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SHORT REPORT

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Low prevalence of anemia among Shuar communities of Amazonian Ecuador

Alicia M. DeLouize[1] | Melissa A. Liebert[2] | Felicia C. Madimenos[3,4] | Samuel S. Urlacher[5,6] | Joshua M. Schrock[1] | Tara J. Cepon-Robins[7] | Theresa E. Gildner[8] | Aaron D. Blackwell[9] | Christopher J. Harrington[1] | Dorsa Amir[10] | Richard G. Bribiescas[11] | James Josh Snodgrass[1,12] | Lawrence S. Sugiyama[1]

[1]Department of Anthropology, University of Oregon, Eugene, Oregon
[2]Department of Anthropology, Northern Arizona University, Flagstaff, Arizona
[3]Department of Anthropology, Queens College (CUNY), Flushing, New York
[4]New York Consortium in Evolutionary Primatology (NYCEP), New York, New York
[5]Department of Anthropology, Baylor University, Waco, Texas
[6]Child and Brain Development Program, CIFAR, Toronto, Canada
[7]Department of Anthropology, University of Colorado-Colorado Springs, Colorado Springs, Colorado
[8]Department of Anthropology, Washington University in St. Louis, St. Louis, Missouri
[9]Department of Anthropology, Washington State University, Pullman, WA
[10]Department of Psychology, Boston College, Chestnut Hill, Massachusetts
[11]Department of Anthropology, Yale University, New Haven, Connecticut
[12]Center for Global Health, University of Oregon, Eugene, Oregon

Correspondence
Alicia M. DeLouize, Department of Anthropology, 1218 University of Oregon, Eugene, OR 97403, USA.
Email: adelouiz@uoregon.edu

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Abstract

Objective: Anemia is an important global health challenge. We investigate anemia prevalence among Indigenous Shuar of Ecuador to expand our understanding of population-level variation, and to test hypotheses about how anemia variation is related to age, sex, and market integration.

Methods: Hemoglobin levels were measured in a total sample of 1650 Shuar participants (ages 6 months to 86 years) from 46 communities between 2008 and 2017 to compare anemia prevalence across regions characterized by different levels of market integration.

Results: Shuar anemia rates among children under 15 years (12.2%), adult women (10.5%), and adult men (5.3%) were less than half of those previously documented in other neo-tropical Indigenous populations. Anemia prevalence did not vary between more traditional and market integrated communities (OR = 0.47, p = .52). However, anemia was negatively associated with body mass index (OR = 0.47, p = .002).

Conclusions: Compared to other South American Indigenous populations, anemia prevalence is relatively low among Shuar of Ecuador and invariant

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with market integration. Understanding this pattern can provide valuable insights into anemia prevention among at-risk populations.

1 | INTRODUCTION

Anemia is a blood disorder characterized by insufficient oxygen transport by hemoglobin (Hb) in erythrocytes and is commonly defined as Hb levels below age- and sex-specific cutoffs (WHO, 2011). It afflicts ~27% of people worldwide, 89% of whom live in low- and middle-income countries (Kassebaum, 2016). Anemia is associated with negative health outcomes including fatigue, headaches, poor growth, reproductive disorders, low blood pressure, shortness of breath, reduced infection resistance, and lower cognitive function (Kassebaum, 2016). Dietary iron is needed for Hb function, with iron requirements varying by age, sex, menstrual cycle status, and reproductive state. Pregnancy and growth increase iron requirements leading to the highest rates of anemia in young children and women (Kassebaum, 2016; Kim, Yetley, & Calvo, 1993). Since anemia is readily treatable by addressing the underlying causes, the WHO considers this health challenge a global priority (WHO, 2011).

Anemia prevalence among South American Indigenous neotropical populations range from 19% to 100% in women, 6% to 79% in men, and 39% to 98% in children (Table 1). These generally high rates are attributed to low dietary iron and vitamin intake, blood loss from intestinal macroparasites, infection with *H. pylori*, and inflammation from other infections (Kassebaum, 2016). Yet, it is unclear how lifestyle changes within these populations influence anemia rates. Data from Shuar of Amazonian Ecuador allow for an analysis of how market integration (MI: the degree of consumption from and production for a market economy; Lu, 2007) affects anemia rates (Liebert et al., 2013). Most Shuar live in two main regions of the Morona-Santiago province in Ecuador: the Upano Valley (UV), which has greater access to healthcare facilities and market centers (Liebert et al., 2013; Urlacher et al., 2016), and Cross-Cutucú (CC), which is more remote and generally associated with high rates of parasitic infection (Cepon-Robins et al., 2014; Gildner et al., 2016, 2020).

