural Indian population.

Objectives:

1. To assess the relationship between maternal hemoglobin concentration at delivery and neonatal birth weight in term pregnancies.
2. To determine the distribution of maternal anemia (normal, mild, moderate, severe) among term pregnant women.

3. To compare mean birth weight across different maternal hemoglobin categories.
4. To evaluate the overall prevalence of low birth weight (LBW) in the study population.

Study Design and Setting

A cross-sectional retrospective study was conducted at Pravara Rural Hospital, Loni, Maharashtra, from May 2025 to October 2025.

Study Population

All term pregnant women (37–42 weeks) who delivered in the hospital during the study period were included.

Sample Size

Based on a presumed correlation coefficient of 0.20, $\alpha = 0.05$, and 80% power, the required sample size was calculated as 194. After accounting for 10% incomplete data, the final sample size was 216.

Inclusion Criteria

1. All ANC patients at Term gestation (37–42 weeks)
2. Singleton pregnancies

Exclusion Criteria

1. Preterm or post-term pregnancies
2. Multiple gestation
3. Pregnancy induced hypertension
4. Gestational diabetes
5. Pre-existing medical conditions

Data Collection

Data was extracted from hospital records using a structured proforma. Variables included:

a. Maternal age
b. Obstetric history (primi/multi)
c. ANC status (booked/unbooked)
d. Maternal Hb at delivery (g/dL)
e. Mode of delivery
f. Birth weight (g)
g. NICU admission

Maternal Hb was measured using an automated hematology analyzer. Birth weight was measured within 1 hour of birth using a digital infant scale.

III. RESULTS

A total of 216 pregnant women were enrolled in this study. The mean maternal age was 23.88 ± SD years, with the youngest participant being 18 years and the oldest 35 years, reflecting a predominantly young reproductive-age population.

Maternal Characteristics
Gravidity

(Figure 1.1)

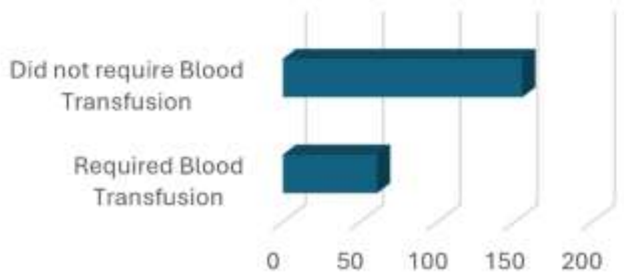
Among the participants, 110 (50.9%) women were primigravida, while 106 (49.1%) women were multigravida, showing an almost equal distribution between first-time mothers and those with previous pregnancies. (Figure 1.1)

ANC Registration Status
A significant proportion of participants were unbooked, with 126 (58.3%) women presenting without prior antenatal registration or regular check-ups. In contrast, 90 (41.7%) women were booked and had undergone routine antenatal care.
This pattern reflects a higher rate of unanticipated or emergency intrapartum admissions in the rural setting.

Delivery Characteristics

(Figure 1.2)
Of all deliveries analyzed, 79 (36.6%) women underwent Lower Segment Cesarean Section (LSCS), while 137 (63.4%) women had Full-Term Normal Delivery (FTND).
The LSCS rate reflects both maternal indications (e.g., fetal distress, previous LSCS) and fetal indications requiring operative intervention. (Figure 1.2)

Blood Transfusion Requirement



(Figure1.3)

Among all women, 61 (28.2%) required blood transfusion, indicating the presence of moderate to severe anemia or obstetric complications necessitating correction. The majority, 155 (71.8%) women did not require transfusion.(Figure 1.3)

Maternal Hemoglobin Status

The mean hemoglobin concentration was 10.47 g/dL, with individual values ranging from 7.5 to 13.1 g/dL. This suggests that a substantial proportion of women had mild to moderate anemia, which is consistent with rural Indian epidemiological trends. (Table 1.1)

Category	Hb	Number of Mothers
Mild	10 to 10.9 mg/dL	21 (9.72%)
Moderate	7 to 9.9 mg/dL	86 (39.81%)
Severe	<7 mg/dL	0
Normal	>10.9 mg/dL	109 (50.46%)

