Estimating the seroprevalence of HTLV-1 in pregnant Peruvian women based on blood bank markers: a road to elimination of mother-to-child transmission of HTLV-1 in Peru

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Abstract

Estimating the seroprevalence of HTLV-1 in pregnant Peruvian women based on blood bank markers: a road to elimination of mother-to-child transmission of HTLV-1 in Peru

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Background: Data regarding the burden of human T-cell lymphotropic virus type 1 (HTLV-1) in pregnant Peruvian women is scarce, thus the impact of potential preventive interventions is largely unknown. Our primary aim was to estimate the prevalence of HTLV-1 in pregnant women in Peru at national and departmental levels using governmental-issued blood bank data. In addition, the number of newborns with HTLV-1 acquired yearly via mother-to-child-transmission (MTCT) was calculated. Methods: This was a retrospective ecological cohort study conducted at the level of department-year for the period 2015-2020. Publicly available data maintained by Peruvian governmental organizations was used. The unit of analysis were the 25 first-level administrative subdivisions of Peru known as departments. An analytic strategy that included correction factors, probabilistic weights and small-area estimation modeling was developed to extrapolate HTLV-1/2 reactivity in blood donors to confirmatory HTLV-1 reactivity in pregnant women. For validation, confirmatory HIV reactivity in pregnant women was estimated using the same data and methods and was compared to official statistics. Results: Between 2015 and 2020, a total of 2,120,344 blood units were screened of which 15,413 (0.73%) were reactive for HTLV-1/2. We estimated there were 4,602 [95% CI: 3,851-5368] pregnant Peruvian women with HTLV-1 per year during 2015-2020 and this represented a confirmatory HTLV-1 reactivity of 1.05% [95% CI: 0.88-1.23]. A total of

12 departments had an estimated confirmatory HTLV-1 prevalence in pregnant women of 1% or higher and a tendency towards higher values in the southern departments was visualized. We noted a strong spatial pattern of our estimates (ϕ = 49%) and an acceptable degree of precision as most of our department-level estimates had a coefficient of variation (CV) of less than 30%. For newborns, we estimated 115 [95% CI: 96-134] cases of HTLV-1 acquired yearly in-utero and 1,009 [95% CI: 920-1,282] cases of HTLV-1 acquired yearly due to breastfeeding. Our estimates for confirmatory HIV reactivity in pregnant Peruvian women were comparable to international and national statistics. Conclusion: Our estimates demonstrated a high burden of HTLV-1 in pregnant Peruvian women and provided critical information needed for the evaluation of HTLV-1 MTCT preventive interventions such as avoidance breastfeeding and formula supplementation. We demonstrated our analytic strategy generated estimates with a fair degree of precision and accuracy, however the potential for underestimation, variability within some departments, and need for population-based studies should be recognized.

I. Introduction

Despite recent efforts to raise awareness of the health implications of human T-cell lymphotropic virus type 1 (HTLV-1) infection, the public health impacts of this infection remain underappreciated by both the general public and scientific audiences. This is, in part, due to (i) geographic restriction of HTLV-1 infection within endemic countries to largely underserved populations such as the Quechua and Shipibo-Conibo communities in Peru, the mostly Afro-descendant city of Salvador in Brazil, the Kyushu-Osaka region in Japan, and the Indigenous population of Australia; and (ii) rarity of two HTLV-1-associated diseases: adult T-cell lymphoma/leukemia (ATL) and HTLV-1 associated myelopathy/tropical spastic paraparesis (HAM/TSP), usually affecting only 5% of its carriers (1).

HTLV-1 belongs to the same *Retroviradae* family as human immunodeficiency virus (HIV),and is transmitted similarly: through vertical transmission (mother-to-child), sexual contact, shared needles, or transfusion of blood products. A country is considered to have endemic HTLV-1 infection when the seroprevalence is at least 1% in adults; transmission in these countries occurs largely via mother-to-child transmission (MTCT), mainly via breastfeeding (2, 3). It is worth noting that HTLV-1 is one of the four members of the human T-cell lymphotropic virus group which also includes HTLV-2, HTLV-3 and HTLV-4. Among them, only HTLV-1 and HTLV-2 are known to be widely distributed around the world, and both have a different epidemiology and pathogenicity despite sharing a similar genomic structure (4).

As of 2025, only three HTLV-1 endemic countries (Japan, Chile, and Brazil) have a national policy to reduce MTCT, which consists of universal antenatal screening with subsequent breastfeeding avoidance or short-term breastfeeding among positive pregnant women (5). This intervention reduces the risk of MTCT from around 20% to 2.5% (6). In Peru, also an endemic country with around 150,000 to 450,000 HTLV-1 carriers, there is no MTCT prevention policy in place (2). There is a paucity of studies in Peru evaluating the seroprevalence of HTLV-1 in pregnant women with only five published to this date (7, 8, 9, 10, 11); prevalence estimates of these studies range from 0.5 to 3.1%, comparable to other countries with universal antenatal screening such as Japan and Brazil (2). Most of these studies were carried out in the capital city of Lima and data from other areas with high endemicity, such as the Peruvian Andean region, are lacking.

Despite this significant evidence gap and absence of a PMTCT policy, since 1997 HTLV-1 blood donor screening has been endorsed by the Peruvian Ministry of Health as a prevention policy, and data on the prevalence of infectious markers in blood donations are publicly available for all 25 departments of Peru (12).

As opposed to HTLV-1, HTLV-2 have been rarely associated with diseases (13) and, in Peru, has a significant lower prevalence, primarily found in Indigenous groups of the Amazon (14). The distinction between these two viruses is relevant since the screening test performed by blood banks targets anti-HTLV-1/2 antibodies either with an enzyme-linked immunoassay (ELISA) or a chemiluminescent immunoassay (CLIA). Positive results then undergo a confirmatory testing via Western Blot (WB) or line immunoassay (LIA) to differentiate between the two viruses (15). A study conducted in a Peruvian national reference laboratory revealed that HTLV-1 accounted for 98% of infections when confirmatory testing was performed in HTLV-1/2 positive blood donors (16).

In this context, this study aims to leverage government-issued blood bank data to estimate the prevalence of HTLV-1 in pregnant women as a first step towards development and implementation of policies for prevention of MTCT (PMTCT) of HTLV-1 infection in Peru. As a secondary aim the number of newborns who acquire HTLV-1 infection via MTCT per year over the study period will also be estimated.

II. Methods

A. Study design

This is a retrospective ecological cohort study, conducted at the level of the department-year for the period 2015-2020 (Table 1).

For our primary aim, we estimated the number and proportion of pregnant women with a positive confirmatory HTLV-1 test. For our secondary aim, we estimated the number of newborns with HTLV-1 acquired via breastfeeding. Our outcomes are presented as average yearly estimates with their corresponding 95% confidence intervals over the study period.

For validation, we used the same data sources and methods to estimate the number and proportion of pregnant women with a confirmatory human immunodeficiency virus (HIV) test, for comparison with official statistics.

B. Setting and population

Study data came from publicly available data maintained by Peruvian governmental organizations. The units of analysis were the 25 first-level administrative subdivisions of Peru known as departments. The study period included the years 2015-2020 as these were the years included in the Peruvian Bulletin on Blood Supply (12).

C. Data collection

Data was obtained from the Peruvian Bulletin on Blood Supply 2015-2020 (12), the Peruvian Demographic Health Survey (DHS) 2015-2020, the Peruvian National Registry, the Peruvian National Institute of Statistics and Information (INEI), and the General Directorate of Epidemiology (DGE) of the Peruvian Ministry of Health (MINSA).

The Peruvian Bulletin on Blood Supply, developed by the Ministry of Health of Peru, presents data on infectious markers reactivity in blood units aggregated by department and year, without data by age or sex. For the case of HTLV, all collected blood units in Peru undergo screening via an antibody immunoassay against both HTLV-1 and HTLV-2, and results are presented as seroreactivity against HTLV-1/2; data on confirmatory testing for HTLV-1 or HTLV-2 are not reported (12).

To extrapolate HTLV-1/2 reactivity results from the Peruvian donor population to pregnant women, a scoping review was performed to identify suitable correction factors to estimate HTLV-1 positivity on confirmatory tests in (i) women of reproductive age, and, subsequently (ii) pregnant women. For the present study, we considered women of reproductive age are those aged between 18 and 49 years, since individuals less than 18 years are not able to donate blood in Peru (17).

Publications recorded in international medical databases (including PubMed and Scielo) and the Peruvian repository ALICIA of the National Council for Science, Technology and Technological Innovation (CONCYTEC) which includes theses from Peruvian universities were between January 01, 1992, and January 11, 2025. Studies that reported the prevalence of HTLV-1/2 in Peruvian blood banks and included data on sex or age distribution among total blood donors were selected. Studies that did not further specify demographic data (sex or age) for HTLV-1/2 reactive blood donors were excluded. Articles in both English and Spanish were included.

Table 1: Variable definitions and source

	Source	Definition
Blood bank variables		
Total number of HTLV-1/2 reactive units	Bulletin on Blood Supply	a
Total number of screened blood units	Bulletin on Blood Supply	b
Proportion of HTLV-1/2 reactive units	Secondary	$\frac{a}{b}$
Demographic variables		
Total population	INEI	
Female population aged 18-49 years	INEI	c
Percentage of women aged 15-49 years currently pregnant	DHS	d
Estimated number of pregnant women	Secondary	$e = \frac{c * d}{100}$
Number of life births	National Registry	
Breastfeeding percentage	DHS	*"Percentage of children born up to 5 years prior to the survey that have ever been breastfeed"*
Length of breastfeeding (months)	DHS	*"Median duration in months of breastfeeding of children born up to 3 years prior to the survey"*
Geographic variables		
Natural regions		Coast (1), jungle (2) and highlands (3)
Model validation variables		
Total number of HIV reactive units	Bulletin on Blood Supply	f
Proportion of HIV reactive units	Secondary	$\frac{f}{b}$
Reported number of pregnant women with HIV	DGE	g
Reported prevalence of pregnant women with HIV	Secondary	$\frac{g}{e}$

*INEI (National Institute of Statistics and Information), DHS (Demographic Health Survey), DGE (General Directorate of Epidemiology)

D. Analysis

Our process to extrapolate data on HTLV-1/2 seroreactivity in total blood donors to estimates for confirmatory HTLV-1 seroreactivity in pregnant women consisted of four steps (Figure 1).

Step 1: Smoothed estimate - HTLV-1/2 reactivity by department-year

Two features of HTLV-1/2 reactivity in blood donors indicate the suitability of using a small area estimation approach to estimate HTLV-1/2 reactivity, implemented using the SUMMER package in R. First, the process of infectious diseases screening during blood donation represents a non-probabilistic sample as donors are tested once they have made the decision to present to a blood bank. Thus, probabilistic weights are needed to generate population estimates.

We calculated probabilistic weights for each department-year based on estimated population and blood units collected:

$$w_i = \frac{Total\ population_i}{Total\ number\ of\ screened\ blood\ units_i}$$

where i indexes department-year.

Second, in the case of HTLV-1/2 screening a spatial structure could be expected as previous studies have shown an increased seroreactivity in areas located in the highlands of southeastern Peru (18). Therefore, accounting for spatiality using a Besag-York-Mollié 2 (BYM2) model allowed us to smooth our estimates and stabilize variance.

$$y_j = \beta + \sum_{k=1}^{n} B_{jk}\,(y_k - \beta) + \varepsilon_j$$

Where:

- j indexes department
- y_j is the target estimand for department j
- β is the intercept (national average)
- k represents each department other than j
- $B_{jk} = \begin{cases} 1 \text{ if departments j and k are neighbors} \\ 0 \text{ otherwise} \end{cases}$
- $\varepsilon_j \sim \mathrm{N}\,(0, \sigma_j^2)$ is iid random error

For our first model, y_j was defined as the proportion of reactive HTLV-1/2 blood units (y_{adult_j}). The results of the present and subsequent models will be presented as means with their respective 95% confidence intervals at a national-level and departmental-level. In addition to this, the coefficient of variation (CV) will be presented to serve as proxy for the variability of our estimates at departmental level.

