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Abstract

We investigate the impact of non-invasive anemia screening on treatment adherence in El Salvador. Anemia is a common childhood condition in low-income countries, due mainly to iron-deficiency, which if left untreated during critical development periods can have lasting health consequences. While effective treatments exist, adherence to treatment is often challenging, since the symptoms of mild to moderate anemia such as lack of energy or paleness can be easily overlooked. We test whether making anemia risks salient through screening during child-well visits can improve treatment adherence, using a cluster-randomized trial in high-poverty areas in El Salvador. Preliminary results indicate that screening enhances treatment adherence and there is suggestive evidence of a reduction of anemia among children 6 to 23 months old. Our results highlight the potential of screening in making anemia risks salient and motivating caregivers to follow treatment plans.

Keywords: Anemia, treatment adherence, salience, child health
JEL codes: I12, D91, J18

I. Introduction

Anemia is a condition that affects 45 percent of children under 5 years of age in middle and low-income countries (WHO, 2016). In El Salvador in 2017 one in every two children aged 6 to 23 months in municipalities with higher poverty rates suffered from anemia. If this condition is not treated, it can reduce cognitive abilities, increase the risk of infections, and in the long-term cause permanent losses in productive capacity (Hass & Brownlie, 2001; Horton & Ross, 2003). Anemia can be caused by iron deficiency, the presence of certain infectious diseases, malaria, or even genetic factors. However, according to the WHO, iron-deficiency anemia is the most common globally, and it is estimated half of all anemia cases are due to iron-deficiency (Ezzati et al 2014). The most common causes of iron-deficiency anemia include inadequate dietary iron intake, poor utilization of iron during chronic or inflammatory diseases, excessive iron loss, or an inability to absorb iron into the blood. In most cases, iron-deficiency anemia is preventable and reversible with iron supplementation. In poverty conditions, iron-deficiency anemia is widespread, especially due to a reduced intake of easily absorbable iron-rich foods, such as those of animal origin. This is accentuated during critical periods of life, like between the ages of 6 and 23 months, where iron demands are high for children's proper physical and cognitive development as they transition from breastfeeding to solid foods.

Treatments have been developed that have proven to be cost-effective for treating and preventing iron-deficiency anemia, such as iron supplementation with ferrous sulfate or with micronutrient powders (De-Regil et al, 2011; WHO, 2016b). Both are considered effective in treating anemia, but ferrous sulfate tends to have problems with adherence since it has a strong taste and it has some unpleasant side-effects such as staining teeth. In micronutrient powders, the iron in this treatment is microencapsulated to mask the taste.

In El Salvador, the supplementation with micronutrient powders was introduced in 2014 into care standards (MOH 2014). This was done within the context of the Mesoamerica Health Initiative (SMI), a public-private partnership aiming to reduce inequities in maternal and child health services in the region. In El Salvador, SMI works with the Ministry of Health (MoH) in 14 of the municipalities with the highest poverty levels, improving the coverage and quality of public health services provided by the Ministry. SMI is divided into three stages in El Salvador, and in conjunction with the MoH, goals are set for each stage, which are externally and rigorously verified by the Institute of Health Metrics and Evaluation (IHME) through household surveys and medical record reviews. In El Salvador, SMI aimed to reduce the prevalence of anemia in children aged 6 to 23 months by 5 percentage points in the prioritized municipalities for the third operation, i.e., by the end of 2022. Therefore, since the first stage of SMI in the country, which began in 2013, work has been done with the MoH to introduce micronutrient powders into the country's guidelines, distribute them, and develop a strategy to increase adherence to treatment, as achieving this could reduce iron-deficiency anemia in these contexts.

The MoH and SMI worked on designing an intervention to distribute micronutrients and monitor treatment adherence. This involves distributing micronutrient powders through child health checks for children aged 6 to 23 months in the Community Health Teams (Ecos F), who provide primary care services in the country, mainly in the most vulnerable areas. Micronutrients are prescribed during child health checks, provided free of charge at Ecos F pharmacies, and promoters follow up on adherence with mothers or caregivers through home visits. During the visits, promoters offer advice on preparing micronutrients, nutrition, and also capture the amount of micronutrients consumed by the child as reported by the mother. Mothers receive a calendar to track the established dosage by MoH guidelines, which is 60 daily packets followed by 120 days of rest every 6 months. Furthermore, educational materials were created, and several social marketing strategies were implemented to promote micronutrient powders in the targeted communities. With this intervention, significant progress was made; 82 percent of mothers of children aged 6 to 23 months received the full dose of micronutrients every 6 months, the same percentage was visited by promoters to discuss nutrition during the same period and began treatment, i.e., they gave it to their children for at least one day. However, only 24 percent reported full adherence to the treatment, meaning they gave it for at least 60 days over the past 6 months.

In clinical studies, adherence to micronutrient powders is variable but generally acceptable (Barros et al, 2016). However, when given on a larger programmatic scale, it becomes a much greater challenge (Rah et al, 2012; Vossenaar et al 2017), so El Salvador's experience is similar to other countries that have implemented micronutrients on a large scale. Reasons for low adherence to micronutrients are varied, but one of the most influential factors in the literature is the positive changes caregivers perceive in their children with micronutrients (Tumilowicz et al 2017).

In El Salvador, qualitative work was conducted in the context of SMI to identify the main barriers to adherence. It was found that, although the treatment is easy to implement, it represents a small daily effort that increases when children start resisting. More importantly, the benefits of treatment are unclear to parents both in the short and long term. This becomes even more crucial in a poverty context, where most children have anemia, and it's challenging to perceive if they suffer from it or its consequences if many children in the community have the same condition. On the other hand, the symptoms of mild or moderate anemia are hard to notice.

