Title

Utilization of a Binational Training Program to Investigate the Prevalence, Correlates, and Etiology of Anemia Among Women and Children in Rural Baja California, Mexico

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Utilization of a Binational Training Program to Investigate the Prevalence, Correlates, and Etiology of Anemia Among Women and Children in Rural Baja California, Mexico

A dissertation submitted in partial satisfaction of the requirements for the degree
Doctor of Philosophy

in

Public Health (Epidemiology)

by

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2015

The dissertation of Molly Ann Moor is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

Chair

University of California, San Diego

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2015

DEDICATION

To my family, friends, and colleagues who supported and encouraged me during the pursuit my doctoral degree.

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LIST OF ABBREVIATIONS

BC	Baja California (Mexico)
CBC	Complete Blood Count
CBPR	Community Based Participatory Research
Hb	Hemoglobin
HCT	Hematocrit
IDA	Iron Deficiency Anemia
MCHC	Mean Corpuscular Hemoglobin Concentration
MCV	Mean Corpuscular Volume
OR	Odds Ratio
RBC	Red Blood Cell
SPSS	Statistical Package for the Social Sciences
TIBC	Total Iron Binding Capacity
UIBC	Unsaturated Iron Binding Capacity
VIIDAI	(Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación/ Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research)
WHO	World Health Organization
YLD	Years Lived with Disability

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ABSTRACT OF THE DISSERTATION

Utilization of a Binational Training Program to Investigate the Prevalence, Correlates, and Etiology of Anemia Among Women and Children in Rural Baja California, Mexico

by

Molly Ann Moor

Doctor of Philosophy in Public Health (Epidemiology)

University of California, San Diego, 2015
San Diego State University, 2015

Professor Stephanie Brodine, Chair

Background: Anemia is a public health concern among Mexican women and children, particularly among those of low socioeconomic status and indigenous heritage. Conducting research among vulnerable populations requires a dependable, long-term relationship with community support and engagement. Thus, Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación [VIIDAI] (Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research), a partnership between universities, non-governmental organizations, and a rural Mexican community was utilized to investigate the prevalence, correlates, and etiology of anemia in a rural region of Baja California, Mexico.

Methods: In affiliation with VIIDAI, a series of cross-sectional studies were performed. Women (15-49 years) and their children (6-59 months) were invited to participate. Data collection occurred at three time points: 2004-2005 (Wave 1), 2011-2012 (Wave 2), and 2012 (Wave 3). In each wave, participants were randomly selected and completed a survey containing demographic, socioeconomic, health, and dietary characteristics and provided a capillary blood sample for anemia testing. A portable HemoCue was used to measure hemoglobin and diagnose anemia; peripheral blood smears were prepared for anemic participants. In Wave 3, venous blood was collected for laboratory testing that elucidated the etiology of anemia. Nutrition education, community health interventions, and clinical health evaluations were offered to residents following Wave 1 and continuing through Wave 3.

Results: Waves 1, 2, and 3, included 201, 146, and 118 women, and 99, 77, and 25 children, respectively. Prevalence of anemia decreased from 42.3% to 23.3% between Waves 1 and 2 in women ($p<0.001$), from 46.5% to 30.2% in children 24-59 months ($p=0.066$), and from 71.4% to 45.8% in children 6-23 months ($p=0.061$). In Wave 1, the consumption of foods that enhance iron absorption (e.g. leafy, green vegetables and fruits high in vitamin C) was protective against anemia ($p=0.043$). Vitamin supplementation was protective against anemia in Wave 3 (OR=0.12, 95% CI 0.02-0.94). In Wave 3, iron deficiency anemia was the primary etiology in 100% of children and 80.8% of women, followed by vitamin B-12 deficiency (11.5%) and combined iron and vitamin B-12 deficiency (7.7%).

Conclusions: Substantial reductions in anemia prevalence were observed. However, nutrition education and improved access to nourishing foods are essential to further reducing anemia prevalence.

INTRODUCTION

Anemia impacts over one billion people worldwide and is a major public health concern, particularly in developing countries. Chronic anemia negatively impacts health and quality of life through immunological, physical and cognitive impairment. The cumulative effects contribute to increased susceptibility to disease, and which may decrease work capacity and hinder economic growth. Thus, alleviating the global burden of anemia would lead to substantial improvements not only on an individual level, but also on a national and international scale.

