Instructions for adjusting haemoglobin data for elevation and smoking and calculating anaemia prevalence from raw haemoglobin data

Updated by CDC IMMPaCt Team: April 2024

The World Health Organization (WHO) released the current Guideline on haemoglobin cutoffs to define anaemia in individuals and populations in March 2024. This document summarizes the steps needed to produce population-level anaemia estimates from raw haemoglobin (Hb) data.

Raw Hb data must be adjusted for smoking and elevation prior to applying cutoffs for anaemia. This is because living at elevations above sea level (starting at 500 m) and smoking cigarettes both increase Hb concentration. If raw Hb data are not adjusted for these factors before applying anaemia cutoffs, the prevalence of anaemia can be under- or overestimated at the population level, depending on the context. You must adjust for both smoking and elevation, so a smoker living at a higher elevation would require two adjustments to their raw Hb value.

Adjustment for elevation

1. Ensure accuracy of elevation data from the tablets/GPS used to collect data.
    a. It is best practice to check the accuracy of the elevation data collected from tablets/GPS units prior to survey data collection. Collecting these data for testing can most easily be incorporated during pre-survey planning visits around the data collection sites or during pilot data collection during training as few data points are needed.
        i. Checking accuracy of the tablet/GPS units can be done by recording elevation using the tablets/GPS that will be used in the survey at locations with known elevations and confirming that the recorded elevation matches the previously established elevation. Other methods of validation could include cross-referencing the recorded elevation data against data recorded by a validated GPS unit, etc.
    b. Manually cross-reference the elevation data recorded by the tablet/GPS unit against a list of elevations produced by entering the latitude and longitude recorded by the tablet/GPS unit into a program that generates elevation for each coordinate.
        i. Upload the data file containing the GPS coordinates of flagged elevation datapoints into https://www.gpsvisualizer.com/elevation.
        ii. This website will create an output file with elevations for each of the coordinates you enter.
            1. NOTE: The website can only handle ~1300 data points at a time, so you must split your data into separate files containing ~1300 datapoints per file before uploading each to the website.

iii. Upload the data file and for "output" select "plain text"
    1. If you have multiple files, each must be converted separately.
iv. Click "Covert & add elevation"
    1. Verify that the .txt file(s) produced includes a column called "altitude (m)" that lists the elevation for each observation.
v. Download the .txt file(s)
    1. If you have done multiple batches, merge all of the .txt files produced to create a single dataset before continuing.
        1. NOTE: Be sure to give the elevation variable produced by the website a name different than that of the elevation variable from your survey (ex: elevation_gps)

2. Clean the elevation data
    a. Impute values for missing elevation.
        i. If you have observations that are missing both elevation and GPS coordinates, you can attempt to impute elevation using data from:
            1. Other members in the same household who have elevation data
            2. Other households in the same village who have elevation data
        ii. NOTE: If there are still households missing data after these imputations, elevation could potentially be imputed from other households in the cluster or region, however, it is important to examine the elevation range in these larger geographic units as it would be imprecise to impute data from a cluster where the elevation range is >100m. Imputations from these regions should be done on a case by case basis according to your own discretion.
            1. Households for which elevation cannot be imputed may need to be excluded from the anemia analyses as their hemoglobin data cannot be adjusted for elevation.
    b. Flag observations with large differences in measurement.
        i. Calculate the difference in elevations between that recorded by the survey and that produced using the GPS coordinates (elevation_gps).
        ii. Create a flag variable (ex: elevation_flag) for datapoints where the difference is greater than +/-100m
        iii. For each flagged data point, manually examine the two datapoints and determine the source of the error. For example, check for data entry errors such as entering a negative elevation.
    c. Flag observations outside of the elevation range for the country of your survey.
        i. Any elevation data point that falls outside of the range of elevations that exist in the country of your survey is a data error and must be corrected. For example, if the possible elevation range for a survey was 621m to 4990 m, an elevation recorded as 590m or 5400m would be marked as a data error.
        iv. Flag any elevation data point outside of your survey area's elevation range in the elevation_flag variable.

v. For each flagged data point, manually compare the elevation recorded by the tablet to that produced by the GPS coordinates (elevation_gps) to identify the correct elevation within the survey country's elevation range.

d. Create a cleaned elevation variable (ex: elevation_clean):
   i. If the elevation recorded in the survey was not flagged or missing, use the survey-recorded elevation value as the clean elevation.
   ii. If the elevation recorded during the survey was determined to be incorrect in the cross-reference or fell outside the country's elevation range, use the elevation derived from the GPS coordinates (elevation_gps) in the cleaned elevation variable.
   iii. If the elevation and GPS data were missing, use the imputed elevation where imputation was possible.

3. Adjust raw Hb data for elevation using the subtraction method.
   a. Using **Table 1** below, determine the adjustment required for each Hb concentration based on its elevation (ex: a measurement at 1200m would be adjusted by 8 g/L).
   b. Adjust each Hb concentration by <u>subtracting</u> the appropriate adjustment value from the raw value.
      i. PLEASE NOTE: the adjustment units are in **g/L** (ex: 120 g/L). If you measured Hb in g/dL (ex: 12.0 g/dL), you must convert the Hb concentrations before making the adjustment.
   c. Example: For a Hb concentration of 120 g/L taken at an elevation of 1200m, subtract 8g/L from 120 g/L – producing an adjusted concentration of 112 g/L.
      i. PLEASE NOTE: It is best practice to create new variables rather than writing over original data. For example, if the raw Hb data are (Hb) then then the adjusted variable could be (Hb_new). This will also prevent confusion when you proceed to adjust for smoking.