In public health terms, anemia screening usually isn't done in high-poverty populations because a large percentage of children either have it or are at risk of having it, so the usual recommendation is to give everyone preventive treatment. However, this rationale doesn't consider the effect that performing such screening can have on the mother or caregiver by providing objective information about the children's health condition. That is, hemoglobin measurement can make the presence of anemia visible, the effect of iron-supplementation on the disease, and therefore influence adherence to treatment. The most common technology for anemia screening at care points is the Hemocue, which uses a capillary blood sample. However, more recent technology allows obtaining a hemoglobin measurement through a pulse oximeter without needing a blood drop at a lower cost (Shamah Levy et al, 2017).

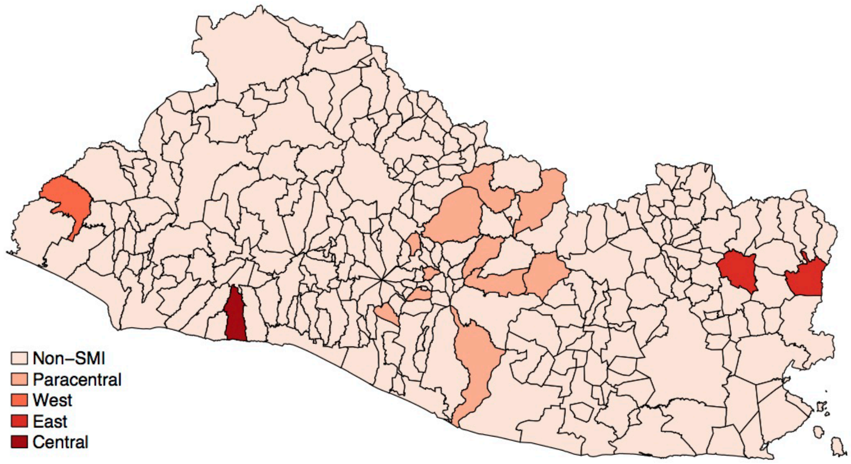
In this context, the aim of this study is to evaluate whether the introduction of non-invasive anemia screening in the context of child health checks currently offered by the MoH has an effect on adherence to iron-supplementation and ultimately anemia. The evaluation is operational in the sense that it is framed within the services and interventions that the MOH currently provides and seeks to understand whether the introduction of anemia screening is an effective intervention that can be easily scaled up.

To estimate the effect of screening on treatment adherence, a clustered randomized experimental evaluation was conducted in the 14 municipalities in which SMI operates. This involved randomly assigning primary health centers in these municipalities to two groups: those that introduce non-invasive anemia screening (intervention group) and those that continue with the current approach (control group). The non-invasive screening was performed by the primary care center's personnel during child well-visits using Masimo's Rad-67 which uses a sensor similar to a pulse oximeter that produces point estimates of hemoglobin. The screening with this device was introduced as an additional activity within the set of guidelines that primary health units use to evaluate the child's health during well-visit. Prior to the introduction of this technology, anemia was assessed clinically using mainly palmar pallor. This was the approach used by the control group. This report describes the preliminary results of the impact evaluation.

2. Study Population

The primary care units eligible for the study are the 75 within the 14 municipalities focused on by the Salud Mesoamerica Initiative (SMI). These municipalities collectively are among the 20 percent of municipalities with the highest poverty rates in the country. Table 1 contains the total number of primary care units per municipality in the targeted area of SMI. Within the units selected randomly into the treatment group, non-invasive anemia screening was performed among children age 12 to 59 months old. In total, it is estimated that that around 27,000 children less than five live within the 14 SMI targeted municipalities.

Table 1. Primary care units in SMI targeted municipalities



Region	Health district	Municipality	Primary Care Units Rural	Urban	Total
Central	La Libertad	Chiltiupán	2	1	3
West	Ahuachapán	Tacuba	9	1	10
East	La Unión	El Sauce	2	1	3
East	Morazán	Sociedad	3	1	4
Paracentral	Cabañas	Ilobasco	12	1	13
Paracentral	Cabañas	Sensuntepeque	7	2	9
Paracentral	Cuscatlán	Monte San Juan	2	1	3
Paracentral	Cuscatlán	San Cristóbal	2	1	3
Paracentral	La Paz	San Antonio Masahuat	1	1	2
Paracentral	La Paz	Santa María Ostuma	2	1	3
Paracentral	San Vicente	Apastepeque	6	1	7
Paracentral	San Vicente	San Esteban Catarina	1	1	2
Paracentral	San Vicente	San Ildefonso	2	1	3
Paracentral	San Vicente	Tecoluca	7	3	10
		Total	**58**	**17**	**75**

Notes: The map contains the municipalities of El Salvador, and those focused on by the SMI are marked in a darker color according to their region. The health districts refer to SIBASIs which are the Basic Systems of Integral Health and manage a set of primary care units for a group of municipalities. The health districts are independent, but all depend on the central level.

