**Table S1. Maximum sample size of hemoglobin observations by altitude.**

|  |  |  |
| --- | --- | --- |
| **Altitude (meters)** | **PSC** | **WRA** |
| **N** | **N** |
| **-27 to -1** | 149 | 385 |
| **0−499** | 14417 | 16521 |
| **500−999** | 3710 | 5063 |
| **1000−1499** | 3598 | 3510 |
| **1500−1999** | 4715 | 3669 |
| **2000−2499** | 3092 | 2336 |
| **2500−2999** | 1531 | 3421 |
| **3000−3499** | 187 | 654 |
| **3500−3999** | 22 | 77 |
| **4000a** | 546 | 590 |
| **Total** | 31967 | 36226 |

a All observations are at 4000 m.

**Table S2. Variation in sample size and in maternal and child characteristics for each country across select models assessing hemoglobin and altitude.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Model by country:** | **Children 6−59 months (PSC)** | | | **Women 15−49 years (WRA)** | | |
| **Crude**  **Adjusted for IDa and VADa** | **Sample size** | **Age in months Mean (SD)** | **Anemiad**  **(%)** | **Sample size** | **Age in years**  **Mean (SD)** | **Anemiad**  **(%)** |
| **Adjusted for inflammation-corrected IDb and VADb** |
| **Restricted to Healthyc** |
| Afghanistan | 818 | 28.2 (14.5) | 44.3 | 1310 | 27.4 (9.4) | 38.8 |
| 601 | 28.5 (14.6) | 40.4 | 953 | 30.9 (8.1) | 41.8 |
| 600 | 28.5 (14.6) | 40.3 | 951 | 30.9 (8.1) | 41.9 |
| 274 | 29.4 (14.8) | 34.3 | 580 | 31.2 (8.2) | 34.8 |
| Azerbaijan | 1089 | 35.3 (14.9) | 29.3 | 2713 | 32.2 (10.2) | 40.8 |
| 1052 | 35.5 (14.9) | 29.0 | 2654 | 32.2 (10.2) | 40.9 |
| 1052 | 35.5 (14.9) | 29.0 | 2654 | 32.2 (10.2) | 40.9 |
| 755 | 37.6 (14.9) | 21.9 | 1493 | 32.3 (10.3) | 24.3 |
| Bolivia | 546 | 9.5 (3.9) | 93.6 | 590 | 26.2 (6.3) | 40.0 |
| 414 | 8.0 (2.5) | 93.5 | 336 | 26.0 (6.3) | 36.0 |
| 414 | 8.0 (2.5) | 93.5 | 336 | 26.0 (6.3) | 36.0 |
| 169 | 7.4 (2.1) | 88.8 | 280 | 26.5 (6.4) | 29.3 |
| Colombia | 7640 | 29.8 (16.6) | 29.0 | 9678 | 29.0 (10.8) | 8.6 |
| 4225 | 37.7 (13.3) | 14.0 | 0 | -- | -- |
| 3792 | 37.7 (13.3) | 13.6 | 0 | -- | -- |