Step 2: Correction for women of reproductive age and confirmatory HTLV-1 testing and smoothed estimate

Next, we calculated the proportion of confirmatory reactive HTLV-1 blood units in women of reproductive age (y_{wra_i}) based on correction factors for female sex, reproductive age, and confirmatory HTLV-1 from our scoping review.

$$y_{wra\_i} = \frac{Number\ of\ HTLV\text{-}1/2\ reactive\ blood\ units_i * \alpha_{HTLV} * \sigma_{HTLV}}{Number\ of\ screened\ blood\ units_i * \delta}$$

Where:

- *i* represents each department-year
- $Number\ of\ HTLV\text{-}1/2\ reactive\ blood\ units_i$ and $Number\ of\ screened\ blood\ units_i$ retain the same values to obtain proportion of reactive HTLV-1/2 blood units in step 1
- α_{HTLV} represents the correction factor for HTLV-1/2 seroreactivity in women of reproductive age
- σ_{HTLV} represents the correction factor for confirmatory HTLV-1 test
- δ represents the correction factor for female blood donors

Our correction factors for age and sex were calculated based on the ratio of HTLV-1/2 reactivity in each group of interest (female and age group 18-49) relative to the total blood donor population (Table 2). These proportions were derived from the sum of number of blood donors with the corresponding characteristics, extracted from the studies included in our scoping review. The decision to obtain factors separately was due to the lack of cross-tabulated results in the studies.

The correction factor for confirmatory test was derived from the proportion of HTLV-1/2 reactive blood units with a subsequent positive confirmatory test for HTLV-1.

Table 2: Calculation of correction factors

Correction factor	Formula
HTLV-1/2 reactivity in women (α_1)	$\frac{\text{HTLV-1/2 reactive female donors / Total female donors}}{\text{HTLV-1/2 reactive donors / Total donors}}$
HTLV-1/2 reactivity in 18-49 age group (α_2)	$\frac{\text{HTLV-1/2 reactive donors in 18-49 age group / Total donors in 18-49 age group}}{\text{HTLV-1/2 reactive donors / Total donors}}$
HTLV-1/2 reactivity in women of reproductive age (α_{HTLV})	$\alpha_1 * \alpha_2$
Female blood donors (δ)	$\frac{\text{Female donors}}{\text{Total donors}}$
HTLV-1 confirmatory testing (σ_{HTLV})	$\frac{\text{HTLV-1/2 reactive donors with a positive confirmatory test for HTLV-t}}{\text{Total HTLV-1/2 reactive donors}}$

After obtaining the corrected proportion for confirmatory HTLV-1 reactivity in women of reproductive age blood donors (y_{wra_j}) at a department-year level, we then conducted a second BYM2 model using y_{wra_j} as the target estimand to obtain smoothed estimates for proportion of confirmatory HTLV-1 in women of reproductive age.

Step 3: Correction for pregnant women

To estimate the average annual number of pregnant women with a confirmatory HTLV-1 test during the study period, we multiplied the smoothed estimates from step 2 by the total female population aged 18-49 years, and the proportion of women 15-49 years currently pregnant in each department.

To estimate the average annual proportion of pregnant women with a confirmatory HTLV-1 test, we divided our previous results at departmental level by the number of live births multiplied by 0.75. The 0.75 factor is derived from the CDC estimation for number of pregnant women based on the proportion of a year a women is pregnant for each pregnancy outcome (live birth) (19).

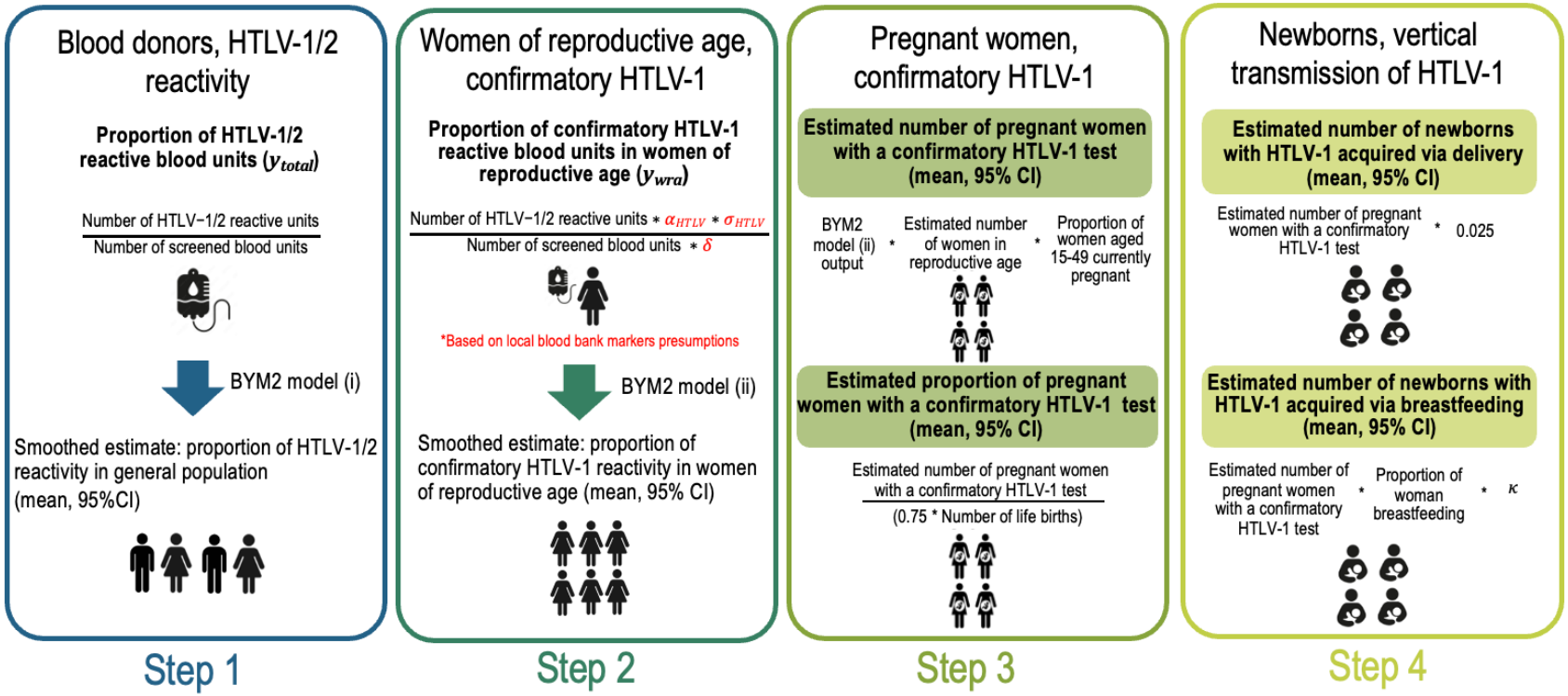
Step 4: HTLV-1 Mother-to-child transmission

To estimate the number of HTLV-1 infected newborns who were infected via delivery we multiplied the estimated number of pregnant women with HTLV-1 by 2.5%, which is the estimated risk of HTLV-1 MTCT from sources other than breastfeeding (19).

To estimate the number of HTLV-1 infected newborns who were infected via breastfeeding, we multiplied the estimated number of pregnant women with HTLV-1 by the proportion of breastfeeding women and the estimated risk of MTCT transmission via breastfeeding (κ) obtained from the length of breastfeeding in days as proposed by Rosadas, et al (20).

$$\kappa = 0.0046 * \frac{(Breasfeeding\ duration\ (in\ days) * 30.4) - 4.1}{100}$$

Figure 1: Process to obtain estimates for confirmatory HTLV-1 in pregnant women



α_{HTLV}: correction factor for HTLV-1/2 reactivity in women of reproductive age
σ_{HTLV}: correction factor for confirmatory HTLV-1 test which equals 0.67 based on Ulloa-Miranda, et al (16)
δ: correction factor for female blood donors
0.75 is derived from the proportion of a year a woman is pregnant per the CDC estimation of number of pregnant women based of live births (18)
0.025 is the risk for HTLV-1 MTCT from sources other than breastfeeding based on Rosadas, et al (19)
κ: risk factor for HTLV-1 MTCT via breastfeeding based on Rosadas, et al (19)

E. Model validation

To assess the accuracy of our estimates, we calculated the estimated number of pregnant women with a confirmatory HIV test and proportion of pregnant women with a confirmatory HIV test and compare them to the numbers reported at department-year level by the DGE of the Ministry of Health of Peru since HIV during pregnancy is a notifiable disease and data for the 25 departments of Peru are available for the study period.

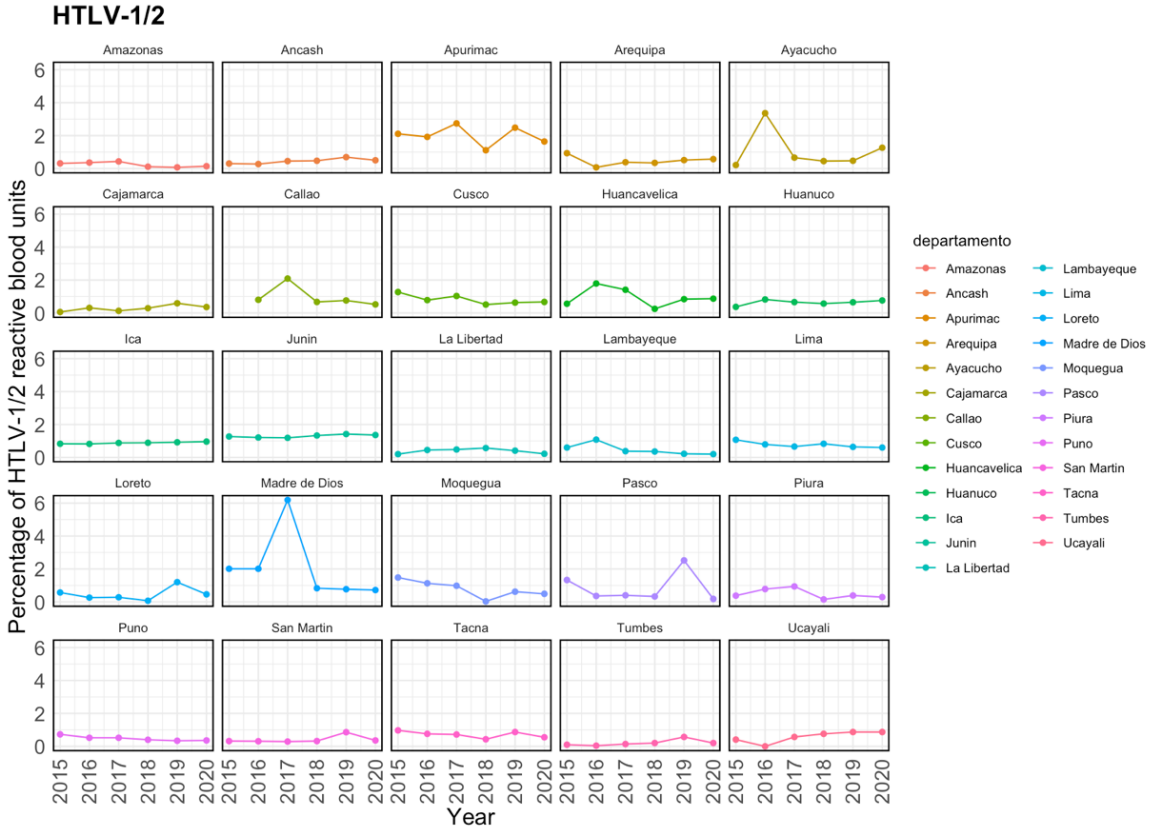
We used the variable proportion of reactive HIV blood units as a starting point and used HIV-specific correction factors from our scoping review to obtain the proportion of confirmatory reactive HIV blood units in women of reproductive age and then performed the previously detailed BYM2 model and calculations to estimate confirmatory HIV reactivity in pregnant women (21) (Supplementary Figure 1). Afterwards, we compared the means of our HIV model results to the yearly means of the numbers reported by the DGE during the study period at a departmental level to assess the correlation of our model estimates with the DGE reported data. Further details in our model validation process are provided in the Appendix.