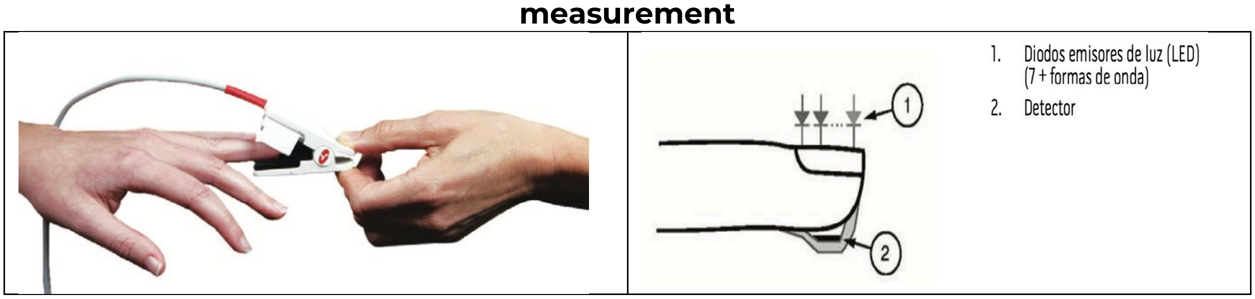
3. Intervention

The intervention involves introducing non-invasive anemia screening for children aged 12 to 59 months during child-well visits at primary care facilities. Prior to the intervention routine anemia diagnosis at this level of care was clinically done through palmar pallor. Even though there is evidence that palmar pallor is effective in detecting cases of severe anemia, it is not for mild or moderate anemia cases (Dusch et al 1999). The introduction of non-invasive anemia screening in this context is to test whether making anemia more salient for caregivers through the screening motivates them to have better adherence to treatment and whether health personnel provide more focused and effective follow-up and counseling to children who have anemia. The intervention was designed jointly with the MoH with support from experts in nutrition.

3.1 Anemia screening technology

In the intervention anemia screening was introduced in the selected primary care units using the Masimo Rad-67 pulse oximeter, which provides spot measurements of total hemoglobin. This device performs measurements of total hemoglobin, oxygen saturation, heart rate, among others, through a sensor placed on the tip of the fingers or toes, so it is considered non-invasive as it does not require capillary blood samples for measurement (see Figure 1). The sensor is universal and can be used in patients weighing 3 kilograms or more in both clinical and non-clinical settings. The sensor uses light-emitting diodes that pass through the tip of a finger or toe to a detector diode that captures changes in light absorption during the blood's pulsatile cycle. The information collected by the sensor is used by algorithms to calculate spot measurements of oxygen saturation and hemoglobin, among others. The stated accuracy of this technology for measuring hemoglobin is +/- 1 g/dL compared to reference values in a range between 8 g/dL and 17 g/dL.[1]

Figure 1. Illustration of the placement of the Rad-67 sensor for hemoglobin measurement



In recent studies, the use of non-invasive hemoglobin measurement technology has been compared with commonly used methods such as Hemocue, which requires a capillary blood sample through a finger prick, and with the gold standard of laboratory measures obtained through a venous blood sample. The studies indicate that, both in clinical contexts and epidemiological studies, Hemocue and Pronto have very similar

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[1] This is the stated accuracy in the device's manual.

performances compared to the gold standard. Both tend to underestimate hemoglobin levels and therefore overestimate the prevalence of anemia. However, these differences are minor, as for both cases they have an average absolute difference of less than 1 g/dL compared to the gold standard (Parker et al, 2018; Shamah Levy et al, 2017).

3.Anemia screening during child well-visits

Non-invasive anemia screening with the Rad-67 was introduced into well-child visits in primary care units of the treatment group. During these visits, where the child's general health status, danger signs, and growth and development are assessed, hemoglobin measurement with the Rad-67 was incorporated to determine if the child has anemia. Current guidelines in the country recommend assessing if a child has anemia during child well-visits, but they do so with palmar pallor and clinically. The non-invasive screening was introduced as an additional aid for health workers and more importantly to provide clear information about the health status of children to caregivers.

Measurement with the Rad-67 device takes approximately 30 seconds, so it is not expected to be an additional time burden for health personnel. The Rad-67 measurement was performed by the doctor or nurse conducting the child-well visit. The screening was scheduled every 6 months between 12 and 24 months and once a year for children between 25 and 60 months of age. The summary of this frequency is found in Table 2.

Table 2. Frequency of Non-Invasive Anemia Screening during child-well visits

Children's age	9-12 months	18 months	24 months	25-60 months
Child-well visits schedule	10 &12 months	18 months	24 months	Twice per year
Anemia screening	12 months	18 months	24 months	Once per year

The intervention takes advantage of a visit to a service that primary care units already offer routinely, and there is already a culture in the population of attending these well-visits. Mothers and caregivers are used to having anthropometric measurements such as height and weight taken during these visits to assess growth and development, and in the context of these checks, the child's nutritional status is evaluated. Non-invasive hemoglobin measurement in this context will provide clear information to mothers about whether their children have any degree of anemia, in addition to providing them with appropriate counseling and treatment depending on the severity of the anemia. In the study area, since 2011, the MoH has been distributing various treatments for preventing or treating anemia, such as micronutrient powders and ferrous sulfate, free of charge (MOH, 2014).

The non-invasive hemoglobin measurement allowed children to be classified according to the presence or severity of the disease as established in the reference values currently used by the MoH and suggested by the WHO (see Table 3).

The specific treatment and follow-up activities of children with and without anemia were determined in conjunction with the MoH, existing guidelines for child well-visits, and nutrition experts and are summarized in Table 4. In all cases, in addition to the screening and use of the device, personnel were trained in explaining patients what anemia is, their consequences for health and options for treatment and prevention. To explain the different cutoffs of anemia a visual aid was provided to personnel of treated facilities (see Figure 2).

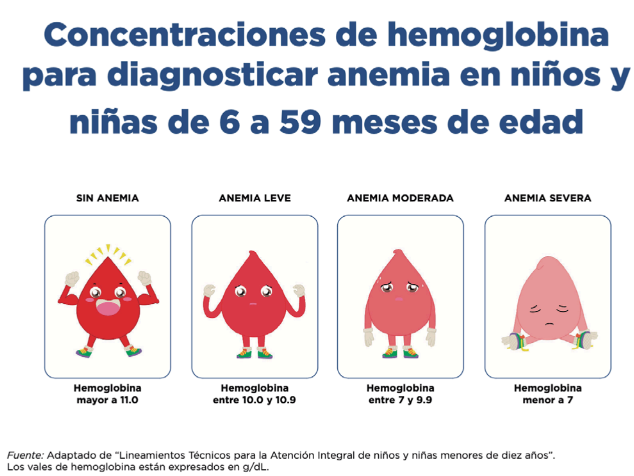
The coordinators of each primary care unit selected into the treatment group participated in a one-day training, where they were trained on the functioning of the Rad-67, best practices to conduct the measurements in children, the screening schedule, the course of action based on the result of the test, and record keeping practices for the new information. The training was conducted in March 2022 and the intervention started in April of that year.