Mexico has been working to combat anemia on a national level. Government programs have been developed to address the problem, and have been credited with decreasing anemia prevalence in the past few decades. However, anemia prevalence remains high among vulnerable populations including low socioeconomic households, individuals of indigenous heritage, and people residing in rural areas. Few studies have examined the prevalence of anemia in marginalized populations, specifically indigenous agricultural workers who possess many of these sociodemographic risk factors for anemia.

Conducting research among vulnerable populations requires a trusting relationship, a dedicated long-term commitment, along with community support and engagement. An existing partnership meeting these criteria was utilized to investigate the prevalence of anemia among a primarily indigenous population of women and children residing in rural, agricultural region of Mexico. The collaborative partnership, known as VIIDAI (Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación/ Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research) integrates universities, non-governmental organizations (NGOs), and an underserved predominately indigenous community in northern Baja California (BC), Mexico to address community health need while training clinical and public health students. VIIDAI utilizes a community-driven, integrative, multi-disciplinary approach to effectively investigate and address community health disparities. Thus, VIIDAI was an ideal platform to learn more about the burden of anemia in this rural Mexican community.

The specific objectives of this dissertation were threefold: 1) To describe the development of VIIDAI as a binational public health training program and illustrate how the collaboration of universities, NGOs, and community members creates a synergistic effect in conducting rapid health assessments, implementing intervention projects, and obtaining long-term outcome information, 2) To measure and compare the prevalence and correlates of anemia among women and children in a rural, Mexican *colonia* over a six year timespan and to determine if there were significant decreases in anemia prevalence following the implementation of community health interventions, and 3) To classify the etiology of anemia among women and children living in a rural Mexican community and identify the individual and community factors that contribute to anemia.

CHAPTER 1

Literature Review

Anemia

Anemia is a condition in which the body either lacks an adequate number of red blood cells (RBCs or erythrocytes) or has a low concentration of Hemoglobin (Hb), the iron-containing oxygen-transport metalloprotein in RBCs that carries oxygen from the lungs to the rest of the body. RBCs are replaced within the body every 120 days, and any disruption of this cycle will result in anemia if the body cannot regenerate enough replacement RBCs.[1] The effect is impairment in the amount of oxygen delivered to bodily tissues. Common clinical manifestations of anemia include shortness of breath, fatigue, lightheadedness, and pallor.[1] More severe symptoms include impaired organ function due to hypoxia, and heart involvement, such as palpitations, hypotension, murmurs, or congestive heart failure.[2]

Public Health Implications of Anemia

Anemia has serious public health implications for both children and adults. In 2010, the global burden of anemia, as a function of the number of years lived with disability (YLD) (calculated by multiplying the number of prevalent cases times the disability weight (or severity) of the disease), was estimated as 68.4 million YLD.[3] Anemia negatively impacts the body in many ways. Anemia can suppress the immune system and increase susceptibility to infection. Maternal anemia is associated with premature delivery, low-birth weight, and increased infant mortality.[4,5] Children with anemia may have an increased risk of contracting infections,[6] exhibiting impaired cognitive and motor skills, and experiencing deficits in social-emotional and neurophysiologic development. These effects may be permanent.[7] Among adults, anemia may result in diminished work performance and productivity,[8] which, in turn, has negative economic consequences on both an individual and national level. Research has shown that eliminating anemia has a measurable impact on individual work capacity; a 10% increase in Hb in a moderately anemic person yields a 10-20% increase in productivity.[9]

Thus, addressing the global burden of anemia is a key component to improving health and productivity.

Etiology of Anemia

Anemia may be caused by a number of mechanisms including nutritional deficiencies, blood loss, parasitic infections, lead poisoning, genetic disorders, chronic diseases, and malignancies. Iron-deficiency is, by far, the most common cause of anemia worldwide,[10] and is more prevalent among women and children.[11] Approximately 98% of anemia in children under 4 years of age is caused by iron deficiency.[2] Infants begin life with iron stores acquired from their mother during the third trimester of pregnancy. These stores are depleted during the first few months after birth. In order to avoid becoming anemic, iron intake must be sufficient to keep pace with the rapid growth of the infant and child.[12] Other nutrient deficiencies in folic acid, vitamin B12, and vitamin A can also contribute to anemia.[1,13]

Excessive blood loss can also cause anemia. Substantial bleeding after injury or surgical procedures are means by which anemia may occur acutely. However, anemia may also occur with chronic blood loss, specifically in women who lose blood during their monthly menses until menopause. This creates the potential for women of childbearing age to develop anemia.[1]