We hypothesize that anemia prevalence will vary according to MI status, with region serving as a proxy for MI. Specifically, we hypothesize that CC Shuar will have higher rates of anemia than UV Shuar. Further, we expect anemia prevalence will be associated with sex, age, and body mass index (BMI).

2 | METHOD

2.1 | Participants

Shuar are an Indigenous lowland neotropical population of ~60 000–110 000 individuals. The CC region is more geographically isolated than the UV region, leading to differences in MI, lifestyle, economics, and diet (Urlacher et al., 2016). Traditional cultigens (including manioc, plantains, sweet potatoes, and yams) remain dietary staples in both regions. Reliance on foraging, fishing, and hunting vary but are generally greater in the CC region (e.g., Liebert et al., 2013; Urlacher et al., 2016). Shuar exhibit high rates of stunting and infectious disease burden but with complex inter- and intra-regional variation in prevalence (e.g., Blackwell, Pryor, Pozo, Tiwia, & Sugiyama, 2009; Gildner et al., 2016, 2020; Urlacher et al., 2018). Helminth infection rates of whipworm and roundworm are high (Cepon-Robins et al., 2014; Gildner et al., 2016, 2020).

Data were collected across nine field seasons from August 2008 through November 2017, as a part of the Shuar Health and Life History Project (shuarproject.org). Participants included 1650 Shuar (746 men, 904 women [26 pregnant]) ranging in age from 6 months to 86 years (M = 19.20, SD = 16.73), including 1062 participants from 29 UV communities (464 men, 598 women), and 588 participants from 17 CC communities (282 men, 306 women). In instances of repeat Hb measures, only the visit with the most recent Hb measurement was used in the analysis; thus, only one measurement was included per individual. Adults provided informed consent to participate. Parental consent and child assent were obtained for children and adolescents <15 years old, the legal age of consent in Ecuador. The study was approved by the IRB of the University of Oregon, by community leaders upon community consensus, and by the *Federacion Interprovincial de Centros Shuar*.

2.2 | Measures

2.2.1 | Predictor variables

Age, height, and weight data were collected as described in detail elsewhere (Liebert et al., 2013; Urlacher et al., 2016). BMI was calculated using standard methods (weight [kg]/height [m]^2).

TABLE 1 Comparison of Shuar mean Hb values and anemia prevalence with other South American populations

	Children			Adults					
				Women		Men			
Group	Anemia (%)	WHO significance	Age (yrs)	Anemia (%)	WHO significance	Anemia (%)	WHO significance	Age (yrs)	References
Aruak/Karibe (Brazil)	66	Severe	0.5–10						Mondini, Rodrigues, Gimeno, & Baruzzi, 2009
Suruí (Brazil)	81	Severe	0.5–10						Orellana, Coimbra Jr, Lourenço, & Santos, 2006
Terena (Brazil)	51	Severe	2–4						Morais, Alves, & Fagundes-Neto, 2005
Indigenous (Brazil)	51	Severe	0.5–5						Leite et al., 2013
Pueblo Tacana (Bolivia)	42	Moderate	0.5–10						Benefice, Monroy, Jiménez, & López, 2006
Tsimane (Bolivia)	39	Moderate	0.5–15	23	Moderate	19	Mild	15+	Blackwell, unpublished
Qom/Toba (Argentina)				28	Moderate			18+	Goetz & Valeggia, 2017
Indigenous (Colombia)				31	Moderate	6	Mild	18+	Castillo, Oliveros, & Mora, 2014
Quechua (Peru)	49	Moderate	0.5–12						Cabada et al., 2015
Indigenous (Peru)	51	Severe	0.5–11						Anticona and San Sebastian 2014
Bari (Venezuela)	54	Severe	1–18						Diez-Ewald et al., 1997
Piaroa (Venezuela)	98	Severe	1–10	88	Severe	79	Severe	11+	Nieves García-Casal et al., 2008
Warao (Venezuela)	61	Severe	7–14						Wilbert & Layrisse, 1980
Interior Alto Ocamo Yanomamo (Venezuela)	84	Severe	0.5–14	100	Severe	58	Severe	15+	Grenfell et al., 2008
Ocamo Yanomamo (Venezuela)	57	Severe	0.5–14	100	Severe	8	Mild	15+	Grenfell et al., 2008
Quechua (Ecuador)				50	Severe	47	Severe	15+	Pleasants, 2014
Secoya (Ecuador)				19	Mild	26	Moderate	15+	Pleasants, 2014
Cofán (Ecuador)				31	Moderate	29	Moderate	15+	Pleasants, 2014
Shuar (Ecuador)	**12**	**Mild**	**0.5–14**	**11**	**Mild**	**5**	**Normal**	**15+**	**This study**
Trans Cutucú Shuar (Ecuador)	**12**	**Mild**	**0.5–14**	**10**	**Mild**	**6**	**Mild**	**15+**	**This study**
Upano Valley Shuar (Ecuador)	**13**	**Mild**	**0.5–14**	**11**	**Mild**	**5**	**Normal**	**15+**	**This study**