| 2652 | 39.2 (12.9) | 11.9 | 0 | -- | -- |
| Ecuador | 2020 | 29.9 (15.0) | 22.6 | 8118 | 30.6 (9.5) | 13.0 |
| 2017 | 30.0 (15.0) | 22.5 | 5978 | 33.3 (8.0) | 13.3 |
| 2017 | 30.0 (15.0) | 22.5 | 5978 | 33.3 (8.0) | 13.3 |
| 1031 | 33.5 (15.6) | 14.7 | 3746 | 33.3 (8.0) | 5.1 |
| Georgia | 2216 | 36.4 (14.8) | 24.0 | 1711 | 32.3 (10.0) | 23.7 |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| Guatemala | 875 | 33.2 (15.1) | 12.6 | 1612 | 29.1 (9.2) | 6.4 |
| 855 | 33.3 (15.1) | 12.5 | 1612 | 29.1 (9.2) | 6.4 |
| 855 | 33.3 (15.1) | 12.5 | 1612 | 29.1 (9.2) | 6.4 |
| 753 | 35.1 (14.7) | 9.3 | 1384 | 29.0 (9.1) | 2.6 |
| Laos | 494 | 32.8 (14.7) | 40.3 | 784 | 29.6 (9.7) | 37.9 |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| Malawi | 1172 | 32.6 (15.2) | 32.1 | 789 | 28.4 (9.7) | 21.9 |
| 1087 | 32.9 (15.1) | 31.5 | 766 | 28.4 (9.7) | 21.5 |
| 1087 | 32.9 (15.1) | 31.5 | 766 | 28.4 (9.7) | 21.5 |
| 800 | 36.0 (14.4) | 26.6 | 621 | 28.3 (9.6) | 14.3 |
| Mexico (2006) | 6617 | 37.3 (13.7) | 25.3 | 3050 | 31.1 (10.1) | 15.0 |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| 0 | -- | -- | 0 | -- | -- |
| Mexico (2012) | 7570 | 36.4 (13.7) | 21.3 | 4174 | 32.7 (9.8) | 13.8 |
| 2278 | 38.8 (13.1) | 17.2 | 0 | -- | -- |
| 2203 | 38.9 (13.1) | 16.9 | 0 | -- | -- |
| 1665 | 40.2 (12.7) | 14.8 | 0 | -- | -- |
| Papua New Guinea | 910 | 31.3 (14.9) | 50.1 | 760 | 29.3 (9.4) | 40.0 |
| 868 | 31.3 (14.9) | 50.1 | 744 | 29.2 (9.4) | 40.5 |
| 867 | 31.3 (14.8) | 50.1 | 744 | 29.2 (9.4) | 40.5 |
| 697 | 31.8 (14.7) | 43.6 | 671 | 29.3 (9.3) | 34.6 |
| United Kingdom | NA | --  --  --  -- | --  --  --  -- | 937 | 32.2 (11.2) | 10.3 |
| 855 | 32.6 (11.2) | 10.5 |
| 848 | 32.7 (11.2) | 10.6 |
| 595 | 33.2 (10.8) | 6.4 |
| **Total** | 31967 | 33.4 (15.4) | 27.6 | 36226 | 30.4 (10.1) | 17.0 |
| 13397 | 34.1 (15.1) | 24.3 | 13898 | 31.7 (9.2) | 22.0 |
| 12887 | 34.1 (15.1) | 24.5 | 13889 | 31.7 (9.2) | 22.0 |
| 8796 | 36.4 (14.7) | 19.4 | 9370 | 31.6 (9.2) | 13.2 |