III. Results

Descriptive statistics

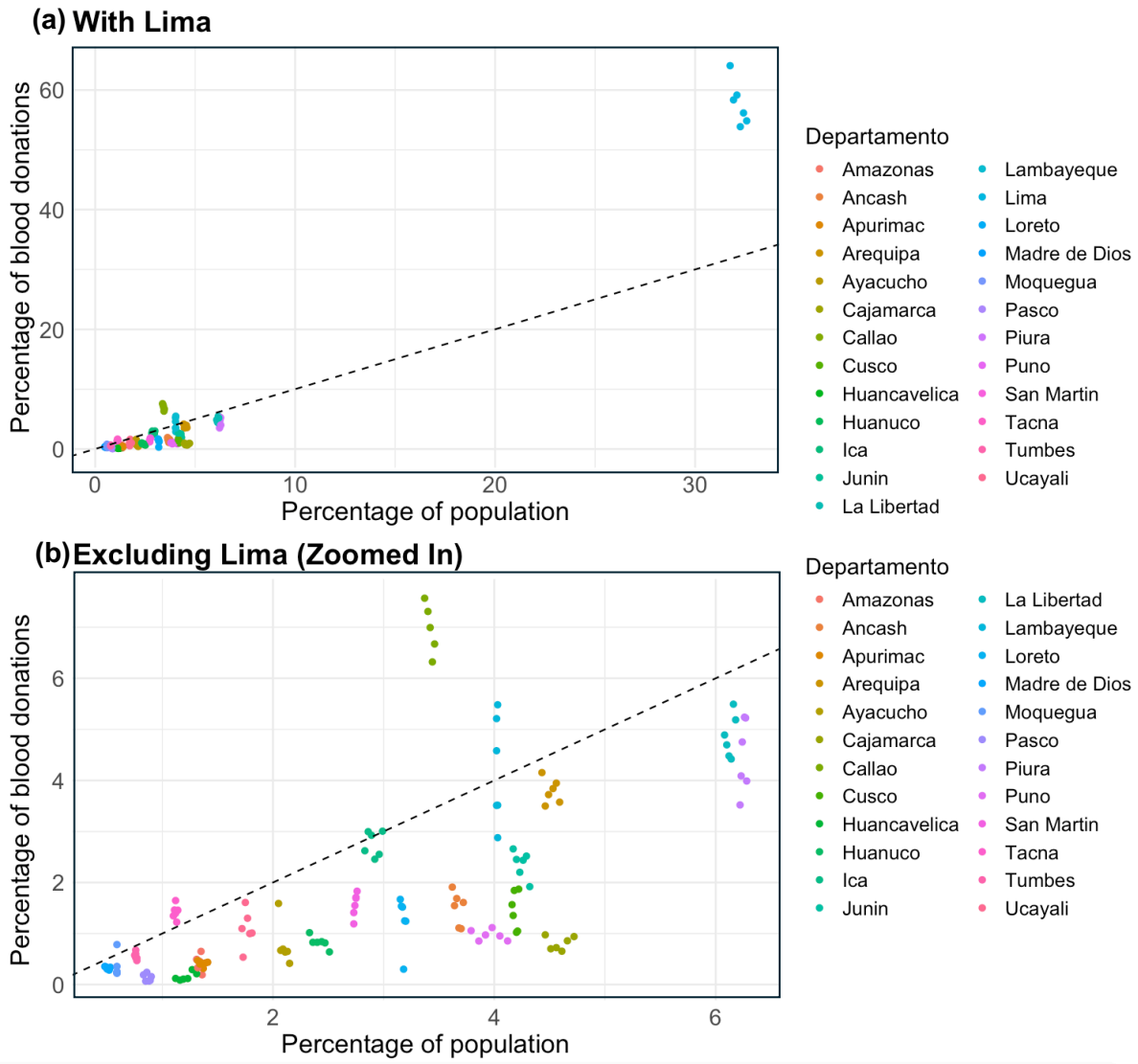
Between the years 2015 and 2020, a total of 2,120,344 blood units were screened of which 15,413 (0.73%) were reactive for HTLV-1/2. Some departments were found to have a significant variability over the study period (Figure 3).

Figure 3: Trend of HTLV-1/2 reactivity in blood units by department over time.



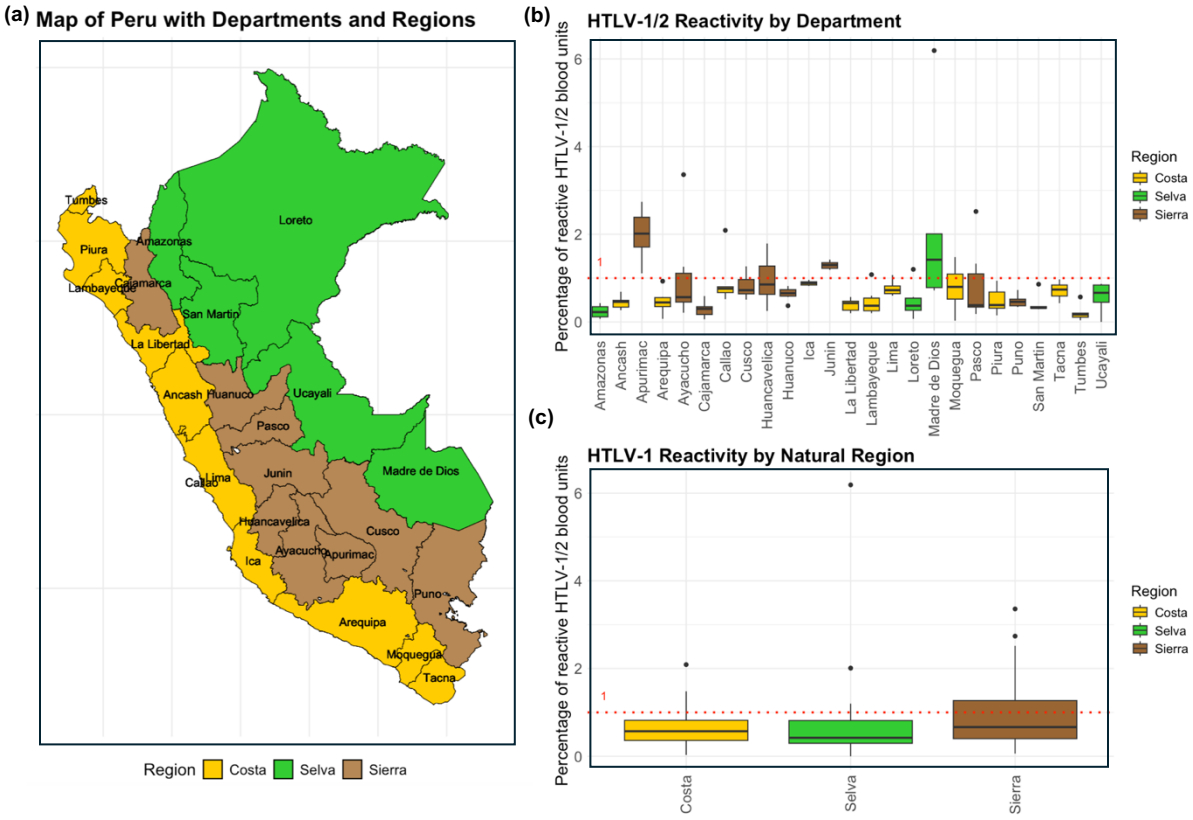
With regards to representativeness, the capital department of Lima was overrepresented in the blood bank data whereas most of the other departments were underrepresented (Figure 4).

Figure 4: Comparison of proportion of donated blood units and proportion of population by departments



The highlands (sierra) region had a higher HTLV-1/2 seroreactivity compared to the other two eco-regions; most of the departments that reported a HTLV-1/2 proportion 1% or higher were located in this region (Figure 5b).

Figure 5. Comparison of percentage of HTLV-1/2 reactive blood units between departments

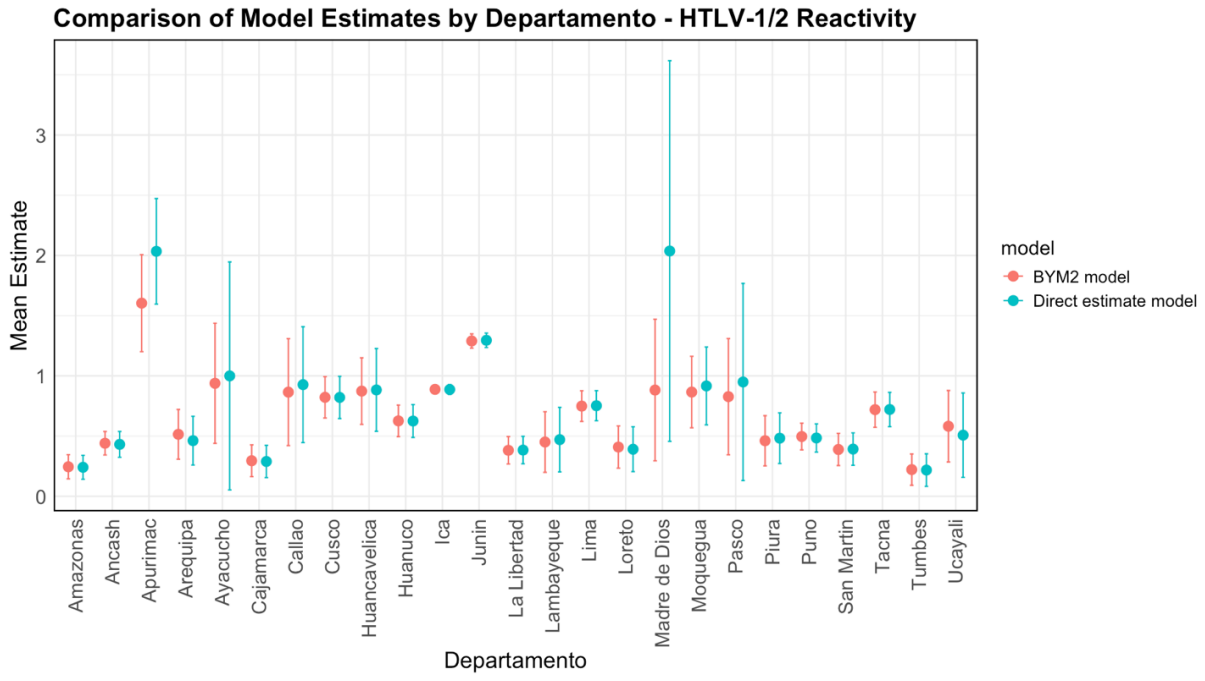


Smoothed estimate - HTLV-1/2 reactivity by department-year

From the first BYM2 model, the national average (intercept) for HTLV-1/2 reactivity in donor blood was 0.7% [95% CI: 0.6-0.8], with evidence of a considerable spatial structure as 49% of the total variance of this estimate could be attributed to its spatial component ($\phi = 0.49$) rather than unstructured random effects (ϕ close to 0) (Table 5). Thus, supporting that neighboring departments tend to have similar values for HTLV-1/2 reactivity.

Stabilized variance achieved from using the BYM-2 model compared with direct estimates is shown in Figure 6.