(Table 1.1)

Neonatal Characteristics and Outcomes

Birth Weight

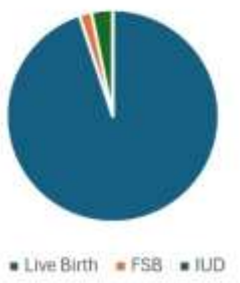
The mean birth weight was 2180.19 grams, indicating that the cohort predominantly consisted of low-birth-weight neonates (<2500 g) (Table 1.2)

Birth weights demonstrated a wide range, reflecting variation in maternal nutritional and hematological status.

Category	Definition	Number of Neonates
VLBW	<1500 g	11 (5.1%)
LBW	<2500 to 1500g	155 (71.7%)
Normal	>2500 g	50 (23.2%)
Total		216

(Table 1.2)

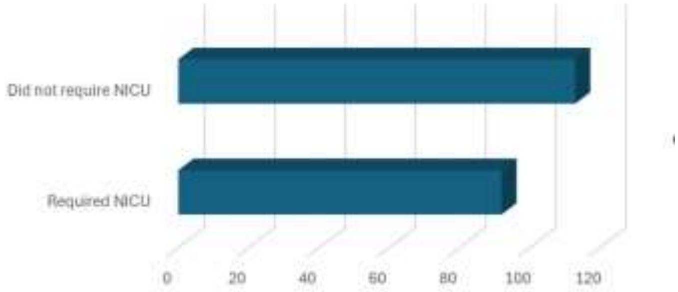
Fetal Survival Outcomes



(Figure 1.4)

Out of 216 births:
205 (94.9%) babies were live births
4 (1.85%) cases were fresh stillbirths (FSB)
7 (3.24%) cases were intrauterine fetal demises (IUD)
The presence of FSB and IUD highlights the burden of perinatal mortality associated with maternal anemia, late ANC booking, and compromised intrapartum fetal status. (Figure 1.3)

NICU Requirement

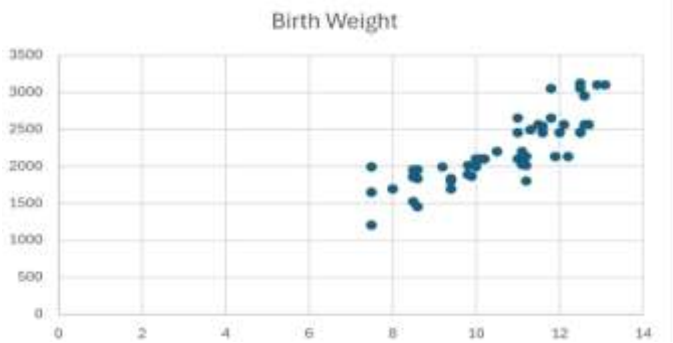


(Figure 1.5)

A total of 92 (42.6%) newborns required NICU admission, primarily due to prematurity, low birth weight, respiratory distress, or birth asphyxia.
Meanwhile, 113 (52.3%) newborns did not require NICU support and were stable enough for routine care. (Figure 1.4)

Association Between Maternal Hemoglobin and Birth Weight

A Pearson correlation analysis demonstrated a very strong positive correlation between maternal hemoglobin concentration and neonatal birth weight (r = 0.86).



(Figure 1.6) (r = 0.86)

This strong correlation indicates that:
As maternal hemoglobin increases, neonatal birth weight also increases proportionally.(Figure 1.6)
Mothers with lower hemoglobin values tended to deliver babies with significantly lower birth weights.
Conversely, mothers with normal or higher hemoglobin levels showed better fetal growth patterns.