TABLE 2 Shuar anemia prevalence and hemoglobin levels by WHO age/sex criteria

Shuar age class	*n*	Hb *M* (mg/dl)	Hb *SD* (mg/dl)	Mild anemia (%)	Moderate anemia (%)	Severe anemia (%)	Anemia prevalence (%)
Children (0–4 yrs)	127	11.75	1.03	15.7	4.7	0.0	20.4
Children (5–11 yrs)	653	12.61	1.00	6.1	4.7	0.0	10.9
Children (12–14 yrs)	164	13.30	1.44	6.7	3.7	0.6	11.0
Nonpregnant Women (≥15 yrs)	382	13.31	1.33	6.2	3.7	0.5	10.5
Pregnant women (>15 yrs)	26	12.10	1.06	7.7	3.8	0.0	11.5
Men (≥15 yrs)	265	15.08	1.36	3.4	1.5	0.4	5.3

Note: The hemoglobin (Hb) cutoff values for anemia, mild anemia, moderate anemia, severe anemia, and anemia cutoff values were determined by current World Health Organization guidelines (WHO, 2011).

2.2.2 | Hemoglobin

A finger prick with a sterile, disposable lancet was used to collect one drop (~10 μl) of whole capillary blood into a microcuvette and analyzed using a HemoCue Hb201+ analyzer (HemoCue AB, Cypress, CA). No daily smokers were in the sample; therefore, Hb levels were only adjusted for minor variation in altitude between communities (WHO, 2011).

2.2.3 | Anemia

Anemia prevalence was evaluated according to WHO (2011) standard cutoff levels for defined anemia groups: children under 5 years, 5–11 years, and 12–14 years; nonpregnant women; pregnant women; and men aged 15 years or older.

2.2.4 | Statistics

Binary logistic regressions with mixed effects were performed to predict anemia from region, sex, and BMI; each predictor was entered into individual models. For analyses between anemia and region and anemia and BMI, sex, age, pregnancy status, and year of data collection were controlled for by including WHO defined anemia groups (WHO, 2011) and year of data collection as random intercepts. For analyses between anemia and sex, juveniles and adults were analyzed separately, pregnancy was included as a fixed effect for adults, and community and year of data collection were included as random intercepts. A binary logistic generalized additive regression was performed to predict anemia from thin plate splines fit to age using *REML*, while controlling for community, year of data collection, sex, and pregnancy status. Analyses were conducted in R 3.6.1 with $\alpha = .05$. All statistical assumptions were met before analysis.

3 | RESULTS

Based on WHO (2011) criteria, anemia rates among most Shuar age- and sex-groups identified in this study are considered of mild public health significance (Table 2). Anemia prevalence for children under 15 years (12.2%), adult women (10.5%), and adult men (5.3%) were less than half that of the next lowest neo-tropical Indigenous comparator (Tsimane; Table 1). Analyses showed that anemia rates did not differ significantly by region ($OR = 0.47$, $p = .52$).

In participants under 15 years, anemia prevalence was higher in boys than girls (13.9% and 10.5%, respectively), but the difference was not significant ($OR = 0.41$, $p = .09$). However, controlling for pregnancy, adult women ≥15 years had higher rates of anemia (11.8%) than adult men (5.6%; $OR = 0.69$, $p = .01$). Anemia risk was significantly associated with age, with rates highest among the youngest and oldest participants ($edf = 4.73$, $p < .001$; Figure S1). Finally, participants with higher BMI levels had lower prevalence of anemia ($OR = 0.47$, $p = .002$).