Table 3. Course of action based on the result of anemia screening.

Screening results	**Key actions**
No anemia (>=11 g/dL)	• Preventive iron supplementation • Schedule next well-visit
Anemia (<11 g/dL)	
Mild (10-10.9 g/dL)	• Therapeutic iron supplementation for 3 months • 1 and 3 month follow-ups to assess progress • If anemia persists after 3 months referral to pediatrician
Moderate (7.0-9.9 g/dL)	• Therapeutic iron supplementation for 3 months • Referral to pediatrician
Severe (<7.0 g/dL)	• Referral to hospital

Notes: The table summarizes the course of action based on the result of the non-invasive anemia screening. This course of action is overall the same that is currently in the MoH guidelines, except that in places with no screening available, the child is evaluated with palmar pallor and clinically and a venous blood sample test is requested if the physician or nurse wants to confirm the diagnosis or rule out other causes of anemia.

Figure 2. Illustration used by health personnel to explain anemia and the hemoglobin measurement results to caregivers



4. Experimental Design

To estimate the effect of non-invasive screening on adherence to anemia treatment, a cluster-randomized experimental evaluation was designed. That is, 38 primary care units from the area of influence of SMI were randomly assigned to a treatment group and the remaining 37 units to a control group. We used block randomization, i.e. units were grouped into blocks and randomization was conducted within each block, to increase statistical power (List, Sadoff & Wagner, 2010).

To form the blocks for randomization, first, the primary care units were divided into rural and urban. This is because the population characteristics and the way the primary care units operate differ between both types of units. The 16 urban units were grouped into a single block. The remaining 58 rural units were grouped by health district and by the most recent average value of adherence to iron-supplementation in children aged 6 to 23 months according to a Household Survey conducted in SMI targeted municipalities during 2017.[2] This grouping was done to increase the likelihood of balance in the main pre-treatment variable of interest. Three blocks of rural units were formed according to this methodology. Table A1 in the Appendix summarizes the characteristics of each block.

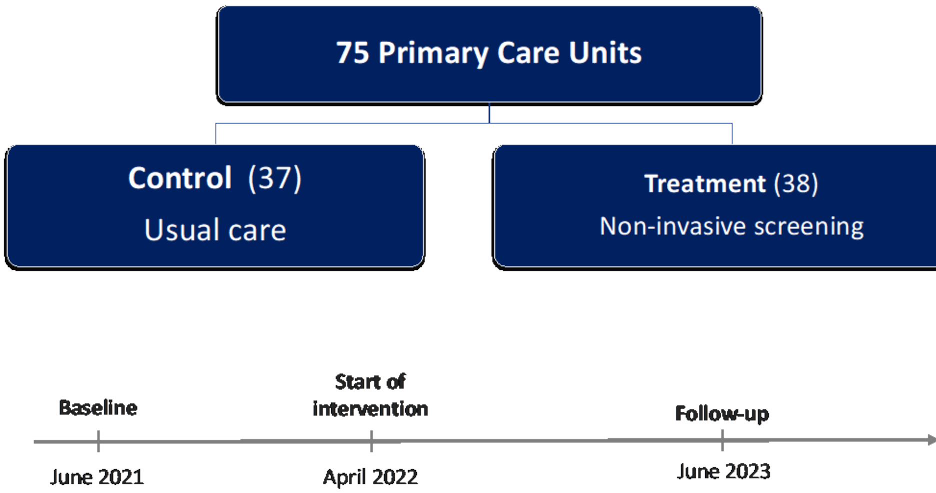
The random assignment to treatment and control groups for each unit was done publicly with representatives of the participating health districts. During the random draw, half of the primary care units in each block were assigned to treatment and the rest to the control group.

The primary care units assigned to the treatment group introduced non-invasive anemia screening during well-child visits for children. The coordinators of each unit were invited to the one-day training related to the intervention in the previous section. An important part of this training aside from the use of the Rad-67 was on key messages to convey to caregivers about the implications of screening, anemia, and available treatments. Once the primary care units in the treatment group were trained, the MoH included in its regular supervision processes the follow-up of key activities related to anemia screening in these teams.

The facilities assigned to the control group continued to operate regularly with existing strategies for the prevention and treatment of anemia, i.e. screening for anemia with clinical signs like palmar pallor and providing nutritional counselling and prescribing preventive iron supplementation. The experimental assignment has been maintained since the start of the intervention in April 2022. Data was collected at baseline in June 2021 and a follow-up data collection was conducted in June 2023 to assess the effect of the intervention. A summary of the evaluation design is found in Figure 3.

[2] This data was used since it was the most recent at the time of random assignment which occurred in early 2021. It is representative of 14 SMI targeted municipalities which constitute the population of the study.

Figure 3. Evaluation design



The clustered experimental design allows to identify the effect of incorporating non-invasive anemia screening on the variables of interest, mainly adherence to iron-supplementation treatment, and ultimately on the prevalence of anemia. This answers a relevant question for health systems in the region and globally about whether incorporating non-invasive anemia measurement adds value to routine activities for the prevention and treatment of anemia.

The estimation of the treatment effect on the variables of interest based on the experimental design can be done using equation (1), through ordinary least squares, and standard errors clustered at the primary care facility level.