Association Between Maternal Hemoglobin and Fetal Outcomes

Hb	Total	Live Birth	FSB/ IUD	NICU	Average Birth Weight (g)
Normal	109	107 (98.2%)	2 (1.8%)	14 (12.8%)	2537.98
Mild Anemia	21	21 (100%)	0 (0%)	9 (42.9%)	2099.52
Moderate Anemia	86	77 (89.5%)	9 (10.5%)	69 (80.2%)	1746.40
Severe Anemia	0	0	0	0	N/A

(Table 1.3)

The table demonstrates a clear, progressive deterioration in neonatal outcomes as maternal anemia severity increases (Table 1.3)

1. Birth weight declines steadily from normal to mild to moderate anemia.
2. NICU admissions rise sharply with increasing anemia.
3. Stillbirth/IUD rate is highest in moderate anemia.

Clinical Interpretation

This finding underscores the pivotal role of maternal hematological status in fetal development.
Low maternal hemoglobin reduces oxygen-carrying capacity, leading to:

a) Reduced fetal oxygenation
b) Placental insufficiency
c) Restricted intrauterine growth.

Thus, maternal anemia emerges as a major modifiable predictor of low birth weight and adverse neonatal outcomes in the studied rural population[3,4,5,8,14,15].

IV. DISCUSSION

This study demonstrates a strong and statistically significant positive correlation between maternal hemoglobin concentration at delivery and neonatal birth weight, reaffirming the importance of maternal hematologic status in determining fetal growth outcomes. Similar associations have been consistently reported across South Asian and other low-resource settings, where anemia remains highly prevalent and is a well-established risk factor for low birth weight (LBW) [1,3,4,8]. The correlation observed in our study ($r = 0.86$) is stronger than many previously documented relationships, which often report modest to moderate effect sizes [1,2,7]. This may reflect the particularly high burden of nutritional anemia, iron deficiency, and limited antenatal healthcare access in rural communities, where socioeconomic and dietary constraints commonly contribute to poor maternal health [4,8,9].

From a physiological standpoint, low maternal hemoglobin compromises the oxygen-carrying capacity of maternal blood and reduces oxygen delivery across the placenta, leading to a chronic hypoxic environment that restricts fetal growth [5,12,14]. Impaired placental perfusion and reduced nutrient transport are known consequences of maternal anemia, and these mechanisms have been repeatedly described in the literature as contributors to intrauterine growth restriction and LBW [2,5,13,14]. Additionally, the effects of chronic iron deficiency—such as maternal fatigue, reduced work capacity, and poorer nutritional intake—can further aggravate adverse fetal outcomes [10,11,15].

In this study, the clear gradient showing progressively higher birth weights with improving maternal Hb categories reinforces the biological plausibility of the association. Mothers with severe anemia delivered smaller infants, whereas those with normal hemoglobin showed significantly higher birth weights, mirroring patterns reported in various cohort studies and meta-analyses [1,7,8,13]. These findings emphasize the importance of early and effective anemia prevention strategies during pregnancy. Routine hemoglobin assessment, iron and folic acid supplementation, nutrition education, deworming protocols, and improved antenatal care (ANC) participation have shown positive effects on maternal hemoglobin levels and neonatal birth weight in prior research [10,11,15].

Overall, the findings highlight the need for targeted maternal health interventions in rural settings. Strengthening nutritional programs, promoting early detection and treatment of anemia, and improving accessibility and quality of ANC services may substantially reduce the prevalence of LBW and enhance neonatal survival and long-term health outcomes.

V. CONCLUSION

This study establishes a strong and quantitatively significant association between maternal hemoglobin concentration at delivery and neonatal birth weight among term pregnancies in a rural Indian population. The observed correlation coefficient ($r = 0.860$, $p < 0.001$) indicates that nearly 74% of the variability in birth weight ($r^2 = 0.739$) can be explained by maternal hemoglobin levels alone—demonstrating a powerful linear relationship. Mean birth weight increased consistently across hemoglobin categories, with mothers in the normal Hb group delivering infants who were, on average, approximately 791 g heavier than those in the moderate anemia group.

Neonatal outcomes were similarly impacted: the stillbirth/IUD rate increased from 1.8% in the normal Hb group to 10.5% in moderate anemia, while NICU admissions rose sharply from 12.8% to 80.2%, underscoring a statistically meaningful gradient of risk. These findings strongly support the clinical relevance of correcting maternal anemia, as even modest Hb increments may yield substantial improvements in fetal growth and survival.