4 | DISCUSSION

Anemia prevalence among Shuar is generally low compared to other South American populations and comparable to levels in high-income countries (Kassebaum, 2016). Furthermore, there was no difference in anemia prevalence between UV and CC Shuar. Yet, BMI was negatively associated with anemia, suggesting that lifestyle (e.g., diet) might influence anemia rates, despite the lack of regional differences (Liebert et al., 2013). The low rate of anemia is surprising given that Shuar have a relatively heavy parasitic and infectious disease burden (Cepon-Robins et al., 2014; Gildner et al., 2016, 2020), severe enough to cause growth faltering in children (Urlacher et al., 2018). However, parasitic species known to contribute most heavily to anemia (e.g., hookworm; Kassebaum, 2016) do not appear to be common in this population (Cepon-Robins et al., 2014; Gildner et al., 2020).

The low rates of anemia among Shuar and lack of regional differences may be due to a variety of factors. Traditional Shuar diet includes iron-rich fish and hunted game, but consumption varies between and within communities. Common staples (e.g., plantains, sweet potatoes, yams) also contain some non-heme iron. Wheat and corn, which inhibit iron absorption and limit bioavailability, are rarely consumed (Liebert et al., 2013). In Ecuador, the National Food Nutrition Program (PANN, 2000) for children 6–24 months includes iron fortification, which reduces anemia (Lutter et al., 2008), yet implementation appears uneven across Shuar communities and Shuar have lower anemia prevalence than Ecuadorians in general (Sackey, Weigel, & Armijos, 2003). Low levels of malaria could also be a contributing factor as the UV is generally above the malarial zone and endemic malaria in CC was reduced through control efforts.

Anemia prevalence among the Shuar is comparable to Europeans, Canadians, and Australians, and lower than Ecuador overall and other South American Indigenous populations (Coa and Ochoa, 2009; Le, 2016; Sackey et al., 2003; Stevens et al., 2013). These findings suggest that subsistence-based lifestyles are not always associated with high rates of anemia. For example, CC and UV anemia rates were similar despite UV Shuar generally exhibiting higher MI, including access to healthcare infrastructure and market centers, and CC having greater reliance on fish and game (Liebert et al., 2013; Urlacher et al., 2016). Future research will consider the relative contributions of dietary factors, infection rates, and infrastructure as contributors to the relatively low anemia prevalence among Shuar. The low prevalence of anemia and similarity between regions are unexpected findings: understanding these results could identify key factors that can be targeted to reduce high anemia rates among at-risk populations and to maintain low anemia prevalence among the Shuar as integration into the market economy accelerates.

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AUTHOR CONTRIBUTIONS

Alicia DeLouize: Data curation; formal analysis; visualization; writing-original draft; writing-review & editing. **Melissa Liebert:** Data curation; formal analysis; funding acquisition; investigation; writing-original draft; writing-review & editing. **Felicia Madimenos:** Funding acquisition; investigation; writing-review & editing. **Samuel Urlacher:** Funding acquisition; investigation; writing-review & editing. **Joshua Schrock:** Funding acquisition; investigation; writing-review & editing. **Tara Cepon-Robins:** Funding acquisition; investigation; writing-review & editing. **Theresa Gildner:** Funding acquisition; investigation; writing-review & editing. **Aaron Blackwell:** Formal analysis; funding acquisition; investigation; visualization; writing-review & editing. **Christopher Harrington:** Investigation. **Dorsa Amir:** Investigation; writing-review & editing. **Richard Bribiescas:** Investigation; writing-review & editing. **James Snodgrass:** Funding acquisition; methodology; project administration; supervision; writing-review & editing. **Lawrence Sugiyama:** Conceptualization; funding acquisition; investigation; methodology; project administration; supervision; writing-original draft; writing-review & editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request by emailing the form found at https://www.shuarproject.org/data-sharing to shuarproject@gmail.com. The data are not publicly available due to privacy or ethical restrictions.

ORCID

Alicia M. DeLouize https://orcid.org/0000-0002-9045-6428
Melissa A. Liebert https://orcid.org/0000-0001-8013-6773
Felicia C. Madimenos https://orcid.org/0000-0001-5442-232X
Samuel S. Urlacher https://orcid.org/0000-0002-6489-4117
Tara J. Cepon-Robins https://orcid.org/0000-0002-4508-8507
Theresa E. Gildner https://orcid.org/0000-0001-7486-5208
Aaron D. Blackwell https://orcid.org/0000-0002-5871-9865

Dorsa Amir https://orcid.org/0000-0003-0255-0228
James Josh Snodgrass https://orcid.org/0000-0002-7021-777X
Lawrence S. Sugiyama https://orcid.org/0000-0003-1279-0006

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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