Figure 6. Comparison of posterior means and confidence intervals of HTLV-1/2 reactivity (in percentage) – BYM2 Model (i)



Correction for women of reproductive age

Correction factors for sex and age came from data from 25 hospital-level blood banks in Peru. We found that females accounted for 31% of blood donors and had a HTLV-1/2 seroreactivity rate 1.26 times higher than the total donor population (Table 4). Regarding age groups, blood donors between 18-49 years (reproductive age) represented 91% of the total population and had a similar HTLV-1/2 reactivity rate to the total donor population (0.95). Based on these findings, we calculated a correction factor for HTLV-1/2 seropositivity in women of reproductive age (α_{HTLV}) of 1.19 and a correction factor for female donors of 0.31 (δ). Further details on the selection and characteristics of the hospital-level blood banks studies are presented in Supplementary Figure 2, Supplementary Table 1 and Supplementary Table 2.

Since confirmatory testing for HTLV-1/2 reactive blood units is performed at national reference laboratories in Peru, results on confirmed HTLV-1 cases are generally not reported at departmental-level blood banks. We used a correction factor of 0.67 for confirmatory HTLV-1 testing (σ_{HTLV}) based in a study performed at a Peruvian national reference laboratory which found a true positive proportion for HTLV-1 infection of 66.5% among positive HTLV-1/2 blood donors in Peru (16).

Table 4. Correction factors based in hospital-level blood bank data

Correction factor	Formula	Calculation	Value
HTLV-1/2 reactivity in women (α_1)	$\frac{\text{HTLV-1/2 reactive women proportion}}{\text{HTLV-1/2 reactive donors proportion}}$	$\frac{1,419 / 147,388}{3,662 / 478,553}$	1.26
HTLV-1/2 reactivity in 18-49 age group (α_2)	$\frac{\text{HTLV-1/2 reactive aged 18-49 proportion}}{\text{HTLV-1/2 reactive donors proportion}}$	$\frac{1,960 / 299,208}{2,264 / 329,921}$	0.95
HTLV-1/2 reactivity in women of reproductive age (α_{HTLV})	$\alpha_1 * \alpha_2$	1.26 * 0.95	1.19
Female blood donors (δ)	$\frac{\text{Female donors}}{\text{Total donors}}$	$\frac{147,388}{478,553}$	0.31
Confirmatory HTLV-1 test (σ_{HTLV})	$\frac{\text{Confirmatory HTLV-1 reactive donors}}{\text{HTLV-1/2 reactive blood donors}}$	$\frac{212}{319}$	0.67

Smoothed estimates: women of reproductive age, pregnant women

After producing the proportion of confirmatory HTLV-1 reactivity in blood donors who were women of reproductive age, we used a second BYM2 model to smooth these estimates. We found a national average for confirmatory HTLV-1 reactivity of 1.8 [95% CI: 1.5-2.1] in women of reproductive age and estimated that from 2015-2020 there were 132,237 women of reproductive age with HTLV-1 per year in Peru (Table 5).

Table 5. Parameters of BYM2 models

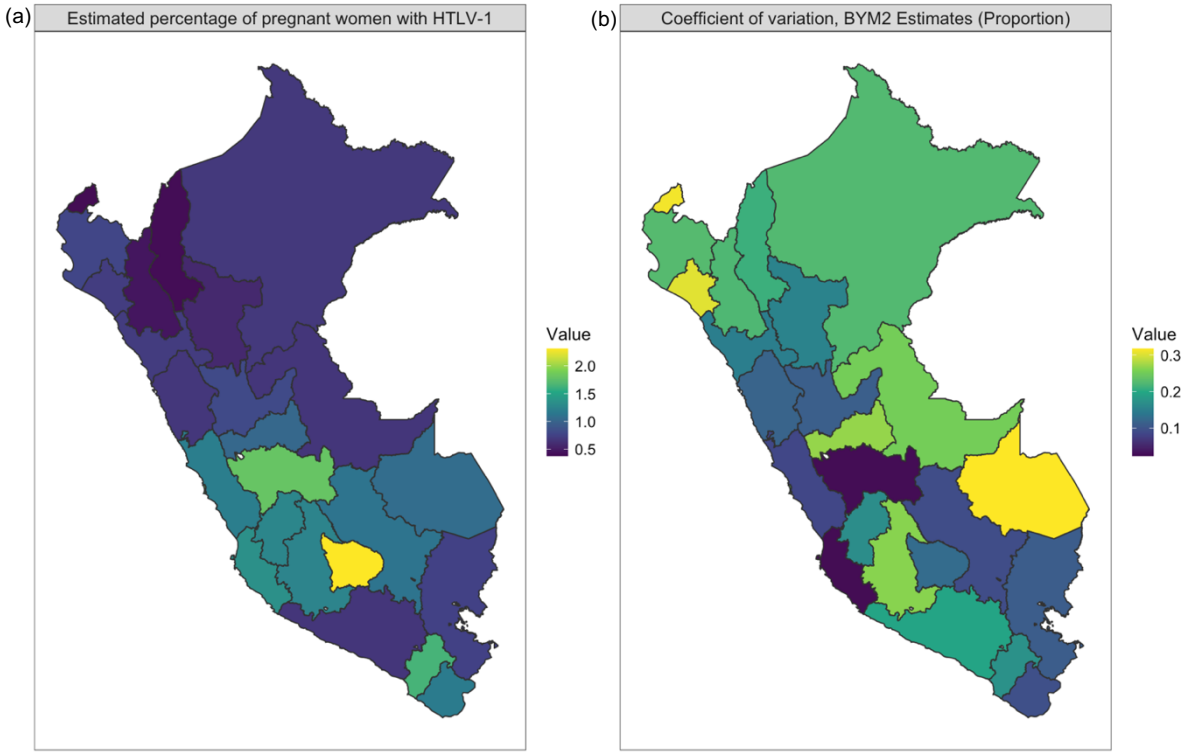
	Mean [95% CI]
Model (i) - HTLV-1/2 reactivity (all)	
β (Global intercept): National average	0.7% [0.6%-0.8%]
ϕ: Spatial component	0.49 [10-90]
Model (ii) – Confirmatory HTLV-1 reactivity (women of reproductive age)	
β (Global intercept): National average	1.8% [1.5% -2.1%]
ϕ: Spatial component	0.49 [0.1-0.9]

ϕ represents the proportion of total variance of the BYM2 model attributed to the spatially structured component

Applying the previously described calculations (Figure 1, Step 3), we estimated that from 2015-2020 there were 4,602 [95%CI: 3,851-5,368] pregnant women with HTLV-1 per year in Peru, and this represented 1.05% [95%CI: 0.88-1.23] of Peruvian pregnant women (Table 6).

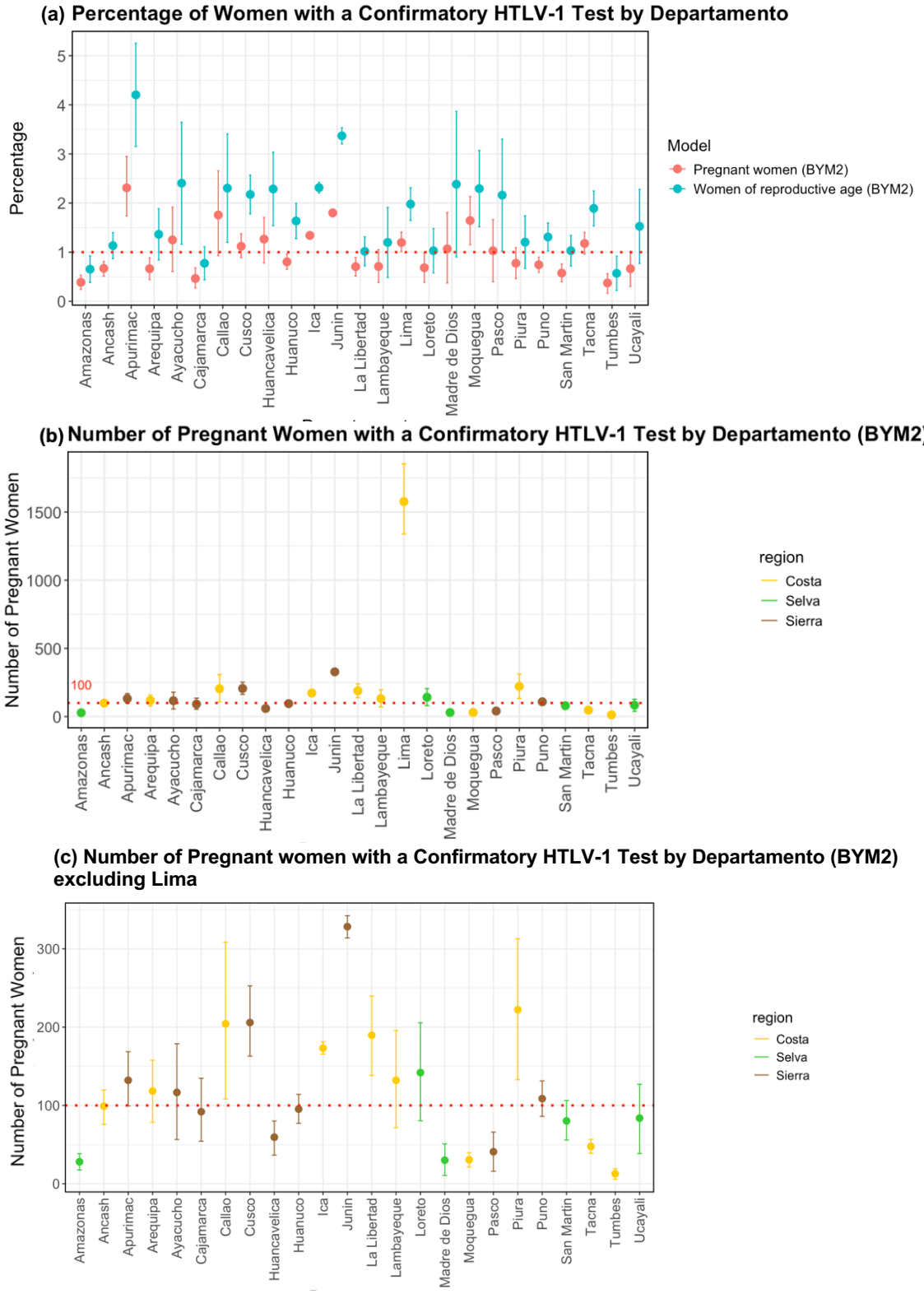
The distribution among departments for the estimated proportion of pregnant women with a confirmatory HTLV-1 test is presented in Figure 8 and a tendency for higher values in the south can be visualized. Additionally, the variability of our estimates is presented as coefficients of variation (CV) for each of the departments; notably this was less than 30% for all departments but Tumbes and Madre de Dios (31%); demonstrating an acceptable level of precision with the use of our BYM2 model as high CV values could indicate potential sampling error and need to be interpreted with caution.

Figure 8. Estimates for confirmatory HTLV-1 reactivity per year by department



When comparing our estimates for confirmed HTLV-1 reactivity between women of reproductive age and pregnant women (Figure 9a), lower values were seen in the latter group. A total of 12 departments (Apurimac, Ayacucho, Callao, Cusco, Huancavelica, Ica, Junín, Lima, Madre de Dios, Moquegua, Pasco, Tacna) had an estimated mean percentage of pregnant women with confirmed HTLV-1 of 1% or higher. The five departments with the highest number of pregnant women with HTLV-1 were Lima, Junín, Piura, Cusco and Callao (Figure 9b).

Figure 9. Estimates for confirmatory HTLV-1 reactivity in pregnant women per year by department



HTLV-1 Mother-to-child transmission

For newborns, we estimated that there were around 115 [95% CI: 96-134] acquired yearly in-utero per year during the period of 2015-2020 and 1,009 [95% CI: 920-1,282] cases of HTLV-1 in newborns acquired yearly due to breastfeeding (Table 6).

To assess the accuracy of our estimates we included values of similar indicators from published literature to serve as point of reference when available (Table 6).