(1) $Y_{ijbt} = \delta T_{jb} + \varphi_b + \varepsilon_{ijbt}$

Where Y_{ijbt} represents the variable of interest at the individual level *i*, in the area of influence of primary care unit *j*, of block *b*, at time *t*; T_{jb} is a dichotomous variable, equal to 1 if facility *j*, in block *b*, is assigned to treatment and 0 otherwise; φ_b are fixed effects at the block level; and ε_{ijbt} is an error term. The parameter of interest in equation (1) is δ, which captures the effect of the intention to treat (ITT) under standard identification assumptions, that is treatment assignment is independent of the outcome of interest. The ex-ante power calculations for the evaluation are included in Appendix Table A2.

In other words, the average difference between the variables of interest for the treatment and control groups, regardless of whether they received the non-invasive anemia screening or not. This ITT estimate is relevant in terms of public policy because it is the one that would indicate the population changes that would be expected by the introduction of the screening during child-well visits.

While equation (1) is the model dictated by the design of the experiment we use an alternative specification to account for baseline imbalances in key variables of interested which are discussed in Section 6. Our alternative specification uses difference-in-differences, which while conservative in terms of precision, provides unbiased estimates of the ITT, as it will account for the baseline imbalance and any time-invariant unobserved characteristics. Equation (2) presents the DID specification, which is our preferred model for the ITT, which in addition to sociodemographic controls (X_{ijbt}), includes facility fixed effects (γ_j). In this specification, D_{jbt} represent the interaction of treatment assignment and the post period and $Post_t$ is an indicator of the post-treatment period. We use clustered standard errors at the facility level for this specification as well.

(2) $Y_{ijbt} = \delta D_{jbt} + \propto Post_t + \varphi_b + \beta X_{ijbt} + \gamma_j + \varepsilon_{ijbt}$

We run our main specification on children aged 6 to 59 months old. While the first screening for anemia occurred at 12 months of age, children 6 to 11 months are included since in this age range, they start being prescribed preventive iron-supplementation and health workers provide information about the subsequent well-visits and when screening will occur. We perform heterogeneity analysis by age for children 6 to 23 months old and children 24 to 59 months old, since anemia prevalence decreases with age as children transition from breastfeeding to solid foods.

5. Data

To obtain data on the variables of interest, as well as the intervention implementation three different instruments were used a household survey, a medical record review and a health unit survey. These instruments were collected in the 75 primary care units included in the study. The baseline was conducted in June 2021 and follow-up in June 2023. Due to budget considerations, by design the baseline data had a smaller sample size than follow-up. Table 4 presents the summary of the sample sizes for baseline and follow-up.

5.1 Data collection instruments

Household survey: The household survey was applied to a random sample of caregivers of children aged 6 to 59 months old in the catchment area of primary care units. The survey is the main source of information to capture adherence to treatment and anemia prevalence. In addition, it captures information regarding knowledge, acceptability and consumption of micronutrients and ferrous sulfate (common forms of iron supplementation used in the country), diet consumed in previous day, exposure to anemia screening, and a non-invasive hemoglobin measure was captured for children 6 to 59 months old using the Rad-67. In addition, the survey contains several behavioral measures to explore whether they are associated with treatment adherence such as present-bias, overconfidence, locus of control, and aspirations for children.

Medical record review: The medical record review captures information on health records of children age 12 to 59 months old in the primary units of the sample. The information from this instrument can be used mostly to understand the implementation of the intervention in each unit as registered in the records. It captures information regarding visits to preventive care and measurements of hemoglobin during those visits as well as any anemia treatment indications in the record.

Health unit survey. This survey was applied to the coordinator of each primary care unit. It captures information on available inputs for the childcare (those related to anemia treatment). It also inquiries about activities related to the anemia screening and the experience of health personnel with it.

Table 4. Sample size at baseline and follow-up

	Baseline	**Follow-up**
Household Survey		
Children 6 to 59 months old	650	1562
Medical Records		
Children 12 to 59 months old	1032	2103
Facility Surveys	72	73

5.2 Variables of Interest

The primary variable of interest for the study is adherence to treatment for anemia, as this will help answer whether non-invasive screening aids in ensuring caregivers persist throughout the treatment. To treat iron deficiency anemia, however, there are several options. The main ones in the study area are micronutrient powders and ferrous sulfate. Therefore, the main variable of interest is the percentage of children who fully adhered to the treatment in the six months prior to the interview date (i.e., 60 days in the previous six months for micronutrient powders or daily in the case of ferrous sulfate).

The secondary variable of interest is the prevalence of anemia as measured from the household survey using the Rad-67. Following Shamah Levy et al (2017) we obtain three consecutive measurements for children 6 to 59 months old. The non-invasive screening requires adequate blood perfusion at the site of measurement to obtain a reliable measurement and technical personnel form Massimo recommended to have a site for measurement with a perfusion index of one or more. For this reason, to measure anemia we use the average hemoglobin measures with a perfusion index greater than one. Following the MoH guidelines and WHO (2011) we define anemia as those children with hemoglobin levels below 11g/dL (see Table 3). No adjustment for altitude is done since the municipalities of interest are all below 1000 meters above sea level.

Although there is little statistical power to observe a change in anemia, this variable will be analyzed to see if at least the changes are moving in the expected direction, that is towards a reduction in anemia. The main source of information for the primary and secondary variables is the household survey since it is representative of the population of interest.

6. Results

6. 1 Balance

Table 5 presents a balance test for the key variables of interest in the analysis. Prior to the intervention, there was a relatively large compliance with well-visits as about 82 percent of children attended at least one in the previous six months. As expected, there was little use of anemia screening, as only 5 percent of caregivers declared to have one for their children. Only about 1 in 5 children adhered fully to iron-supplementation with either micronutrients or ferrous sulfate. The surprising finding is that anemia prevalence at baseline is much lower than expected at only 4 percent overall, using the Rad-67. Previous estimates shown in Appendix A3, indicated that anemia prevalence among children 6 to 59 months old in our study area was about 37 percent in 2017, which was the available data at the time of designing the intervention. These latter estimates were obtained using capillary blood samples and Hemocue. Given that the difference is very large we will discuss in more detail possible reasons behind this in section 6.4.