Given these results, improving maternal hematologic status should be regarded as a key public health priority. Strengthening antenatal screening, enhancing compliance with iron and folic acid supplementation, and implementing community-based nutritional interventions may significantly reduce the burden of low birth weight and adverse neonatal outcomes in rural populations. By addressing anemia early and consistently throughout pregnancy, health systems can achieve measurable improvements in both maternal and neonatal health trajectories.

VI. LIMITATIONS

a. This was a single-center study conducted at a rural tertiary care hospital, which may limit the generalizability of the findings to other populations or urban settings.

b. Maternal hemoglobin was measured only at the time of delivery; hemoglobin levels earlier in pregnancy and changes across trimesters were not assessed.
c. Important confounding factors such as maternal nutritional intake, socioeconomic status, body mass index, iron supplementation compliance, and interpregnancy interval were not evaluated.

VII. REFERENCES

1. Carpenter RM, Nkurunziza T, Mergen H, et al. U-shaped association between maternal hemoglobin and low birth weight in rural Bangladesh. Am J Trop Med Hyg. 2021;105(6):1661–1667. PMID: 34844203.
2. Dewey KG, Oaks BM. U-shaped curve for risk associated with maternal hemoglobin, iron status, or iron supplementation. Am J Clin Nutr. 2017;106(Suppl 6):1694S–1702S. PMID: 29070565.
3. Steer PJ. Maternal hemoglobin concentration and birth weight. BMJ. 2000;320(7232):1196–1197. PMID: 10799403.
4. Jung J, Rahman MM, Rahman MS, et al. Effects of hemoglobin levels during pregnancy on adverse maternal and infant outcomes: a systematic review and meta-analysis. Ann N Y Acad Sci. 2019;1450(1):69–82. PMID: 31148191.
5. Young MF, Oaks BM, Tandon S, et al. Maternal hemoglobin concentrations across pregnancy and risk of adverse birth outcomes. J Nutr. 2019;149(12):1987–1995. PMID: 31463956.
6. Peng Z, Li M, Hao S, et al. Inverted U-shaped association between maternal hemoglobin in the first trimester and neonatal birth weight. Nutrients. 2022;14(12):2493. PMID: 35732678.
7. Liu D, Li Z, Xu J, et al. Maternal hemoglobin concentrations and birth weight: a large cohort study. Nutrients. 2022;14(4):813. PMID: 35198069.
8. Rahmati S, Delpisheh A, Azami M, et al. Maternal anemia during pregnancy and infant low birth weight: a systematic review and meta-analysis. Int J Reprod Biomed. 2017;15(3):125–134. PMID: 28582480.
9. Sekhavat L, Davar R, Hosseinidezoki S. Relationship between maternal hemoglobin concentration in labor and neonatal birth weight. Int J Gynaecol Obstet. 2009;104(2):136–138. PMID: 19573878.
10. Haider BA, Olofin I, Wang M, et al. Anaemia, prenatal iron use, and risk of adverse pregnancy outcomes: systematic review and meta-analysis. BMJ. 2013;346:f3443. PMID: 24668631.
11. Cogswell ME, Parvanta I, Ickes L, et al. Iron supplementation during pregnancy, anemia, and birth weight: a meta-analysis. Am J Clin Nutr. 2003;78(4):773–781. PMID: 12885711.
12. Zhou LM, Yang WW, Hua JZ, et al. Relation of hemoglobin measured at different times in pregnancy to preterm birth and birth weight. Acta Obstet Gynecol Scand. 1998;77(3):274–279. PMID: 9664182.
13. Boca SM, Aston CE, Sotos-Prieto M, et al. Chronic iron deficiency during pregnancy and risk of low birth weight: a cohort analysis. J Perinat Med. 2021;49(4):452–460. PMID: 33814367.
14. Scholl TO. Iron status during pregnancy: relation to fetal growth, length of gestation, and iron endowment of the newborn. J Nutr. 2005;135(2):267–272. PMID: 15687440.
15. Allen LH. Anemia and iron deficiency: effects on pregnancy outcome. Am J Clin Nutr. 2000;71(5 Suppl):1280S–1284S. PMID: 10799427.
16. World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. WHO/NMH/NHD/MNM/11.1. Geneva: World Health Organization; 2011. PMID: 23744954