Table 6. Estimates for confirmatory HTLV-1 reactivity per year in Peru (2015-2020)

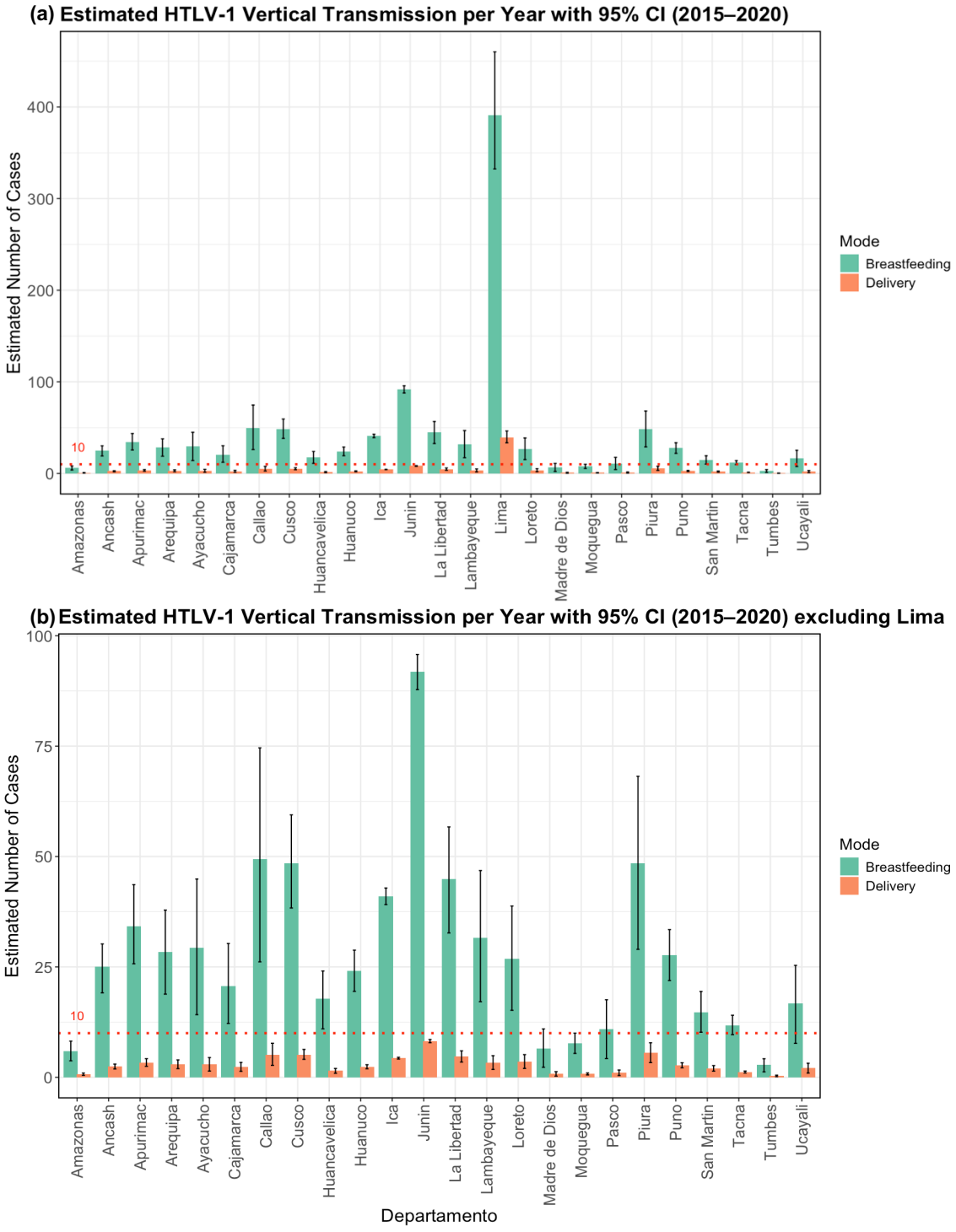
	Mean [95% CI]	Reference value
Women of reproductive age		
Confirmatory HTLV-1 reactivity (%)	1.8 [1.5-2.1]	
Confirmatory HTLV-1 reactivity (#)	132,237 [110,672-154,249]	150,000-450,000 HTLV-1 carriers* (Gessain, 2012)
Pregnant women		
Confirmatory HTLV-1 reactivity (%)	1.05 [0.88-1.23]	1.02 [0.75-1.33] ** (Sanchez-Nunez, 2024)
Confirmatory HTLV-1 reactivity (#)	4,602 [3,851-5,368]	
Newborns		
Cases of HTLV-1 in newborns acquired in-utero (#)	115 [96-134]	
Cases of HTLV-1 in newborns acquired due to breastfeeding (#)	1,009 [920-1,282]	

*Estimates include male and female HTLV-1 carriers in Peru

**Estimated confirmatory HTLV-1 prevalence in pregnant women in South America and the Caribbean

Figure 10 presents our estimates for number of vertically transmitted HTLV-1 cases at a departmental level. A similar distribution to the estimates for number of pregnant women with HTLV-1 is seen, with Lima, Junín, Piura, Cusco and Callao being the departments with the largest estimates.

Figure 10. Estimates for MTCT HTLV-1 cases per year by department



Validation

Table 7 summarizes our results for HIV estimates and compare them to reference estimates to assess the performance of our model. Further HIV-specific details such as BYM2 model parameters and

correctional factors are presented in Supplementary Table 3, Supplementary Table 4, Supplementary Table 5 and Supplementary Table 6.

Table 7. Estimates for confirmatory HIV reactivity per year in Peru (2015-2020)

	Mean [95% CI]	Reference value	
Women of reproductive age			
Confirmatory HIV reactivity (%)	0.17 [0.14-0.2]	0.2* (UNAIDS, 2020)	
Confirmatory HIV reactivity (#)	12,737 [10,710-14,847]	16,000 [14,000-19,000] ** (UNAIDS, 2020)	
Pregnant women			
Confirmatory HIV reactivity (%)	0.1 [0.09-0.12]	0.2 (mean, DGE 2015-2020)	<0.25 (Chow, 2019)
Confirmatory HIV reactivity (#)	443 [373-517]	526 (mean, DGE 2015-2020)	1,300 [1,100-1,500] *** (UNAIDS, 2020)

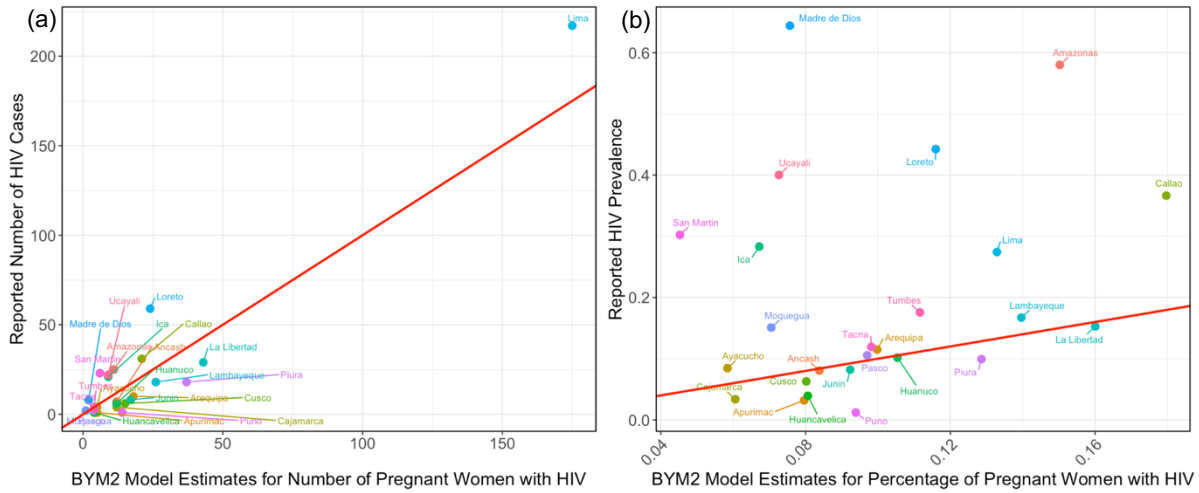
*Estimates for women aged 15-49 years HIV prevalence rate in Peru

**Estimates for number of women aged 15-49 years living with HIV in Peru

***Estimates for pregnant women who received antiretrovirals for PMTCT in Peru

The departmental-level comparison of both our estimated percentage and number of HIV reactivity in pregnant women with the mean of the reported cases of pregnant women living with HIV by the DGE are presented in Figure 11. The comparison revealed notable lower blood bank-derived estimates in departments with a high HIV burden such as Lima, Callao, Madre de Dios, Amazonas, Loreto, Ucayali, San Martin and Ica.

Figure 11. Comparison of HIV estimates in pregnant women from blood bank data with data from the Peruvian DGE



IV. Discussion

Our blood bank-derived estimates revealed a significant burden of HTLV-1 in Peruvian pregnant women with a confirmatory HTLV-1 prevalence of 1.05% [95%CI: 0.88-1.23] during the period of 2015-2020. Higher estimates were noted in the departments from the southern part of the country (Figure 9) with Apurimac and Junín, both also in the highlands, presenting the highest rate of seropositivity with 2.31% [95% CI: 1.74-2.95] and 1.8% [95%CI: 1.72-1.88], respectively (Supplementary Table 8). From a quantitative perspective, we calculated an approximate of 4,602 [95% CI: 3,851-5,368] confirmed cases of HTLV-1 in pregnant women per year during the study period throughout the country. A total of 15 departments reached a HTLV-1 seroprevalence of 1% in pregnant women within their confidence intervals, whereas a total of 18 reached a value of at least 100 annual cases of pregnant women with confirmed HTLV-1 (Figure 9).

Regarding cases of HTLV-1 in newborns, we estimated approximately 1,009 [95% CI: 920-1,282] cases are acquired yearly due to breastfeeding during the study period. Notably, if breastfeeding transmission would have been interrupted during the study period the number of estimated HTLV-1 cases in newborns would be reduced to just the cases acquired in-utero, which were less than 10 cases yearly for all departments but Lima (Figure 10).

Our national estimate for the proportion of pregnant women with a confirmatory HTLV-1 test during the period of 2015-2020 is comparable to a previously reported prevalence of 1.02% [95% CI: 0.75-1.33] for confirmed HTLV-1 in pregnant women for the Latin America and the Caribbean region based on a metanalysis by Sanchez-Nunez, et al (22). This systemic review included 39 studies with confirmatory results for HTLV-1 prevalence in pregnant women of which 6 were conducted in Peru and contained samples from 5 different departments. It is worth pointing out that our estimate had a narrower confidence interval possibly due to use of data from a single country and our use of a spatial smoothing model.

When comparing our departmental-level estimates to the few studies that have reported HTLV-1 prevalence in pregnant women in sub-national regions of Peru, we found our estimates to be somewhat lower as detailed below: Cusco: estimated 1.1% vs reported 2.3% (7), Ayacucho:

estimated 1.3% vs reported 1.3% (8), Ica: estimated 1.3% vs reported 3.8% (8), Iquitos: estimated: 0.7% vs reported: 1.7% (9) and Lima: estimated 1.2% vs reported: 1.7% (11).

In high-income countries, these lower estimates could be explained by the “healthy donor effect” (23). In such settings, most donations are voluntary and donors have been found to have a healthier profile than the general population (23). For example, in the US donors are more likely to be non-Hispanic whites, US-born, college graduates, employed, physically active or never smokers (24). However, studies that have used blood donor data to estimate the general population prevalence of other infections such as HIV and Hepatitis B have shown a similar distribution of demographic and geographic characteristics between the two groups (blood donors and general population) despite the lower prevalence in the donor group (25, 26, 27). Furthermore, a particular characteristic of blood donors in Peru is that the vast majority (79-94% during the study period) are replacement blood donors, meaning that the blood donation is provided by relatives or friends of a patient that requires a transfusion (12, 17). Although replacement blood donors undergo the same exhaustive screening process as voluntary donors, it has been shown that this specific group have a higher rate of positive of infectious markers when compared to voluntary blood donors (17, 28, 29). As such, bias due to the healthy donor effect is likely to be minimal in this setting.