Abbreviations: ID, iron deficiency; NA, data not available; PSC, preschool-aged children (6**−**59 months); VAD, vitamin A deficiency; WRA, women of reproductive age (15**−**49 years).

a Biomarkers for ID and VAD not corrected for inflammation.

b Biomarkers for ID and VAD corrected for inflammation using BRINDA method.23, 24

c No ID and no VAD, biomarkers corrected for inflammation.

d Unweighted, hemoglobin <110 g/L PSC, <120 g/L; adjusted for altitude and smoking based on current WHO guidelines.2

**Table S3. Equations for adjustment to hemoglobin (g/L) for altitude by model. Highlighted model indicated the model used for proposed adjustments for each population group.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Model description** a | | **N** | **Equation for Hb adjustment** | | | | | | | **R2** |
| **1**  **(SE)** | |  | | **2**  **(SE)** | |  |
| **Preschool-Aged Children (6−59 months)** | **Model 1**: Crude | 31967 | 0.0039679  (0.0003195) | \* altitude + | | 0.0000005  (0.0000001) | | \* altitude2 | | 0.21 |
| **Model 2**: Adjusted for ID and VAD b | 13397 | 0.0044791  (0.0004386) | \* altitude + | | 0.0000005  (0.0000002) | | \* altitude2 | | 0.33 |
| **Model 3**: Adjusted for inflammation-corrected ID and VAD c | 12887 | 0.0048108  (0.0004499) | \* altitude + | | 0.0000004  (0.0000002) | | \* altitude2 | | 0.32 |
| **Model 4**: Restricted to healthy  (No ID and No VAD c) | 8796 | 0.0054162  (0.0005223) | \* altitude + | | 0.0000002  (0.0000002) | | \* altitude2 | | 0.30 |
| **Sensitivity**: Model 3 excluding surveys reporting altitude in categories | 12887 | 0.0048108  (0.0004499) | \* altitude + | | 0.0000004  (0.0000002) | | \* altitude2 | | 0.32 |
| **Sensitivity**: Model 3 with ID defined using serum ferritin only | 12020 | 0.0041874  (0.0004593) | \* altitude + | | 0.0000005  (0.0000002) | | \* altitude2 | | 0.28 |
| **Sensitivity**: Model 3 excluding Bolivia | 12473 | 0.0047982  (0.0004480) | \* altitude + | | 0.0000004  (0.0000002) | | \* altitude2 | | 0.32 |
| **Sensitivity**: Model 4 excluding cases with WHZ<-2 or malaria | 8431 | 0.0054720  (0.0005160) | \* altitude + | | 0.0000002  (0.0000002) | | \* altitude2 | | 0.29 |
| **Women of Reproductive Age (15−49 years)** | **Model 1**: Crude | 36226 | 0.0061474  (0.0002967) | \* altitude + | | 0.0000003  (0.0000001) | | \* altitude2 | | 0.28 |
| **Model 2**: Adjusted for ID and VAD b | 13898 | 0.0050908  (0.0004326) | \* altitude + | | 0.0000004  (0.0000001) | | \* altitude2 | | 0.47 |
| **Model 3**: Adjusted for inflammation-corrected ID and VAD c | 13889 | 0.0052792  (0.0004508) | \* altitude + | | 0.0000003  (0.0000002) | | \* altitude2 | | 0.43 |
| **Model 4**: Restricted to healthy  (No ID and No VAD c) | 9370 | 0.0062478  (0.0004627) | \* altitude + | | 0.0000000  (0.0000002) | | \* altitude2 | | 0.41 |
| **Sensitivity**: Model 3 excluding surveys reporting altitude in categories | 13041 | 0.0052786  (0.0004565) | \* altitude + | | 0.0000003  (0.0000002) | | \* altitude2 | | 0.43 |
| **Sensitivity**: Model 3 with ID defined using serum ferritin only | 13145 | 0.0039502  (0.0004595) | \* altitude + | | 0.0000007  (0.0000002) | | \* altitude2 | | 0.43 |
| **Sensitivity**: Model 3 excluding Bolivia | 13553 | 0.0052797  (0.0004517) | \* altitude + | | 0.0000003  (0.0000002) | | \* altitude2 | | 0.39 |
| **Sensitivity**: Model 4 excluding cases with malaria | 9270 | 0.0062702  (0.0004609) | \* altitude + | | 0.0000000  (0.0000002) | | \* altitude2 | | 0.41 |

Abbreviations: ID, iron deficiency; PSC, preschool-aged children (6**−**9 months); SF, serum ferritin; VAD, vitamin A deficiency; WRA, women of reproductive age (15**−**49 years).

aAll models include age (in months for PSC, years for WRA) and survey as a fixed effect.

bID and VAD not corrected for inflammation.