Table 1: Adjustments to haemoglobin concentration (g/L in 500 m increments in elevation[a]

Elevation range (metres above sea level)	Adjustments in haemoglobin concentration (g/L)[b]
1–499	0
500–999	4
1000–1499	8
1500–1999	11
2000–2499	14
2500–2999	18
3000–3499	21
3500–3999	25
4000–4499	29
4500–4999	33

[a] Adjustments are the amount subtracted from an individual's observed haemoglobin level or added to the haemoglobin cutoff defining anaemia (in g/L).
[b] Proposed adjustments for all population groups based on the equation: Haemoglobin adjustment (g/L) = (0.0056384 x elevation) + (0.0000003 x elevation^2).

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Adjustment for smoking

1. After adjusting for elevation, adjust Hb data for smoking. Thus, you will use the new variable you created in the Adjusting for Elevation section (Hb_new) and adjust it using the following steps.
    a. This means that if someone lives at elevation and smokes, their Hb concentration will be adjusted twice.
2. Using **Table 2** below, determine the adjustment required for each Hb concentration based on the number of cigarettes smoked per day (ex: someone who smoked 8 cigarettes a day would be adjusted by 3g/L).
3. Adjust each Hb concentration by subtracting the appropriate adjustment value from the measured Hb concentration.
    a. PLEASE NOTE: the adjustment units are in **g/L** (ex: 120 g/L). If you measured Hb in g/dL (ex: 12 g/dL), you must convert to g/L before making the adjustment.
4. Example: For an individual who had a recorded Hb concentration of 120 g/L and lived at 1200m. After adjusting their Hb for elevation, they had an elevation-adjusted Hb concentration of 112 g/L. If this individual also reported smoking 8 cigarettes per day, subtract an additional 3g/L from 112 g/L – producing an adjusted concentration of 109 g/L.
    a. PLEASE NOTE: It is best practice to create new variables rather than writing over original data. For example, if the elevation-adjusted Hb data are called (Hb_new) then then the smoking adjusted variable could be (Hb_final).

Table 2: Adjustments to measured haemoglobin concentration for smokers[a, b]

Cigarettes per day	Haemoglobin adjustment (g/L)
Smoker, quantity unknown	3
<10	3
10–19	5
>20	6

[a] The adjustment consists in the corresponding value in the table added to the haemoglobin cutoff defining anaemia, or subtracted from an individual's observed haemoglobin level.

[b] Adjustments based on haemoglobin adjustment (g/L) = (0.4565 x cigarette_number) + (−0.0078 x cigarette_number^2), solved for the <10 cigarettes/day category using cigarette_number = 9 and for the 10–19 category cigarettes/day using cigarette_number = 19. The adjustment for the >20 cigarettes/day category was solved using cigarette_number = 30. The formula provided may be used in place of the categorical adjustments.

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Calculate anaemia prevalence

1. Apply the age- and sex-appropriate cutoffs in **Table 3** to the Hb data that has been adjusted for both elevation and smoking (Hb_final).
    a. Round the adjusted Hb concentration to 0 decimal points if using g/L (ex: 120 g/L) or 1 decimal point if using g/dL (ex: 12.0 g/dL). This rounded concentration is the final adjusted concentration.
2. Use the values in **Table 3** to determine anaemia status. Use the values in **Table 4** to determine anaemia severity level.

Table 3: Haemoglobin cutoffs to define anaemia in individuals and populations

Population	Haemoglobin concentration (g/L)[a]
Children, 6–23 months	<105
Children, 24–59 months	<110
Children, 5–11 years	<115
Children, 12–14 years, nonpregnant girls	<120
Children, 12–14 years, boys	<120
Adults, 15–65 years, nonpregnant women	<120
Adults, 15–65 years, men	<130
Pregnancy	
First trimester	<110
Second trimester	<105
Third trimester	<110

[a] Based on 5th percentile.

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Table 4: Haemoglobin cutoffs to define anaemia severity in individuals [a]

Population	Haemoglobin concentration (g/L)			
	No anaemia	Mild anaemia	Moderate anaemia	Severe anaemia
Children, 6–23 months	≥105	95–104	70–94	<70
Children, 24–59 months	≥110	100–109	70–99	<70
Children, 5–11 years	≥115	110–114	80–109	<80
Children, 12–14 years, nonpregnant girls	≥120	110–119	80–109	<80
Children, 12–14 years, boys	≥120	110–119	80–109	<80
Adults, 15–65 years, nonpregnant women	≥120	110–119	80–109	<80
Adults, 15–65, years men	≥130	110–129	80–109	<80
Pregnancy				
First trimester	≥110	100–109	70–99	<70
Second trimester	≥105	95–104	70–94	<70
Third trimester	≥110	100–109	70–99	<70

[a] WHO 2024.

Other considerations for interpretation of anaemia prevalence:

In addition to adjusting for elevation and smoking, it is important to note that the source of blood used in obtaining the Hb data (venous, single capillary drop, or pooled capillary) also affects the resulting Hb concentration. Due to the wide variability in capillary blood, the preferred blood collection method is venous blood.

Estimates derived from venous versus capillary blood should not be directly compared, even if taken in the same population. Capillary blood produces Hb concentration estimates that are generally higher than those produced by venous blood, but there is no specific correction factor to convert capillary estimates to venous estimates due to the wide variability in Hb estimates made from capillary blood.

References

Guideline on haemoglobin cutoffs to define anaemia in individuals and populations. Geneva: World Health Organization; 2024. Licence: CC BY-NC-SA 3.0 IGO.