Another possible explanation of these lower values is that we used the total number of women aged 18-49 years to calculate our estimates in pregnant women as the minimum age to donate blood in Peru is 18 years old, although the start of reproductive age in Peru is considered 15 years for population-based calculations (17, 30). We also did not include number of abortions or fetal loss in our calculations for number of pregnant women as abortion is illegal in Peru and official data is not available (11).

It is also possible that these prior estimates are overestimates. Two of the cited studies (7, 10) were carried out in groups of pregnant women with specific characteristics such as belonging to an ethnic minority or living in rural areas associated with a higher HTLV-1 seroprevalence (22).

The main limitation to using blood bank data to estimate the HTLV-1 burden among pregnant women in Peru is this specific group is not allowed to serve as blood donors as a result a direct estimation is

conflicting (12, 17). To address this limitation, we developed an analytic strategy to obtain the estimated seroprevalence of HTLV-1 first in women of reproductive age and then pregnant women. Validation of our approach using HIV data allowed us to assess the accuracy of our results using the proposed strategy. When comparing corresponding HIV-related estimates to official statistics (Figure 10), our estimates on average were lower; with this difference being more pronounced in departments with the highest burden of HIV in Peru – mostly those located in the jungle region (Madre de Dios, Amazonas, Loreto, Ucayali, San Martin) and the densely populated departments of Lima and Callao (31). The previously described healthy donor effect could explain this finding as both voluntary and replacement blood donor candidates with high-risk behaviors are deferred. In Peru, if tentative blood donors are found to have any risky behaviors which include various known HIV risk factors such as anal intercourse, multiple sexual partners, transactional sex or intravenous drug use, they are asked to refrain from donation (17). Since HTLV-1 transmission in Peru is mainly driven by MTCT rather than sexual transmission, we again do not expect this restriction to greatly impact our estimates for HTLV-1. The assumption of our model that identical correction factors for sex, age and confirmatory testing apply for all the departments could also contribute to the notable lower estimates for areas with higher HIV burden as the predictive positive value of the screening test depends on the department-level prevalence of the disease of interest. In the case of our HIV model, assuming a correction factor of 0.33 (σ_{HIV}) for the jungle region could explain our lower estimates when compared to the DGE reported numbers (Figure 11b). Future iterations of our model could include either department or natural region level correction factors for sex, age and confirmatory testing if detailed blood donor characteristics are available. Overall, however, when comparing the absolute values of our estimates at national level (Table 7) we did not find a significant underestimation as our estimated yearly number of pregnant women living with HIV of 443 [95% CI: 373-517] was about 15-20% lower the reported annual average of 526 cases reported by the DGE during the study period. Again, this calculation did not include women aged 15-17 years, and this could have also played a role in our lower estimates.

Another potential limitation is the use of different HTLV-1/2 screening tests by the Peruvian blood banks as the Ministry of Health endorses the use of either ELISA or CMIA techniques for the

screening process and several commercial tests are available (12). However, the Ministry of Health requires retesting of blood units that have reactive or indeterminate results before their registration as reactive units and subsequent disposal (32), and blood banks in Peru are subject to a strict quality control endorsed by the Direction of Blood Banks and Hemotherapy (DIBAN-PRONAHEBAS) which includes the periodic internal and external assessment of serological testing (33), indicating comparison across departments is suitable even if different tests are used for initial screening. The concordance of the geographic distribution of our estimates with the previously described higher HTLV-1 prevalence in the southern region of Peru support the comparison of blood bank results.

In this context, the use of small-area estimation model for the generation of our estimates allowed us to have more precise results. This approach has been used in many public health applications to smooth estimates at different administrative levels when data in some domains is sparse (34). In this specific case, although data was available for all departments, variance in each department-year (Figure 3) was reduced with the implementation of a BYM2 model, with the reduction of confidence interval width (Figure 6) and a coefficient of variation of 8% for the national average and less than 30% for virtually all departments (Figure 8b and Supplementary Table 8). This could be considered an acceptable level of uncertainty for our estimates as the US Census Bureau considers CV values larger than 30% as a serious data quality issue in its Statistical Quality Standards (35). Possible explanations for the variation seen within each department during the study period could include changes in the blood donor population (increase of female or older donors, relaxed standards for blood donor selection) or changes in the screening test performed. As HTLV-1 causes a chronic lifelong infection that affects a small proportion of the total population, significant changes in its prevalence within blood donors would not be expected during our 6-year study period (36). Nevertheless, the use of our small-area estimation model allowed for a reduction of this effect. We decided to not include covariates in our final small-area estimation model as our intention in the present study was the use of spatial structure to smooth our estimates after the application of correction factors to blood bank data.

While there are limitations of using blood bank data for the generation of our estimates, its main advantage relies on the significant number of subjects screened for HTLV-1 infection and the

representativeness of this sample, with data available for all the departments in Peru. Furthermore, we were able to demonstrate that our analytic strategy generated estimates with a fair degree of precision and accuracy, however the possibility of underestimation, variability within some departments, and the need for further population-based studies on HTLV-1 prevalence in pregnant women should be recognized.

Finally, our estimates for the burden of HTLV-1 in pregnant women and newborns in Peru provide novel information to understand the burden of this infection particularly with the implementation of PMTCT interventions by other HTLV-1 endemic countries in recent years. Both absolute and relative estimates are essential when a proposed PMTCT policy could entail avoidance of breastfeeding and the need of formula supplementation as the attendant risks and costs need to be assessed both at a departmental and national level before implementation of a such policy in Peru.

For example, in the case of HIV there is a current national policy for PMTCT, and seropositive mothers are advised to avoid breastfeeding and are provided formula supplementation by the Peruvian government (37). Our findings revealed a higher overall burden of HTLV-1 compared to HIV and this was markedly disproportionate in the highlands of Peru (Supplementary Table 10), suggesting that the implementation of such as a strategy for HTLV-1 could be more difficult in these departments as their need for formula supplementation would surpass the current supply to prevent HIV MTCT.

V. References

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VI. Appendix

Calculation of estimates for confirmatory HIV in pregnant women

We also used a four-step approach to obtain to extrapolate data on HIV seroreactivity in total blood donors to estimates for confirmatory HIV seroreactivity in pregnant women (Supplemental Figure 2).

Step 1: Smoothed estimate - HIV reactivity by department-year

Previous studies have noted a higher prevalence of HIV in the departments of Lima and Callao, as well as the ones located in the jungle nature region when compared to others, thus a spatial component could also be expected (31). We first performed a BYM2 (model iii) using the proportion of reactive HIV blood units as the target estimand to assess the reduction of variability in our estimates with this method. Since both the data on HIV and HTLV-1/2 reactivity in blood donors share the same population, we used the same probabilistic weights and BYM2 structure as previously described.

Step 2: Correction and smoothed estimate for women of reproductive age and confirmatory HIV testing

We calculated specific correction factors for HIV as it has a different epidemiological profile than HTLV-1. We used articles from our scoping review that also reported data on HIV reactivity. The same applied for our confirmatory test correction factor and for this case we based our factor in literature provided by the CDC (21).

The detailed formulas for the calculation of the HIV-specific correction factors are presented in Table 8.

Table 8: Calculation of correction factors for HIV

Correction factor	Formula
HIV reactivity in women **(α_3)**	$\frac{\text{HIV reactive female donors / Total female donors}}{\text{HIV reactive donors / Total donors}}$
HIV reactivity in 18-49 age group **(α_4)**	$\frac{\text{HIV reactive donors in 18-49 age group / Total donors in 18-49 age group}}{\text{HIV reactive donors / Total donors}}$
HIV reactivity in women of reproductive age **(α_{HIV})**	$\alpha_3 * \alpha_4$
HIV confirmatory testing **(σ_{HIV})**	Based on CDC true positive HIV rate in settings with low HIV prevalence (21)

With these specific factors, we proceeded to calculate the proportion of confirmatory reactive HIV blood units in women of reproductive age (z_{wra_i}) as detailed below.

$$z_{wra\_i} = \frac{\text{Number of HIV reactive blood units}_i * \alpha_{HIV} * \sigma_{HIV}}{\text{Number of screened blood units}_i * \delta}$$

Where:

- *i* represents each department-year
- $Number\ of\ HIV\ reactive\ blood\ units_i$ and $Number\ of\ screened\ blood\ units_i$ retain the same values to obtain proportion of reactive HIV blood units in step 1
- α_{HIV} represents the correction factor for HIV seroreactivity in women of reproductive age
- σ_{HIV} represents the correction factor for confirmatory HIV test
- δ represents the correction factor for female blood donors

We then conducted a fourth BYM2 model using z_{wra_j} as the target estimand to obtain smoothed estimates for proportion of confirmatory HIV in women of reproductive age.

Step 3: Correction for pregnant women

We then multiplied the recently obtained smoothed estimates by the total female population aged 18-49 years and the proportion of women 15-49 years currently pregnant at a departmental-level to calculate our estimates for the total yearly number of pregnant women with a confirmatory HIV test during the study period.

Next to obtain the estimated proportion of pregnant women with a confirmatory HIV test, we divided our previous results at departmental-level by the number of life births multiplied by 0.75.

Step 4: Comparison of smoothed estimates with reported data

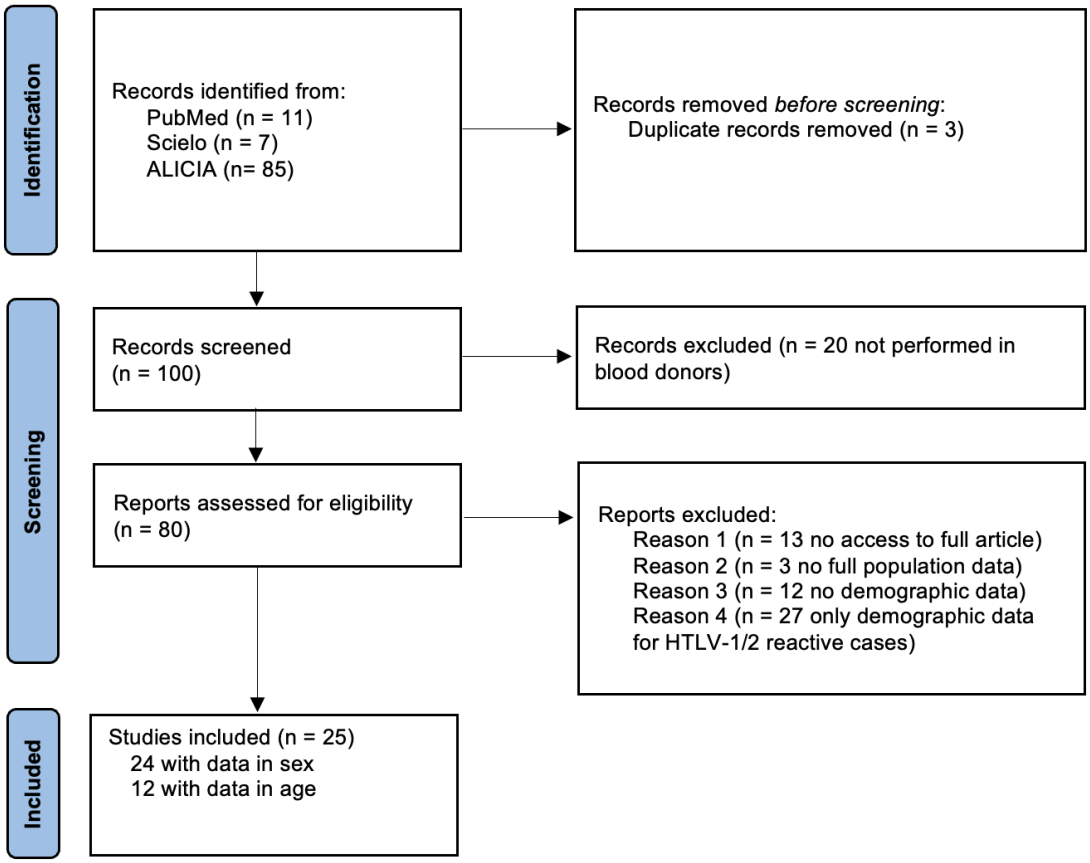
We obtained the yearly mean of the number of pregnant women with HIV reported by the DGE at a departmental-level to compare it to our estimate of total yearly number of pregnant women with a confirmatory HIV test during the study period.