cID and VAD corrected for inflammation using BRINDA method.23, 24

**Table S4. Proposed adjustmentsa to hemoglobin (g/L) by 500-m increments of altitude by survey for each population group where data was available for analysis of Model 3 (adjusted for inflammation-corrected ID and VAD). Adjustments shown only for the range of altitude assessed within each survey. Current WHO recommendations2 and proposed adjustments based on the analysis of all surveys combined provided for comparison.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Altitude** | **WHO cutoffs** | **All surveys combinedb** | **Afghanistan** | **Azerbaijan** | **Colombiac** | **Ecuador** | **Guatemala** | **Malawi** | **Mexico (2012)c** | **Papua New Guinea** |
| **-50 to -1** | 0 | 0 |  | 0 | **0** |  |  |  |  |  |
| **0** | 0 | 0 | 0 | 0 | **0** | **0** | 0 | 0 | 0 | **0** |
| **1−499** | 0 | 1 | -1 | 0 | **1** | **1** | 1 | -1 | 1 | **0** |
| **500−999** | 0 | 4 | -1 | 1 | **4** | **2** | 3 | -2 | 4 | **3** |
| **1000−1499** | 2 | 7 | 0 | 4 | **7** | **4** | 5 | 1 | 7 | **7** |
| **1500−1999** | 5 | 10 | 2 | 10 | **10** | **7** | 8 | 7 | 10 | **14** |
| **2000−2499** | 8 | 13 | 4 |  | **14** | **10** | 11 |  | 12 | **23** |
| **2500−2999** | 13 | 16 | 8 |  | **19** | **13** | 14 |  | 15 |  |
| **3000−3499** | 19 | 20 | 13 |  | **24** | **17** | 18 |  |  |  |
| **3500−3999** | 27 | 24 |  |  |  | **21** |  |  |  |  |
| **4000−4499** | 35 | 28 |  |  |  | **26** |  |  |  |  |
| **-50 to -1** | 0 | 0 |  | **0** |  |  |  |  |  |  |
| **0** | 0 | 0 | **0** | **0** |  | **0** | 0 | 0 |  | **0** |
| **1−499** | 0 | 1 | **0** | **1** |  | **1** | 2 | 1 |  | **2** |
| **500−999** | 0 | 4 | **1** | **2** |  | **4** | 5 | 4 |  | **8** |
| **1000−1499** | 2 | 7 | **2** | **4** |  | **6** | 8 | 7 |  | **13** |
| **1500−1999** | 5 | 10 | **5** | **6** |  | **9** | 11 |  |  | **19** |
| **2000−2499** | 8 | 13 | **9** |  |  | **13** | 13 |  |  | **25** |
| **2500−2999** | 13 | 17 | **13** |  |  | **16** | 16 |  |  |  |
| **3000−3499** | 19 | 20 | **18** |  |  | **20** | 18 |  |  |  |
| **3500−3999** | 27 | 24 |  |  |  | **24** |  |  |  |  |
| **4000-4499** | 35 | 28 |  |  |  | **29** |  |  |  |  |

Abbreviations: PSC, preschool-aged children (6**−**59 months); WRA, women of reproductive age (15**−**49 years)

a Adjustment is amount (g/L) added to the hemoglobin cutoff defining anemia, or subtracted from an individual’s observed hemoglobin level. Adjustment based on solving equation for the midpoint of altitude range (e.g., 250 m for the 1**−**499 range).

b Hb\_adjustment (g/L) based on Model 3 equation shown in Table S3. For PSC, Hb\_adjustment (g/L) = (0.0048108 \* altitude) + (0.0000004 \* altitude2). For WRA, Hb\_adjust\_altitude (g/L) = (0. 0052792 \* altitude) + (0.0000003 \* altitude2).

c Survey specific cut-points for WRA not included because vitamin A status was not assessed in survey.