Overall, while there is balance in most variables shown in Table 5, there are imbalances in some key variables of interest, despite the randomization. There was a larger prevalence of anemia in the treatment group of about 3 percentage points, that was statistically significant at the 10% level. In addition, children in the treatment group were less likely to have consumed iron-rich foods by 4 percentage points. Given these imbalances we present the intent-to-treat estimates using difference-in-differences as discussed in Section 4.

Table 5. Baseline balance of key variables of interest

	Total		Treatment		Control		Difference (T-C)	
	N	Mean	N	Mean	N	Mean	Diif	p-value
Child well-visits in the last 6 months								
Attended at least one child-well visit	653	0.82	362	0.8	291	0.85	-0.04	[0.34]
Anemia screening in the last 6 months								
Had a non-invasive anemia test	651	0.05	360	0.04	291	0.05	-0.02	[0.62]
Supplementation in the last 6 months								
Full adherence to iron supplementation	650	0.19	361	0.18	289	0.21	-0.03	[0.16]
Feeding practices in the previous day								
Consumed Iron-rich foods	655	0.91	364	0.89	291	0.93	-0.04*	[0.06]
Hemoglobin and anemia at time of survey								
Obtained a at least 1 hemoglobin measurement	653	0.66	362	0.64	291	0.69	-0.05	[0.27]
Average hemoglobin	428	12.77	228	12.67	200	12.89	-0.25	[0.45]
Anemia prevalence	428	0.04	228	0.05	200	0.02	0.03*	[0.08]

Notes: Difference obtained using equation (1), that is considering the block randomization. The p-value is obtained using clustered standard errors at the primary care unit level. *p<0.1, **p<0.05, ***p<0.01

6.2 Intermediate outcomes

Since the intervention consisted on introducing non-invasive anemia screening during child well-visits, we first see if these two variables were influenced. As shown in Table 6, there is no effect of the intervention on attending a child well-visit. This is to be expected as a result of the intervention, although if caregivers valued the information provided by the non-invasive anemia screening, they could have increased their attendance. It seems that this could have been the case for children aged 6 to 23 months old, as they increase their attendance by about 7 percentage points (an 8 percent increase from baseline), but we do not have power to detect that. More importantly, the intervention did have an effect on increasing the likelihood of children having a non-invasive anemia screening in the last six months of around 21 percentage points. This effect was relatively similar between age-groups.

6.3 Treatment adherence

The aim of this study is to understand whether anemia screening makes anemia more salient and hence influences caregiver behavior regarding adherence to iron-supplementation as well as feeding practices. Table 7 shows that the intervention increased adherence to iron supplementation by 7 percentage points (or a 38% increase from baseline), although this effect is only significant at the 10 percent level. While there are no significant effects when we estimate effects by age group, it does seem that the magnitude of effects are larger among the 6 to 23 months old age group. In contrast with the effect on adherence to treatment we do not find any effect on consumption of iron-rich foods in the previous day.

Table 6. Effect on child well visits and anemia screening

	Child's age					
	All children		6 to 23 months old		24 to 59 months old	
	Baseline Mean (1)	ITT (2)	Baseline Mean (3)	ITT (4)	Baseline Mean (5)	ITT (6)
Child well-visits in the last 6 months						
Attended a child-well visit	0.80	0.03	0.89	0.07	0.76	-0.03
		(0.0290)		(0.0493)		(0.0471)
Anemia screening in the last 6 months						
Had a non-invasive anemia test	0.04	0.21***	0.03	0.21***	0.05	0.22***
		(0.0403)		(0.0459)		(0.0512)
Observations		2208		881		1238

Notes: ITT estimates are obtained using differences-in-differences as in Equation (2) and controlling for household assets, women's education, child's age, and sex, as well as block effects. Standard errors are clustered at the primary unit level. *p<0.1, **p<0.05, ***p<0.01

Table 7. Effect on iron-supplementation and feeding practices

	Child's age					
	All children		6 to 23 months old		24 to 59 months old	
	Baseline Mean (1)	Effect (2)	Baseline Mean (3)	Effect (4)	Baseline Mean (5)	Effect (6)
	Panel A. Intent-to-Treat					
Supplementation in the last 6 months						
Full adherence to iron supplementation	0.18	0.07*	0.27	0.10	0.12	0.03
		(0.0380)		(0.0771)		(0.0397)
Feeding practices in the previous day						
Consumed Iron-rich foods	0.89	0.02	0.92	0.05	0.97	-0.01
		(0.0209)		(0.0364)		(0.0205)
Observations		2199		875		1234

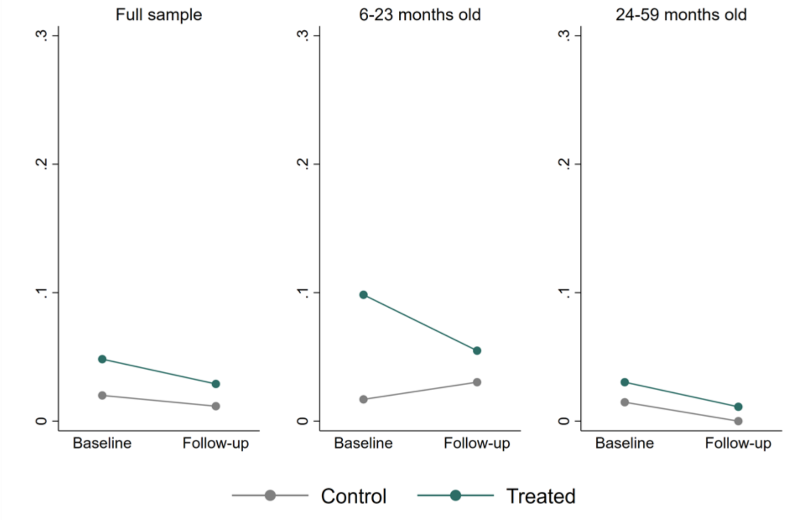
Notes: ITT estimates are obtained using differences-in-differences as in Equation (2) and controlling for household assets, women's education, child's age, and sex, as well as block effects. Standard errors are clustered at the primary unit level. *p<0.1, **p<0.05, ***p<0.01