Populations affected by poverty are the most at risk for anemia as a result of malnutrition and water-related infections. Schistosomiasis and soil transmitted helminths (*Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm) are intestinal parasites that frequently lead to anemia in humans through direct blood loss,[14] malnutrition,[15] and diarrhea.[16]

Lead exposure may occur from a variety of sources including the environment (soil, air, and water), workplace, paint, and contaminated foods.[17] Elevated serum lead levels directly affect the production of heme, a cofactor found in hemoglobin.[18] In addition, lead toxicity causes hemolysis by weakening the membrane of the RBCs and damaging their ability to transport oxygen to bodily tissues and organs.[19] The result is anemia due to lead toxicity.

Genetic blood disorders that have a causal relation to anemia include thalassemia and sickle cell anemia. In thalassemia, the body makes both fewer healthy red blood cells and abnormally less hemoglobin, resulting in anemia. Several types of thalassemia exist, producing varying degrees of anemia. Sickle cell disease (or sickle cell anemia) is an inherited condition in which there is an abnormality in the hemoglobin protein leading to the RBCs assuming a sickled shape, which ultimately causes damage to the cell membrane. The damaged cell membranes cause a decrease in the RBCs elasticity, which causes the cells to assume an abnormal, sickle shape. These sickle shaped cells are hemolyzed within the body, leading to a decrease in the number of RBCs, thus resulting in anemia. In contrast to the normal lifespan of 120 days for RBCs, sickle cells typically live for only 10-20 days. Consequently, the body cannot produce cells fast enough to replace those that are dying.[1]

Another factor that may lead to the development of anemia is chronic disease. Anemia of chronic disease follows iron deficiency in prevalence. The condition has been referred to as "anemia of inflammation." Conditions included in this classification are long-term infections, cancer, chronic kidney diseases, and autoimmune disorders. A change in iron homeostasis is one of the primary mechanisms leading to this form of anemia.[20]

Diagnosis of Anemia

Measurement of Hb, hematocrit, or red cell concentration in whole blood can be utilized to identify anemia.[1] However, assessing Hb concentration is the most sensitive and direct test for anemia.[21] The diagnosis of anemia is achieved by comparing individual Hb test results to age and gender-appropriate anemia diagnostic criteria (Table 1.1)[22] which allows further characterization by index level of mild, moderate, or severe.

Table 1.1 Hemoglobin (Hb) thresholds levels used to define anemia

Age and Gender	Normal (Hb g/dL)	Mild Anemia (Hb g/dL)	Moderate Anemia (Hb g/dL)	Severe Anemia (Hb g/dL)
Children 6-59 mos.	≥11.0	10.0-10.9	7.0-9.9	<7.0
Children 5-11 yrs.	≥11.5	11.0-11.4	8.0-10.9	<8.0
Children 12-14 yrs.	≥12.0	11.0-11.9	8.0-10.9	<8.0
Non-Pregnant Women 15-49 yrs.	≥12.0	11.0-11.9	8.0-10.9	<8.0
Pregnant Women	≥11.0	10.0-10.9	7.0-9.9	<7.0
Men > 15 yrs.	≥13.0	11.0-12.9	8.0-10.9	<8.0

The gold standard for measuring Hb concentration is a venous blood sample measured using the direct cyanmethemoglobin method.[23] However, this is not always practical to use, especially in a field setting. When the rapid diagnosis of anemia is required, a simple finger prick and measurement of Hb with a photometer, such as the HemoCue, can provide an accurate reading of Hb concentration in less than 2 minutes.[23] Compared to the cyanmethemoglobin method (gold standard), the HemoCue has been found to have a sensitivity of 70.6% and a specificity of 95.2% when utilized for Hb testing in a remote setting. Furthermore, the HemoCue is more accurate than an indirect cyanmethaemoglobin assay and does not require transport of any samples to an off-site laboratory.[24]

Once the diagnosis of anemia is made, additional laboratory tests are warranted to elucidate the etiology of anemia. A complete blood count (CBC) with differential is routinely used in the evaluation of patients with anemia. This test includes both a red and white blood cell count per unit volume, a platelet count per unit volume, absolute hemoglobin amount per volume, red blood cell volume as a percentage of total blood volume (Hematocrit or HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and reticulocyte count (young RBC). The differential provides information related to the absolute amount and percentage of the subtypes of white blood cells, including neutrophils, lymphocytes, monocytes, basophils, and eosinophils, which may be elevated in the presence of an infection.[1] A peripheral smear may also be obtained to evaluate the size and color of the red blood cells, as well as to assess the blood for the presence of any abnormally shaped red blood cells, which may signify a hemoglobinopathy,[25] a hemolytic process, an enzyme deficiency, or a heavy metal toxicity. Lead poisoning, for example, will produce pathognomonic basophilic stippling on the periphery of the RBCs.[26]