**Table S5. Variation in sample size and in maternal characteristics for each country across select models assessing hemoglobin and smoking status (smoker, nonsmoker) or number of cigarettes smoked per day**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Model by country:** | **Smoking Status Models** | | | **Cigarette Quantity Models** | | |
| **Crude** | **Sample size** | **Age in years**  **Mean (SD)** | **Anemiac**  **(%)** | **Sample size** | **Age in years**  **Mean (SD)** | **Anemiac**  **(%)** |
| **Adjusted for inflammation-corrected IDa** |
| **Restricted to Healthyb** |
| Cambodia | 446 | 30.1 (6.6) | 44.0 | 446 | 30.2 (6.6) | 44.0 |
| 432 | 30.1 (6.5) | 43.1 | 432 | 30.2 (6.5) | 43.1 |
| 418 | 30.2 (6.5) | 42.1 | 418 | 30.2 (6.5) | 42.1 |
| Colombia | 9674 | 29.0 (10.8) | 8.6 | 0 | -- | -- |
| 9062 | 29.0 (10.7) | 8.1 | 0 | -- | -- |
| 6803 | 29.0 (10.7) | 5.0 | 0 | -- | -- |
| Ecuador | 2225 | 31.5 (8.9) | 12.9 | 2002 | 31.6 (8.8) | 12.9 |
| 2225 | 31.5 (8.9) | 12.9 | 2002 | 31.6 (8.8) | 12.9 |
| 1441 | 31.5 (8.8) | 5.1 | 1301 | 31.6 (8.7) | 5.2 |
| Georgia | 1710 | 32.3 (10.0) | 23.7 | 1710 | 32.3 (10.0) | 23.7 |
| 1674 | 32.3 (10.0) | 24.0 | 1674 | 32.3 (10.0) | 24.0 |
| 1647 | 32.3 (10.0) | 23.7 | 1647 | 32.3 (10.0) | 23.7 |
| Guatemala | 1616 | 29.2 (9.2) | 6.4 | 1616 | 29.2 (9.2) | 6.4 |
| 1616 | 29.2 (9.2) | 6.4 | 1616 | 29.2 (9.2) | 6.4 |
| 1387 | 29.1 (9.1) | 2.6 | 1387 | 29.1 (9.1) | 2.6 |
| Mexico (2006) | 939 | 22.7 (9.6) | 14.5 | 846 | 23.2 (10.0) | 14.9 |
| 929 | 22.7 (9.6) | 14.6 | 836 | 23.2 (10.0) | 15.1 |
| 608 | 22.4 (9.6) | 9.5 | 550 | 22.9 (10.0) | 10.0 |
| Mexico (2012) | 1110 | 32.4 (9.6) | 11.0 | 1018 | 33.8 (8.8) | 11.2 |
| 981 | 32.4 (8.4) | 11.4 | 976 | 34.4 (8.4) | 11.5 |
| 556 | 34.7 (8.4) | 6.3 | 553 | 34.8 (8.3) | 6.3 |
| Papua New Guinea | 759 | 29.3 (9.4) | 39.9 | 755 | 29.2 (9.4) | 40.1 |
| 743 | 29.2 (9.4) | 40.4 | 739 | 29.2 (9.4) | 40.6 |
| 672 | 29.3 (9.3) | 34.7 | 668 | 29.3 (9.3) | 34.9 |
| United Kingdom | 896 | 33.0 (10.9) | 10.2 | 886 | 33.1 (10.8) | 10.1 |
| 839 | 33.4 (10.8) | 10.4 | 829 | 33.5 (10.8) | 10.3 |
| 599 | 33.8 (10.5) | 6.7 | 592 | 33.9 (10.4) | 6.6 |
| United States | 897 | 34.3 (10.2) | 7.0 | 891 | 34.3 (10.2) | 7.0 |
| 883 | 34.4 (10.2) | 7.0 | 877 | 34.3 (10.2) | 7.0 |
| 712 | 34.6 (10.1) | 1.8 | 709 | 34.6 (10.1) | 1.8 |
| **Total** | 20272 | 29.2 (10.4) | 12.5 | 10170 | 31.0 (9.9) | 16.3 |
| 19384 | 30.0 (10.3) | 12.4 | 9981 | 31.1 (9.8) | 16.4 |
| 14843 | 30.1 (10.3) | 9.4 | 7825 | 31.1 (9.8) | 13.4 |

Abbreviations: ID, iron deficiency; WRA, women of reproductive age.

a Biomarkers for ID corrected for inflammation using BRINDA method.23, 24 Data not shown for models with ID not corrected for inflammation as there were only 12 women without a marker of inflammation, thus age and anemia distributions are near identical.

b No ID, biomarkers corrected for inflammation.

c Unweighted, hemoglobin <120 g/L WRA, adjusted for altitude and smoking based on current WHO guidelines.2