6.4 Anemia prevalence

Finally, we analyze whether the intervention had an effect on anemia prevalence. Figure 4, presents the prevalence of anemia in both treatment and control groups at baseline and follow-up. Overall while it seems that anemia was reduced in both treatment and control groups it seems to have been reduced slightly faster in the treatment group. Among 6 to 23 months old, it is clear there was a sharp reduction in anemia among the treated group, and a slight increase among the control group.

Among children 24 to 59 months old, anemia prevalence seems to have decreased but at the same rate in both groups.

Figure 4. Anemia prevalence by age group



Notes: Anemia prevalence obtained in household surveys using Rad-67 which is a non-invasive technology. Each child in the sample had 3 consecutive measurements, the prevalence is estimated using the average of the highest quality measurements, which are those with a perfusion greater than 1.

This is confirmed in Table 8, where we present the ITT of anemia prevalence. The estimate goes in the expected direction, as it is negative, and it is economically significant, although we do not have enough power to detect it. Overall, anemia decreased by 2 percentage points (or a 40 percent decline from baseline) among all children, but 8 percentage points among children 6 to 23 months old (an 80 percent decrease from baseline, which is substantial). It is important to note, that a valid hemoglobin measurement could not be obtained for a relatively large share of children (about 36 percent at baseline), since the Rad-67 is sensitive to movement, and it was also challenging to obtain an adequate perfusion on younger children. However, these issues were common for children across treatment and control groups.

Table 8. Effect on anemia prevalence

	Child's age					
	All children		6 to 23 months old		24 to 59 months old	
	Baseline Mean	Intent-to-treat	Baseline Mean	Intent-to-treat	Baseline Mean	Intent-to-treat
	(1)	(2)	(3)	(4)	(5)	(6)
Hemoglobin measurement						
Obtained a at least 1 measurement	0.64	0.04	0.47	0.06	0.88	0.01
		(0.0368)		(0.0753)		(0.0358)
Observations		2181		879		1240
Hemoglobin and anemia						
Average hemoglobin	12.67	0.43	12.89	-0.35	12.58	0.71*
		(0.3107)		(0.5372)		(0.4090)
Anemia prevalence	0.05	-0.02	0.10	-0.08	0.03	-0.01
		(0.0186)		(0.0539)		(0.0173)
Observations		1872		693		1172

Notes: ITT estimates are obtained using differences-in-differences and controlling for household assets, women's education, child's age, and sex, as well as block effects. Standard errors are clustered at the primary unit level. The IV estimates are obtained using two-staged least squares. *p<0.1, **p<0.05, ***p<0.01

A key point of discussion is why anemia prevalence is much lower than that found in previous measurements conducted prior to the baseline in the targeted municipalities during 2017 (see Appendix A3). Previous studies of the non-invasive technology we used suggest that they might tend to overestimate anemia (Shamah Levy et al 2017; Parker et al 2018). The 2017 anemia prevalence was obtained using a single drop of capillary blood and Hemocue. While this is the most common method to obtain anemia prevalence in population studies, recent evidence suggests that it can be highly variable, with differences ranging up to 31 percentage points (Hruschka et al, 2020) when compared to venous blood samples. The causes of this variability are multiple, but they are most likely due to sources of the blood sample (capillary vs venous), technique to obtain the blood sample (i.e milking the finger), and even physiological differences depending on time of day, temperature or previous activity. A recent study in Mexico found that other techniques such as pooling multiple capillary blood drops or using venous blood could be more precise (De la Cruz-Góngora, 2022). For this reason, the most recent health and nutrition survey conducted in Mexico during 2022, used venous blood instead of single capillary drop as in previous surveys. In 2022 in Mexico anemia prevalence, was of 6.8% using venous blood among children age 1 to 4, while previous estimates using single drop where of around 23% (Mejía Rodriguez et al, 2023). While there is not as much evidence using the non-invasive technology for population studies, as for capillary blood sample and Hemocue, the recent literature suggest that the prevalence might have been lower than what had been previously estimated in the population of study.

An additional explanation of the lower prevalence of anemia in the population of study is that the prevalence of anemia did in fact was reduced from 2017. There is evidence of this as an additional household survey was conducted in the same 14 municipalities of interest during 2022 using Hemocue and the similar data collection methods as those during 2017 and the estimated prevalence among children 6 to 59 months old was of 13.5%, that is a reduction of about 24 percentage points relative to 2017 (see Appendix A3). However, it is not clear why such a sharp reduction occurred particularly after the pandemic, which caused important shocks to household consumption, employment, and food security (Durán, 2022).

In any case, given that we use the same technology, personnel, and training procedures to measure anemia in treatment and comparison groups, as long as the sources of error are common among these two groups, this might cancel out when estimating the differences in prevalence of anemia.

7. Conclusion

This study aimed to assess the effect of introducing non-invasive anemia screening during child well-visits to increase the saliency of anemia among caregivers and health workers and influence adherence to iron-supplementation protocols among children aged 6 to 59 months in selected high-poverty municipalities within El Salvador. The intervention's goal was to address the significant public health issue of anemia, which has been shown to have detrimental effects on children's cognitive and physical development if left untreated. The study was embedded within the broader efforts of the Salud Mesoamerica Initiative (SMI) and the Ministry of Health to mitigate maternal and child health disparities.