Once these initial laboratory parameters are obtained, one may begin to classify anemia using one of three main approaches: the cytometric approach, the erythrokinetic approach, and the biochemical method. Because morphologic parameters are more easily and less expensively measured than are erythrokinetic and biochemical ones, it is most practical to work from the cytometric classification, to the erythrokinetic, and then to the biochemical. This approach relies on microscopic analysis of the peripheral blood smear to assess RBC size (MCV), followed by flow cytometry to determine the Hb concentration per RBC (MCHC). The cytometric classification divides anemia into three types. First are the normocytic anemias (normal MCHC, normal MCV). These include anemias due to chronic disease, hemolysis, and acute hemorrhage, as well as aplastic anemias, which are characterized by the disappearance of RBC precursors from the bone marrow. Next are the microcytic anemias (low MCHC, low MCV). These are the most common type, and include iron deficiency anemia and the thalassemias.[2,26] The Mentzer index (MCV/RBC ratio) can be used to differentiate between iron deficiency anemia and thalassemia, with a MCV/RBC ratio greater than 13 signifying iron deficiency anemia.[27] The final category of anemias are those classified as macrocytic (normal MCHC, high MCV). These include anemias caused by Vitamin B_{12} or folate deficiency.[2,26]

Further evaluation of the anemic patient consists of evaluation of RBC production (erythrokinetic method), using the reticulocyte (a precursor of mature RBCs) count. This parameter can be obtained as part of the CBC. An elevated reticulocyte count indicates an increase in RBC production due to either ongoing hemolysis (RBC destruction) or bleeding. Patients can then be further evaluated based on the morphologic parameters obtained from the peripheral smear and cytometric studies. While it may be useful to obtain the reticulocyte count prior to performing cytometric analysis in some clinical settings, usually one can accurately predict the direction of the reticulocyte count based on clinical history and examination alone (high reticulocyte counts are seen in response to acute blood loss or hemolysis, while low reticulocyte counts are seen in conditions which affect RBC production, (e.g. iron deficiency anemia and bone marrow failure).[2,26]

Finally, biochemical classification relies on more advanced laboratory studies to further delineate the etiology of anemia. These tests focus on identifying a depleted cofactor necessary for normal production of RBCs (iron, ferritin, folate, and vitamin B_{12}), an abnormally functioning enzyme (glucose-6-phosphate dehydrogenase, pyruvate kinase), or abnormal function of the immune system. In order to utilize the biochemical classification to describe iron deficiency anemia, a series of laboratory studies are required, which include the following: serum iron (circulating iron bound to transferrin), transferrin (iron transport protein), total iron binding capacity (TIBC) (maximum amount of iron that can be carried in the blood), unsaturated iron binding capacity (UIBC) (amount of free receptor sites on transferrin), transferrin saturation (percentage of transferrin binding sites that are occupied by iron), and ferritin (intracellular protein that binds stored iron in the body). These parameters should be measured in all patients with anemia. In a person with isolated iron deficiency anemia, the serum iron, transferrin saturation, and ferritin are often lower than normal, while TIBC and UIBC are typically higher than normal.[2,26] However, these parameters are not as reliable when iron deficiency anemia occurs in conjunction with other illnesses.

It is also essential to ascertain a thorough health history in the workup of the patient with anemia. For women, their menstrual and pregnancy history, as well as breastfeeding practices should be obtained. All patients should be asked about family history, gastrointestinal and other health symptoms, and major medical conditions.