Since the prevalence of HIV in pregnant women is not reported by DGE, we generated a proxy variable by dividing the number of pregnant women with HIV reported by the DGE by the total number of pregnant women. Again, this were obtained as yearly means for the study period and at a departmental-level. We

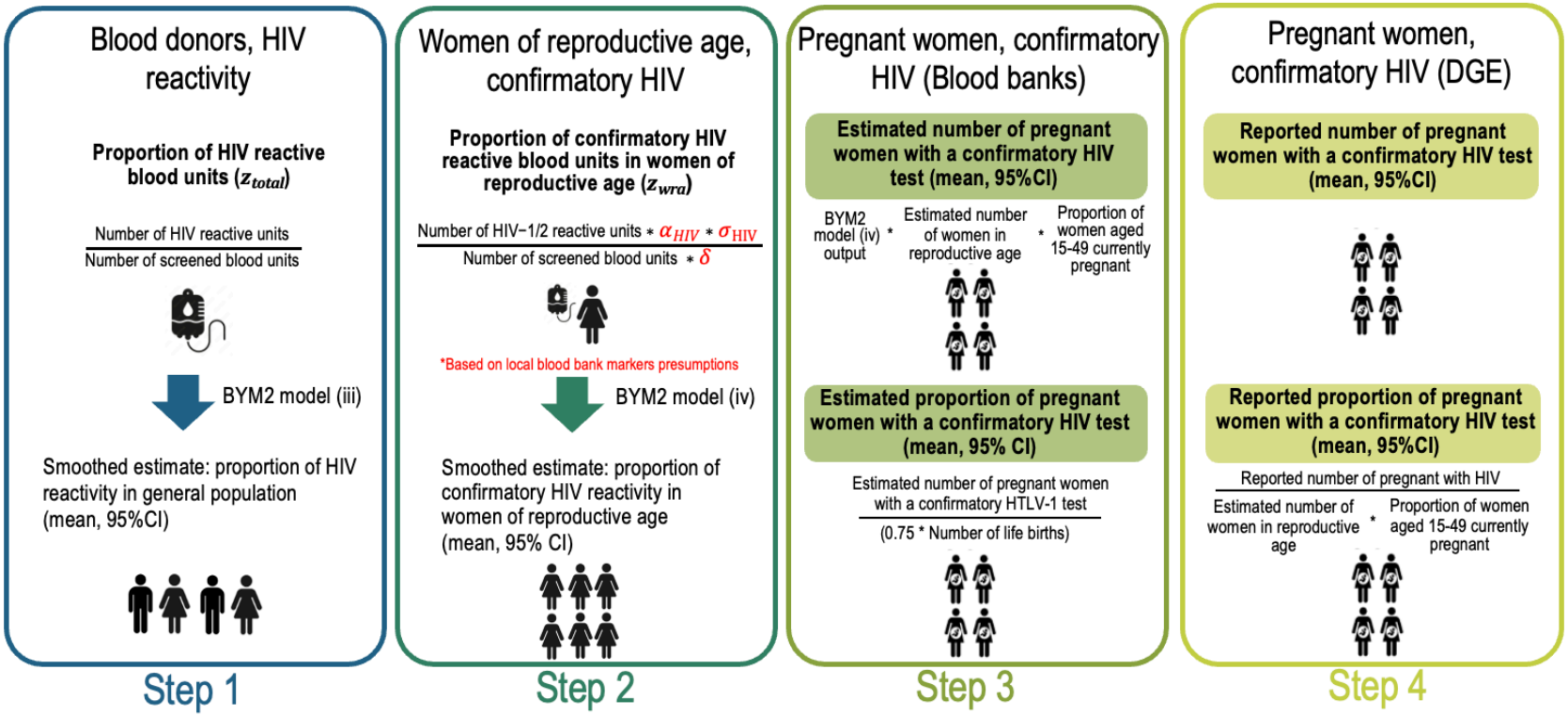
then compared the newly calculated prevalence of HIV in pregnant women based on the DGE to our estimated proportion of pregnant women with a confirmatory HIV test.

VII. Supplementary data

Supplementary Figure 1. PRISMA 2020 flow diagram for selection of studies in HTLV-1/2 seroprevalence in blood banks from Peru



Supplementary Figure1.



α_{HIV}: correction factor for HIV reactivity in women of reproductive age
σ_{HIV}: correction factor for confirmatory HIV test which equals 0.33 based on the CDC (20)
δ: correction factor for female blood donors
0.75 is derived from the proportion of a year a woman is pregnant per the CDC estimation of pregnant women based on live births (18)

Supplementary Table 1. HTLV-1/2 seroprevalence by sex (Hospital-level blood bank data)

First author, year of publication	Department (Years)	Donors (n=478,553)		Positive HTLV-1/2 donors (n=3,662)		HTLV-1/2 seroprevalence (%)		
		Male	Female	Male	Female	Male	Total	Female
Ramirez-Soto, 2018	Apurimac (2010-2015)	1,834	1,061	48	49	2.6	3.4	4.6
Alcarraz-Alfaro, 2019	Apurimac (2012-2016)	2,179	1,127	42	27	1.9	2.1	2.4
Paredes-Sarmiento, 2017	Arequipa (2016)	56	64	1	1	1.8	1.7	1.6
Aquino-Janampa, 2020	Ayacucho (2015-2018)	5,704	4,172	51	31	0.9	0.8	0.7
More-Yupanqui, 2021	Callao (2018)	4,250	1,662	28	11	0.7	0.7	0.7
Misme-Gonzales, 2018	Cusco (2014-2016)	37	72	2	2	5.4	3.7	2.8
Reyes-Garcia, 2018	Ica (2013-2015)	3,231	738	14	2	0.4	0.4	0.3
Vasquez-Espinar, 2023	Iquitos (2015-2021)	6,254	2,473	46	27	0.7	0.8	1.1
Arias del Aguila, 2021	Iquitos (2017)	1,854	279	9	4	0.5	0.6	1.4
Saboya-Vela, 2018	Iquitos (2017)	2,118	440	14	5	0.7	0.7	1.1
Amaya-Murayari, 2022	Iquitos (2020)	1,646	711	10	2	0.6	0.5	0.3
Chaquilla-Guevara, 2018	Lambayeque (2017)	295	76	2	3	0.7	1.4	3.9
Melendez-Verastegui, 2017	Lima (2015)	3,890	692	40	17	1	1.2	2.5
Urco-Collachagua, 2022	Lima (2019-2020)	12,357	9,479	38	53	0.3	0.4	0.6
Santiago-Chavez, 2022	Lima (2016-2021)	138,663	65,784	778	503	0.6	0.6	0.8
Coaguila-Bastidas, 2018	Lima (2016-2017)	5,813	2,778	34	19	0.4	0.4	0.5
Zapata-Camara, 2025	Lima (2018-2022)	6,528	1,423	33	10	0.5	0.5	0.7
Carrasco-Randrianarison, 2022	Cajamarca (2018-2021)	6,626	4,945	22	24	0.3	0.4	0.5
	Lima (2018-2021)	2,898	1,016	13	5	0.4	0.5	0.5
Morales, 2021	Lima (2012-2015)	19,825	8,259	201	110	1	1.1	1.3
Rojas-Suyo, 2018	Lima (2014-2016)	5,167	2,269	47	24	0.9	1	1
Rivas-Cardenas, 2020	Lima (2014-2016)	78,917	26,542	656	398	0.8	1	1.5
Coyla-Mamani, 2023	San Martin (2019-2021)	12,843	7,263	53	40	0.4	0.5	0.6
Cahuaya-Chuquicallata, 2021	Tacna (2016-2018)	5,822	2,364	46	41	0.8	1.1	1.7
Guillen-Macedo, 2020	Puno (2014-2018)	2,358	1,699	15	11	1.7	1.8	1.9
	Total	**331,165**	**147,388**	**2,243**	**1,419**	**0.7**	**0.8**	**1**

Supplementary Table 2. HTLV-1/2 seroprevalence by age group (Hospital-level blood bank data)

First author, year of publication	Department (Years)	Donors (n=329,921)					Positive HTLV-1/2 donors (n=2,264)					HTLV-1/2 seroprevalence (%)		
		18-19	20-29	30-39	40-49	>50	18-19	20-29	30-39	40-49	>50	Total	18-49	>50
Ramirez-Soto, 2018	Apurimac (2010-2015)	101	1,338	812	506	136	1	32	22	34	8	3.4	3.2	5.9
Alcarraz-Alfaro, 2019	Apurimac (2012-2016)	136	1,000	1,000	996	174	2	21	21	21	4	2.1	2.1	2.3
Aquino-Janampa, 2020	Ayacucho (2015-2018)	528	4,193	3,087	1,606	462	4	30	26	20	2	0.8	0.8	0.4
More-Yupanqui, 2021	Callao (2018)	835	1,340	1,339	2,028	400	0	7	6	7	9	0.7	0.4	2.3
Jimenez-Flores, 2018	Ica (2010-2017)	3,052	3,052	8,034	3,929	1,946	14	15	42	29	6	0.5	0.6	0.3
Vasquez-Espinar, 2023	Iquitos (2015-2021)	2,191	2,906	2,218	1,025	387	16	22	19	11	5	0.8	0.8	1.3
Arias del Aguila, 2021	Iquitos (2017)	573	416	600	272	272	0	3	5	2	3	0.6	0.5	1.1
Saboya-Vela, 2018	Iquitos (2017)	771	498	754	266	269	1	4	6	4	4	0.7	0.7	1.5
Urco-Collachagua, 2022	Lima (2019-2020)	4,196	6,926	6,925	3,745	44	18	24	24	25	0	0.4	0.4	0
Santiago-Chavez, 2022	Lima (2016-2021)	24,558	49,118	61,291	48,287	21,193	128	258	372	317	206	0.6	0.6	1
Morales, 2021	Lima (2012-2015)	1,547	9,727	8,685	6,019	2,106	9	78	110	73	41	1.1	1	2
Coyla-Mamani, 2023	San Martin (2019-2021)	4,728	4,018	4,018	4,018	3,324	25	17	17	18	16	0.5	0.5	0.5
	Total	**43,216**	**84,532**	**98,763**	**72,697**	**30,713**	**218**	**511**	**670**	**561**	**304**	**0.7**	**0.7**	**1**

Supplementary Table 3. HIV seroprevalence by sex (Hospital-level blood bank data)

First author, year of publication	Department (Years)	Donors (n=411,912)		Positive HIV donors (n=1,348)		HIV seroprevalence (%)		
		Male	Female	Male	Female	Male	Total	Female
More-Yupanqui, 2021	Callao (2018)	4,250	1,662	30	18	0.7	0.8	1.1
Zurita-Vera, 2018	Cusco (2017)	200	82	1	0	0.5	0.4	0
Reyes-Garcia, 2018	Ica (2013-2015)	3,231	738	3	0	0.1	0.1	0
Vasquez-Espinar, 2023	Iquitos (2015-2021)	6,254	2,473	20	6	0.3	0.3	0.2
Chaquilla-Guevara, 2018	Lambayeque (2017)	295	76	1	0	0.3	0.3	0
Melendez-Verastegui, 2017	Lima (2015)	3,890	692	13	1	0.3	0.3	0.1
Urco-Collachagua, 2022	Lima (2019-2020)	12,357	9,479	21	6	0.2	0.1	0.1
Santiago-Chavez, 2022	Lima (2016-2021)	138,663	65,784	534	188	0.4	0.4	0.3
Coaguila-Bastidas, 2018	Lima (2016-2017)	5,813	2,778	24	9	0.4	0.4	0.3
Zapata-Camara, 2025	Lima (2018-2022)	6,528	1,423	12	4	0.2	0.2	0.3
Rojas-Suyo, 2018	Lima (2014-2016)	5,167	2,269	9	2	0.2	0.1	0.1
Rivas-Cardenas, 2020	Lima (2014-2016)	78,917	26,542	310	87	0.4	0.4	0.3
Coyla-Mamani, 2023	San Martin (2019-2021)	12,843	7,263	22	7	0.2	0.1	0.1
Cahuaya-Chuquicallata, 2021	Tacna (2016-2018)	5,822	2,364	12	1	0.2	0.2	0.04
Guillen-Macedo, 2020	Puno (2014-2018)	2,358	1,699	3	4	0.1	0.2	0.2
	Total	**286,588**	**125,324**	**1,015**	**333**	**0.4**	**0.3**	**0.3**