Our findings suggest the intervention was effective in increasing the adherence to iron supplementation by 7 percentage points (equating to a 38% increase from baseline). In addition, while the effect on anemia goes in the expected direction, with a large reduction particularly among children 6 to 23 months old, we have limited statistical power to conclusively determine the intervention's effect on reducing anemia prevalence.

These results suggest that while non-invasive anemia screening can potentially enhance adherence to iron supplementation further research is necessary to fully understand the intervention's efficacy and its scalability in high-risk populations. This is particularly the case since the anemia prevalence was much lower than previous studies showed in targeted areas for the intervention.

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9. Appendix

Table A1. Blocks of primary care units for random assignment

Block	Health District	External Monitoring Household Survey 2017	Primary Care Units	
		Iron-supplementation adherence among children 6 to 23 months old	Rural	Urban
Rural units				
1	La Libertad	17.0%	2	
1	Morazán	17.0%	3	
1	San Vicente	17.0%	16	
1	*Total Block 1*		*21*	
2	Cabañas	21.0%	19	
2	La Paz	24.0%	3	
2	*Total Block 2*		*22*	
3	Ahuachapán	30.0%	9	
3	Cuscatlán	50.0%	2	
3	La Unión	50.0%	4	
3	*Total Block 3*		*15*	
Urban units				
4	*Total Block 4*			*16*

Notes: The rural blocks are organized by the average value of adherence to iron-supplementation in children aged 6 to 23 months as of 2017.

Table A2. Ex-ante power calculations for the main variables of interest

	Minimum detectable effect		
Variable of interest	**Iron-supplementation adherence**		**Anemia prevalence**
Source	External Monitoring Household Survey		Household Survey IHME
Period	2015	2017	2018
Prevalence	**0.15**	**0.24**	**0.47**
Intracluster correlation	0.11264	0.11264	0.07987
Tamaño del cluster			
5	0.146	0.164	0.166
10	0.119	0.135	0.134
15	0.109	0.124	0.122
20	0.104	0.118	0.115
25	0.100	0.115	0.111
30	0.098	0.112	0.108

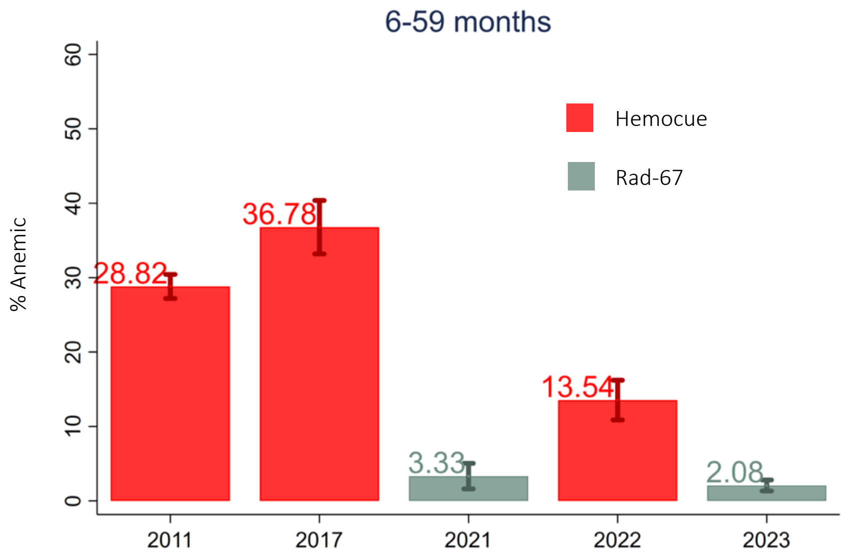
Notes: Calculations are based on a statistical power of 80%, a confidence level of 95%, 37 clusters in treatment and 37 in control, and the values of the variable of interest described in the table. The adherence data come from the Household Survey of the External Monitoring of the SMI in El Salvador. The anemia data come from the Household Survey of the Evaluation of the Second Operation of the SMI in El Salvador, conducted by IHME.

To estimate the statistical power of the evaluation, data from the 2015 and 2017 External Monitoring Survey of SMI in El Salvador were used as a reference. This survey captures information from the 75 primary care units in the study area on adherence to iron-supplementation among children aged 6 to 23 months. Various scenarios for the value of this indicator were considered, based on the value observed in 2015 and the latest observed in 2017 in the household survey, i.e., 15% or 24%. The intra-cluster correlation was also estimated using External Monitoring data. Based on these data, with an 80% power, a 95% confidence level, 37 treatment and control clusters, and 25 observations per cluster, the study is estimated to have a minimum detectable effect of between 10.0 to 11.5 percentage points in treatment adherence.

On the other hand, the minimum detectable effect on anemia is estimated at 11.1 percentage points, considering a pre-treatment anemia prevalence of 47% and an intra-cluster correlation of 0.079. This data comes from the Housing Survey for the Evaluation of the Second Operation of SMI in El Salvador collected by IHME in 2017.

The power calculations are considered conservative, as they do not consider block randomization or the inclusion of controls in the estimates of the parameters of interest, which would increase the precision of the estimation.

Appendix A3. Prevalence of anemia over time in the 14 targeted municipalities among children aged 6 to 59 months old.



Notes: The figure presents the estimates of the prevalence of anemia according to several household surveys conducted over time in the 14 targeted municipalities. All surveys are representative of the population of these 14 municipalities. The bars in red represent the prevalence obtained from household surveys conducted by the Institute of Health Metrics and Evaluation using capillary blood samples and Hemocue. The gray bars represent the prevalence of anemia as obtained from the household surveys used for the evaluation of the non-invasive screening in El Salvador. The prevalence of anemia in these surveys is obtained using Massimo's Rad-67, which is non-invasive technology. The 95% confidence interval is presented for each prevalence.