Worldwide Prevalence of Anemia

Anemia is a significant public health problem in developing countries. Over 1.5 billion people worldwide suffer from anemia, with most of the burden occurring in developing countries.[28] The prevalence, as well as the threshold used to define anemia, varies by age (Table 1.1). Women of childbearing age and children are most impacted by anemia. The World Health Organization (WHO) estimated the global anemia prevalence in children age 6 months to 5 years to be 47.4% (95% CI 45.7-49.1) during 1993-2005. Amongst children aged 5 years to 15 years the global prevalence was 25.4% (95% CI 19.9-30.9). In adults aged 15-49 years the global prevalence of anemia was highest among pregnant women (41.8%, 95% CI 39.9-43.8), followed by non-pregnant women (30.2%, 95% CI 28.7-31.6), and lowest among men (12.7%, 95% CI 8.6-16.9).[28] The WHO considers populations with an anemia prevalence of 40% or higher to be of severe public health significance, anemia prevalence rates of 20-39.9% to be of moderate public health concern, and prevalence rates between 5-19.9% to be of mild concern.[22]

Anemia in Mexico

Anemia is a public health problem among women and children in Mexico. For over a decade, Mexico has been conducting national health studies to measure the prevalence of anemia. The 1999 Mexican National Health Survey of nearly 18,000 households[29] revealed

31.4% of pregnant women, 21.6% of non-pregnant women,[30] 26.3% of children 24-59 months, and 54.9% of young children 12-23 months were anemic,[29,30] constituting a moderate public health concern among women and children 24-59 months, and a severe public health concern among young children 12-23 months. Iron deficiency anemia was the primary etiology in all age groups.[29,31] Subsequent national studies showed declining rates of anemia among women and children.[30] The most recent national statistics from 2012 indicate anemia prevalence of 11.6% among non-pregnant women, 17.9% among pregnant women,[30,32], and 18.8% among children 24-59 months of age, and 38.3% among young children 12-23 months.[30] Although anemia prevalence rates decreased by nearly half among women and by almost one-third among children in just over a decade, anemia is still a public health concern among adult women and children 24-59 months, and a moderate concern among young children 12-23 months.

The reduction in anemia prevalence may be partially attributable to the implementation of government programs.[31] The most widespread government program is *Prospera* (formerly called *Oportunidades* and *Progressa*), which was established in 1997, and presently provides services to 25 million Mexicans (5.8 million families). *Prospera* is a conditional cash transfer program targeting low-income families. The female head of household receives regular payments contingent upon their children's school attendance, family members attending regular medical check-ups, and participation in preventive health workshops.[33] The amount of money provided to each family is dependent upon maternal characteristics (i.e. currently pregnant or lactating), as well as the age, gender, and education level of children living in the household.[34] Stipends may range from $10 to well over $150 US dollars per month,[34] and are provided as a means to improve health and quality of life.[35,36] The impact of *Prospera* is mixed. Some studies show enrollment in *Prospera* is associated with decreased anemia prevalence;[31,36] one study indicated that children who received assistance from *Prospera* were 25.5% less likely to be anemic than children who did not receive benefits from the program.[37] However, other studies have found no associations between *Prospera* participation and anemia status among women.[32] As of 2010, *Prospera* exists in all of Mexico's municipalities and approximately 100,000 localities, with 99% located in rural or semi-urban areas.[38]

Risk Factors for Anemia

Many national studies have been conducted in Mexico to measure anemia prevalence and risk factors. Maternal characteristics, socioeconomic status (SES), indigenous heritage, geography, diet, and exposure to lead through painted cookware have all been implicated in the development of anemia.

During pregnancy, blood volume increases to support the developing fetus, and nutritional stores, particularly iron and other vitamins required to make Hb are depleted,[1] which accounts for why anemia occurs more frequently in pregnancy. Multiparous women, specifically those who have had five or more children, may have an increased likelihood of having anemia,[37] possibly due, in part, to the depletion of nutrient reserves during successive pregnancies.[39–41]

Multiple studies reveal higher anemia prevalence rates among women and children living in low SES households.[32,37,42] Having an indigenous heritage,[43,44,45] and residing in the southern region or in rural areas of Mexico have also been associated with anemia.[44,45] One possible explanation is that southern Mexico is more rural, has a greater concentration of indigenous people, and provides fewer economic opportunities.[43] Characteristics of low SES households in Mexico, including the inability to purchase nutritious foods, poor living conditions, and lack of health care utilization may contribute to increased anemia prevalence.[46]

However, in recent years, some studies have shown equalization in regional and ethnic differences in anemia prevalence.[31]