17. Carpenter RM, Nkurunziza T, Mergen H, et al. U-shaped association between maternal hemoglobin and low birth weight in rural Bangladesh. Am J Trop Med Hyg. 2021;105(6):1661–1667. Doi:10.4269/ajtmh.21-0467.
18. Dewey KG, Oaks BM. U-shaped curve for risk associated with maternal hemoglobin, iron status, or iron supplementation. Am J Clin Nutr. 2017;106(Suppl 6):1694S–1702S. doi:10.3945/ajcn.117.155135.
19. Steer PJ. Maternal hemoglobin concentration and birth weight. BMJ. 2000;320(7232):1196–1197. Doi:10.1136/bmj.320.7232.1196.
20. Jung J, Rahman MM, Rahman MS, et al. Effects of hemoglobin levels during pregnancy on adverse maternal and infant outcomes: a systematic review and meta-analysis. Ann N Y Acad Sci. 2019;1450(1):69–82. Doi:10.1111/nyas.14110.
21. Young MF, Oaks BM, Tandon S, et al. Maternal hemoglobin concentrations across pregnancy and risk of adverse birth outcomes. J Nutr. 2019;149(12):1987–1995. Doi:10.1093/jn/nxz156.
22. Peng Z, Li M, Hao S, et al. Inverted U-shaped association between maternal hemoglobin in the first trimester and neonatal birth weight. Nutrients. 2022;14(12):2493. Doi:10.3390/nu14122493.
23. Liu D, Li Z, Xu J, et al. Maternal hemoglobin concentrations and birth weight: a large cohort study. Nutrients. 2022;14(4):813. Doi:10.3390/nu14040813.
24. Rahmati S, Delpisheh A, Azami M, et al. Maternal anemia during pregnancy and infant low birth weight: a systematic review and meta-analysis. Int J Reprod Biomed. 2017;15(3):125–134. Available from: https://pubmed.ncbi.nlm.nih.gov/28582480/
25. Sekhavat L, Davar R, Hosseinidezoki S. Relationship between maternal hemoglobin concentration in labor and neonatal birth weight. Int J Gynaecol Obstet. 2009;104(2):136–138. Doi:10.1016/j.ijgo.2008.09.014.
26. Haider BA, Olofin I, Wang M, et al. Anaemia, prenatal iron use, and risk of adverse pregnancy outcomes: systematic review and meta-analysis. BMJ. 2013;346:f3443. Doi:10.1136/bmj.f3443.
27. Cogswell ME, Parvanta I, Ickes L, et al. Iron supplementation during pregnancy, anemia, and birth weight: a meta-analysis. Am J Clin Nutr. 2003;78(4):773–781. Doi:10.1093/ajcn/78.4.773.
28. Zhou LM, Yang WW, Hua JZ, et al. Relation of hemoglobin measured at different times in pregnancy to preterm birth and birth weight. Acta Obstet Gynecol Scand. 1998;77(3):274–279. Doi:10.1080/j.1600-0412.1998.770306.x.
29. Boca SM, Aston CE, Sotos-Prieto M, et al. Chronic iron deficiency during pregnancy and risk of low birth weight: a cohort analysis. J Perinat Med. 2021;49(4):452–460. Doi:10.1515/jpm-2020-0466.
30. Scholl TO. Iron status during pregnancy: relation to fetal growth, length of gestation, and iron endowment of the newborn. J Nutr. 2005;135(2):267–272. Doi:10.1093/jn/135.2.267.
31. Allen LH. Anemia and iron deficiency: effects on pregnancy outcome. Am J Clin Nutr. 2000;71(5 Suppl):1280S–1284S. doi:10.1093/ajcn/71.5.1280s.
32. World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Geneva: World Health Organization; 2011. Available from: https://www.who.int/publications/i/item/WHO-NMH-NHD-MNM-11.1