Supplementary Table 4. HIV seroprevalence by age group (Hospital-level blood bank data)

First author, year of publication	Location (Years)	Donors (n=261,058)					Positive HIV donors (n=852)					HIV seroprevalence (%)		
		18-19	20-29	30-39	40-49	>50	18-19	20-29	30-39	40-49	>50	Total	18-49	>50
More-Yupanqui, 2021	Callao (2018)	835	1,340	1,339	2,028	400	9	12	11	15	1	0.8	0.8	0.3
Vasquez-Espinar, 2023	Iquitos (2015-2021)	2,191	2,906	2,218	1,025	387	11	9	4	2	0	0.3	0.3	0
Urco-Collachagua, 2022	Lima (2019-2020)	4,196	6,926	6,925	3,745	44	10	8	7	2	0	0.1	0.1	0
Santiago-Chavez, 2022	Lima (2016-2021)	24,558	49,118	61,291	48,287	21,193	94	190	235	142	61	0.4	0.4	0.3
Coyla-Mamani, 2023	San Martin (2019-2021)	4,728	4,018	4,018	4,018	3,324	8	7	7	6	1	0.1	0.2	0.03
	Total	**36,508**	**64,308**	**75,791**	**59,103**	**25,348**	**132**	**226**	**264**	**167**	**63**	**0.3**	**0.3**	**0.2**

Supplementary Table 5. Correction factors based in hospital-level blood bank data

Correction factor	Formula	Calculation	Value
HIV seropositivity in women (α_1)	$\frac{\text{Seropositive women proportion}}{\text{Seropositive donors proportion}}$	$\frac{333 / 125{,}324}{1{,}348 / 411{,}912}$	0.81
HIV seropositivity in 18-49 age group (α_2)	$\frac{\text{Seropositive aged 18-49 proportion}}{\text{Seropositive donors proportion}}$	$\frac{789 / 235{,}710}{852 / 261{,}058}$	1.03
HIV seropositivity in women of reproductive age (α_{HIV})	$\alpha_1 * \alpha_2$	0.81 * 1.03	0.83
Confirmatory HIV test (σ_{HIV}^)			0.33

^Based on CDC (21)

Supplementary Table 6. Parameters of BYM2 models (in percentage)

	Mean [95% CI]
Model (i) - HIV reactivity (all)	
β (Global intercept): National average	0.19 [0.16-0.22]
ϕ: Spatial component	18 [1-61]
Model (ii) – Confirmatory HIV reactivity (women of reproductive age)	
β (Global intercept): National average	0.17 [0.14-0.2]
ϕ: Spatial component	18 [1-61]

ϕ represents the proportion of total variance of the BYM2 model attributed to the spatially structured component

Supplementary Table 7. Demographic characteristics (means) by department (2015-2020)

	Total population	Density	Women of reproductive age 18-49 (#)	Women aged 15-49 currently pregnant (%)	Estimated pregnant women aged 18-49 (#)	Life births (#)	Breastfeeding (%)	Breastfeeding (months)
Coastal regions								
Ancash	1,148,158	32	260,280	3.3	8,676	19,676	99.3	21.8
Arequipa	1,411,246	22.3	345,910	2.5	8,763	23,748	99	20.9
Callao	1,078,295	7336.3	264,285	3.2	8,457	15,499	97.5	21.3
Ica	910,315	42.7	206,389	3.6	7,464	17,200	98.2	20.8
La Libertad	1,918,039	75.2	455,180	4.2	19,118	35,771	99.2	20.6
Lambayeque	1,259,299	88.5	298,643	3.6	10,801	24,814	98.4	21
Lima	10,100,000	289.2	2,605,407	3.1	79,465	175,748	98.4	21.7
Moquegua	184,659	11.7	40,964	3.3	1,331	2477	99.2	21.8
Piura	1,954,878	54.5	460,327	4	18,183	38,229	98.8	19.3
Tacna	350,464	21.8	87,062	3	2,525	5,387	99.2	21.5
Tumbes	238,675	51.1	51,942	4.4	2,285	4,555	98.8	19.4
Highland regions								
Apurímac	426,074	20.4	93,126	3.4	3,151	7,623	99.3	22.3
Ayacucho	656,164	15	142,346	3.3	4,745	12,430	98.9	21.8
Cajamarca	1,433,138	43	326,511	3.6	11,863	26,402	98.7	19.9
Cusco	1,310,374	18.2	300,666	3.2	9,571	24,493	99.3	20.5
Huancavelica	379,071	17.1	79,317	3.2	2,538	6,253	99.3	25.4
Huánuco	756,077	20.5	171,855	3.4	5,900	15,810	98.8	21.9
Junín	1,327,376	30	304,678	3.2	9,750	24,305	98.9	23.9
Pasco	271,413	10.7	60,225	3.2	1,897	5,292	98.9	22.9
Puno	1,235,448	17.2	288,225	2.9	8,310	19,477	99	22
Jungle regions								
Amazonas	417,708	10.6	91,258	4.7	4,320	9,633	99	18.9
Loreto	992,768	2.7	207,568	6.5	13,388	27,666	98.9	17.1
Madre de Dios	158,420	1.9	35,117	3.6	1,247	3,753	98.3	19.2
San Martin	858,201	16.7	184,519	4.1	7,627	18,621	99.1	16.7
Ucayali	551,216	5.4	120,135	4.6	5,526	16,835	99.2	17.9

Supplementary Table 8. HTLV-1 estimates (means) by department (2015-2020)

	HTLV-1/2 seroprevalence in blood banks (%)	Estimated HTLV-1 seroprevalence in women of reproductive age	Coefficient of variation (%)	Estimated number of women of reproductive age with HTLV-1	Estimated number of pregnant women with HTLV-1	Estimated HTLV-1 seroprevalence in pregnant women	Estimated number of newborns with HTLV-1 acquired in-utero	Estimated number of newborns with HTLV-1 acquired via breastfeeding
Coastal regions								
Ancash	0.4	1.1	12	2,972	99	0.7	2	25
Arequipa	0.5	1.4	20	4,673	118	0.7	3	28
Callao	1	2.3	24	6,190	204	1.8	5	49
Ica	0.9	2.3	2	4,786	173	1.3	4	41
La Libertad	0.4	1	15	4,514	190	0.7	5	45
Lambayeque	0.5	1.2	30	3,653	132	0.7	3	32
Lima	0.8	2	9	51,699	1,577	1.2	39	391
Moquegua	0.8	2.3	17	940	31	1.6	1	8
Piura	0.5	1.2	23	5,625	222	0.8	6	48
Tacna	0.7	1.9	10	1,641	48	1.2	1	12
Tumbes	0.2	0.6	31	291	13	0.4	0	3
Highland regions								
Apurímac	2	4.2	13	3,905	132	2.3	3	34
Ayacucho	1.1	2.4	26	3,499	117	1.3	3	29
Cajamarca	0.3	0.8	22	2,531	92	0.5	2	21
Cusco	0.8	2.2	9	6,466	206	1.1	5	48
Huancavelica	1	2.3	17	1,857	59	1.3	1	18
Huánuco	0.6	1.6	11	2,776	95	0.8	2	24
Junín	1.3	3.4	2	10,260	328	1.8	8	92
Pasco	0.9	2.2	27	1,296	41	1	1	11
Puno	0.5	1.3	11	3,770	109	0.7	3	28
Jungle regions								
Amazonas	0.2	0.7	21	593	28	0.4	1	6
Loreto	0.5	1	22	2,201	142	0.7	4	27
Madre de Dios	2.1	2.4	32	846	30	1.1	1	6
San Martin	0.4	1	15	1,942	80	0.6	2	15
Ucayali	0.6	1.5	25	1,822	84	0.7	2	17

Supplementary Table 9. HIV estimates (means) by department (2015-2020)

	HIV seroprevalence in blood banks (%)	Estimated HIV seroprevalence in women of reproductive age	Coefficient of variation (%)	Estimated number of women of reproductive age with HIV	Estimated number of pregnant women with HIV	Estimated HIV seroprevalence in pregnant women	Reported HIV cases in pregnant women	Reported HIV prevalence in pregnant women
Coastal regions								
Ancash	0.16	0.14	19	371	12	0.08	7	0.08
Arequipa	0.23	0.21	12	702	18	0.1	10	0.11
Callao	0.3	0.23	18	633	21	0.18	31	0.37
Ica	0.12	0.12	15	240	9	0.07	21	0.28
La Libertad	0.26	0.22	13	1,022	43	0.16	29	0.15
Lambayeque	0.29	0.23	19	718	26	0.14	18	0.17
Lima	0.25	0.22	8	5,741	175	0.13	217	0.27
Moquegua	0.1	0.1	8	40	1	0.07	2	0.15
Piura	0.22	0.2	14	933	37	0.13	18	0.1
Tacna	0.17	0.16	9	137	4	0.1	3	0.12
Tumbes	0.17	0.17	16	87	4	0.11	4	0.18
Highland regions								
Apurímac	0.12	0.15	33	134	5	0.08	1	0.03
Ayacucho	0.12	0.12	25	163	5	0.06	4	0.08
Cajamarca	0.09	0.1	21	330	12	0.06	4	0.03
Cusco	0.16	0.16	21	463	15	0.08	6	0.06
Huancavelica	0.09	0.15	37	118	4	0.08	1	0.04
Huánuco	0.24	0.21	14	364	12	0.11	6	0.1
Junín	0.2	0.17	14	526	17	0.09	8	0.08
Pasco	0.35	0.2	33	122	4	0.1	2	0.11
Puno	0.18	0.17	14	476	14	0.09	1	0.01
Jungle regions								
Amazonas	0.28	0.25	9	229	11	0.15	25	0.58
Loreto	0.45	0.18	34	373	24	0.12	59	0.44
Madre de Dios	1.19	0.17	36	60	2	0.08	8	0.64
San Martin	0.08	0.08	14	153	6	0.05	23	0.3
Ucayali	0.19	0.16	26	199	9	0.07	22	0.4

Supplementary Table 10. Comparison of HTLV-1 estimates with reported HIV cases (means) by department (2015-2020)

	Estimated seroprevalence of HTLV-1 in pregnant women (%)	Reported HIV prevalence in pregnant women (%)	HTLV-1 to HIV ratio
Coastal regions			
Ancash	0.7	0.08	9
Arequipa	0.7	0.11	6
Callao	1.8	0.37	5
Ica	1.3	0.28	5
La Libertad	0.7	0.15	5
Lambayeque	0.7	0.17	4
Lima	1.2	0.27	4
Moquegua	1.6	0.15	11
Piura	0.8	0.1	8
Tacna	1.2	0.12	10
Tumbes	0.4	0.18	2
Highland regions			
Apurímac	2.3	0.03	77
Ayacucho	1.3	0.08	16
Cajamarca	0.5	0.03	17
Cusco	1.1	0.06	18
Huancavelica	1.3	0.04	33
Huánuco	0.8	0.1	8
Junín	1.8	0.08	23
Pasco	1	0.11	9
Puno	0.7	0.01	70
Jungle regions			
Amazonas	0.4	0.58	1
Loreto	0.7	0.44	2
Madre de Dios	1.1	0.64	2
San Martin	0.6	0.3	2
Ucayali	0.7	0.4	2