Analyses of the typical Mexican diet show low consumption of heme iron, which is found in meat, poultry, and fish, and is easily absorbed by the body. The majority of iron is consumed is non-heme, present in legumes, grains, fruits, and vegetables, which is not as easily absorbed by the body. Furthermore, the Mexican diet is very high in phytate (fiber), an iron absorption inhibitor, which is present in grains, cereals, and seeds. The combination of these factors results in low bioavailable iron, which can contribute to iron deficiency anemia.[37,47,48] However, iron absorption from non-heme sources can be enhanced by consuming certain iron absorption promoters. Ascorbic acid (vitamin C) found in fruits and leafy, dark green vegetables, is the most effective iron absorption promoter. Citric acid, malic acid, and tartaric acid, present in fruits, also enhance iron absorption.[48] A study among iron deficient Mexican women showed that simultaneously consuming 25 milligrams (mg) of vitamin C twice per day with meals has been shown to more than triple the amount of iron absorbed by the body.[49]

Lead exposure can also cause anemia. One source of lead exposure in Mexico comes from consuming food prepared in cookware decorated with lead-based paint. Traditional hand-crafted cookware, used by many indigenous people in Mexico, is often decorated with lead-based paint. If not properly cured, the lead from the paint can leach into food during the cooking process. In one study, children who consumed food prepared on lead glazed cookware had significantly higher blood lead levels than those who did not.[17] Furthermore, research has shown a dose-response relationship between blood lead level and anemia.[50]

Because there are multiple risk factors, elucidating the underlying factors involved in the development of anemia may be challenging.

Study Setting

VIIDAI (Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación/ Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research), is a binational public health training program for medical and graduate students. The program is a multi-institutional collaborative effort between the Graduate School of Public Health (GSPH) at San Diego State University, the University of California San Diego (UCSD) School of Medicine, the Universidad Autónoma de Baja California (UABC) Tijuana School of Medicine and Psychology, and non-governmental organizations (NGOs) including Rotary International and the Bixby Foundation. For over a decade, the VIIDAI program has afforded students the opportunity to gain practical, international field experience, delivering clinical care, conducting public health assessments, and providing health education in an underserved *colonia* (small community) in Baja California, Mexico. The VIIDAI program provides a mutual benefit to both students and community members.

The rural *colonia* where VIIDAI operates is approximately 200 miles south of the United States/Mexico border and is home to 3,800 residents.[51] The population is primarily composed of indigenous Mexicans who migrated from the southern regions of Mexico to northern Mexico for agricultural work. Most *colonia* households are of low SES and have limited utilization of health services.

Project Description

The ethics of conducting research among vulnerable Mexican populations requires community support, program transparency, clear priorities, and the establishment of a trusting partnership.[52] The VIIDAI program incorporates these facets, while incorporating community input to identify health needs that are of greatest concern. VIIDAI also provides a student training component that adheres to the standards of promoting cross-cultural exchange, while providing students with a supervised skill-building opportunity.[52,53] Furthermore, he cross-disciplinary, multi-institutional collaboration universities and NGOs ensures the capacity and funding to identify, measure, and intervene to improve health.[54] A primary goal of this project is to describe the development of VIIDAI as a binational public health training program and to illustrate how the collaboration of universities, NGOs, and community members creates a synergistic effect in conducting rapid health assessments, implementing intervention projects, and obtaining long-term outcome information.

The existing VIIDAI partnership infrastructure, in parallel with community concern about anemia prevalence, provided the opportunity to conduct an anemia study in a rural *colonia* with many risk factors for anemia. Because of their increased vulnerability for developing anemia, women and children were selected as the target population for the study. Women age 15-49 years and children age 6-59 months residing in the *colonia* were eligible for participation. Participants were recruited through attendance at a temporary VIIDAI clinic and by household sampling. Informed consent was obtained from all participants. As part of the VIIDAI field experience, integrated teams of U.S. and Mexican students administered surveys and obtained blood samples to test for anemia, under the supervision of VIIDAI faculty. Data collection occurred at multiple time points, as depicted in Figure 1.1.

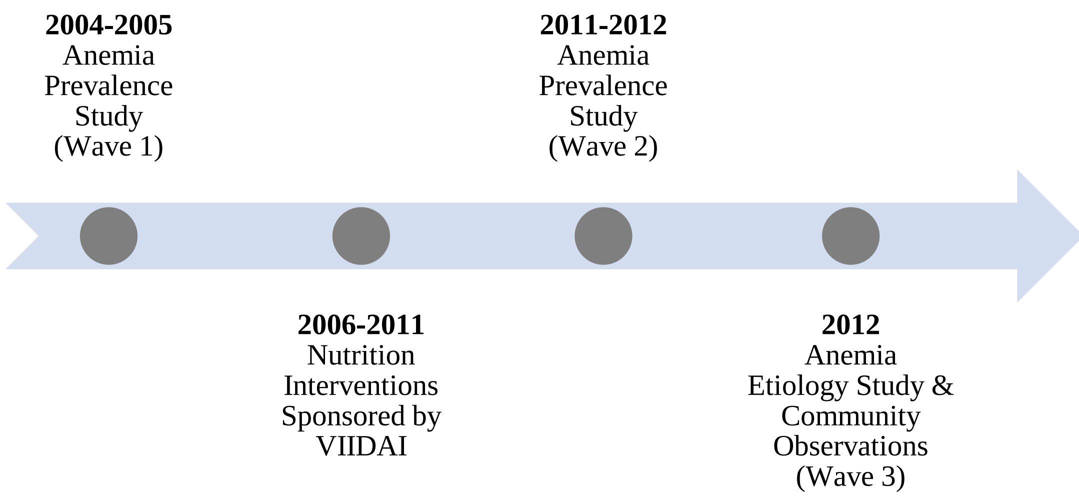

Figure 1.1 Timeline of data collection

A study concerning the prevalence and correlates of anemia was performed in 2004-2005 (Wave 1), which occurred prior to this dissertation project. The results revealed a high prevalence of anemia, prompting the design and implementation of community intervention projects focusing on improving the health of community residents. These interventions included community nutritional and hygiene education programs, an exchange program for lead-glazed painted cookware, a remodel of the local school kitchen with modifications of the school menus to provide students with nutritious meals, and biannual free health clinics for *colonia* residents. To investigate if anemia prevalence decreased after the implementation of these interventions, a second anemia prevalence study was performed in 2011-2012 (Wave 2). Because similar methodology was used in both studies, comparisons in the prevalence and correlates of anemia were performed between Waves 1 and 2. A third study was also performed in 2012 (Wave 3) to further elucidate the etiology of anemia in the community by obtaining whole blood samples and performing laboratory diagnostics. Further examination of individual characteristics and community food availability was performed to identify factors that may contribute to anemia in the *colonia*.

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CHAPTER 2

Transcending Borders with VIIDAI: A Binational Approach to Public Health Education

ABSTRACT

VIIDAI is a binational program that prepares clinical and public health graduate students to respond to public health needs in underserved communities. The program is a collaborative partnership between universities, non-governmental organizations (NGOs), and an underserved, predominately indigenous community in northern Baja California (BC), Mexico. The synergy between these three components allows for the implementation of both short and long-term projects encompassing the pillars of clinical care, epidemiology, and health promotion. With input from community leaders, guidance from faculty, and support from NGOs, students are able to implement high-impact, multidisciplinary public health projects. The unique structure of VIIDAI serves as a successful model, with mutual benefits for community members, faculty, and students, and serves as a prototype for replication and implementation by other universities and NGOs in similar resource-limited communities.

BACKGROUND

Public health is a trans-disciplinary field with increasing emphasis on preparing students to function as global practitioners.[1,2] Universities are tasked with developing curricula that instills students with skills to address emerging global health issues. Thus, in 1998, a collaboration was established between the School of Medicine and Psychology at Universidad Autónoma de Baja California (UABC) in Tijuana, the Graduate School of Public Health at San Diego State University (SDSU), and the School of Medicine at the University of California San Diego (UCSD) to form VIIDAI (Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación/Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research). Soon after formation, local Rotary clubs joined VIIDAI, as core partners in planning and executing projects. VIIDAI has evolved as a binational public health training program that integrates U.S. and Mexican faculty and students to engage in a multidisciplinary, cross-cultural exchange of knowledge and delivery of clinical and public health services to a rural, predominately indigenous, population. We describe the structure of VIIDAI, provide examples of the synergistic nature of the program, and offer recommendations for replicating this impactful program.

STRUCTURE

VIIDAI utilizes an integrative, community-based, participatory research (CBPR)[3] approach between community members, NGOs, and universities (Figure 2.1). Community leaders are key resources for identifying and prioritizing health needs, providing input to projects development, and offering feedback on program effectiveness. Universities and NGOs provide the capacity and resources to implement community-oriented, high impact public health services (Figure 2.2). Twice yearly, over 140 faculty, students, and NGO volunteers participate in the 4-day field experience. Prior to each trip, participants attend a project-planning seminar organized by the three universities.

Universities

One principal faculty member from each university coordinates VIIDAI with core disciplines of epidemiology, behavioral sciences, primary care medicine and psychology. Guest faculty members (i.e. anthropology) join for particular projects. For medical students, VIIDAI is an elective course or a volunteer clinical service opportunity. SDSU public health graduate students incorporate VIIDAI into a semester-long course and field research experience. Leadership opportunities exist for students at all three universities to develop and lead projects in fulfillment of dissertation and thesis requirements.

Community Setting

Several rural and indigenous *colonias* with the infrastructure to host clinical and public programs were identified in consultation with Mexican health officials as potential sites for VIIDAI. Core VIIDAI faculty and NGO members toured the *colonias* and met with *colonia* leaders to gauge their interest and commitment concerning participation in the VIIDAI program. The current *colonia* is comprised of 3,800[4] primarily indigenous residents near San Quintín, BC (Table 2.1). VIIDAI utilizes existing community infrastructure to offer clinical services in the local primary school, with classrooms providing compartmentalized space for clinical and public health services. The *colonia* has been mapped to allow for systematic sampling strategies for students to conduct epidemiologic studies in the clinic and surrounding community.

Non-governmental Organizations (NGOs)

Collaborating NGOs include local Rotary Clubs (Old Mission Rotary Club of San Diego, CA, and Club Rotario Ensenada Riviera), the Bixby Foundation, Thousand Smiles, AmeriCares, and the Grassini Family Foundations. The Rotary functions as a core partner, and as demonstrated in Figure 2.2, can provide resources to perform projects, engage the local Mexican Rotary clubs and the community, and complete independent projects. A Bixby grant supported development of curriculum for the primary and secondary schools in reproductive health and has also provided general program support.

Cost

Students pay approximately $200 per trip to contribute to food, lodging, transportation, and insurance. A San Quintín hotel with the capacity to house up to 140 participants and provide a meeting hall offers significant government discounts. Research and medical equipment, incentives for study participation, and materials for community development projects are donated by NGOs. Grant funding supports long-term VIIDAI projects, provides student scholarships. The VIIDAI field experience is included as part of the teaching requirement for core faculty members.

Integration

UCSD and UABC physicians supervise medical students from both schools and engage collaboratively in patient care. Through these interactions, U.S. students and faculty gain insights about their Latino/a patients' expectations, while Mexican students and faculty learn how their U.S. counterparts care for patients. All public health projects and survey teams are comprised of Mexican and U.S. students to address both cultural sensitivity and enhance the experience.

ACTIVITIES

Table 2.2 highlights some of the VIIDAI public health activities.

Medical Services

Each trip incorporates free medical services encompassing primary care, reproductive health screenings, family planning, mental health consultations, dental care, eye exams, pharmaceuticals, and laboratory diagnostics. Some trips offer specialty screenings or services (e.g. tuberculosis screening, nutrition counseling, etc.) as part of epidemiological research studies. An average of 220-260 patients receive care during each trip. VIIDAI's semi-annual clinics provide healthcare continuity in a community with limited health resources. Diagnostic capacity has increased over time with grant and NGO resources. Medications are donated by the two participating medical schools.

Research Activities

Requests for rapid assessments and epidemiologic studies are generated from both the community leaders and Mexican health officials. For example, an outbreak of Rocky Mountain Spotted Fever (RMSF)[5] in Mexicali and Tijuana prompted the exploration of community knowledge and exposure to risk factors for RMSF within the *colonia* by public health students who created and administered a survey to residents (Table 2.2).

Interventions

VIIDAI provides the capacity for developing and implementing interventions during successive trips based on previous findings. For example, RMSF assessment results (Table 2.2) prompted behavioral sciences students to develop interventions to educate residents about RMSF prevention strategies. Rotary supplemented education efforts by presenting community members with toolkits containing tweezers, tick collars for dogs, and garbage removal supplies. Furthermore, Rotary donated extermination equipment to the local veterinarian for vector control.

Some interventions are conducted over several years. For example, the community requested reproductive health education, and the Bixby Foundation sponsored a multi-year study. UABC psychology students trained *Promotora*s (peer health educators) to teach elementary school children about sexual health. The pilot program was so successful that *colonia* leaders requested expansion to include middle school students (Table 2.2). Additional *Promotoras* along with local teachers were trained to implement the curriculum, yielding positive results[6] and further transition of the program into community schools.

VIIDAI also fosters partnerships with research institutions. Limited water availability and lack of sanitation services are concerns in the *colonia*. The J. Craig Venter Institute (JCVI) approached VIIDAI faculty to leverage the existing community partnership to evaluate cutting-edge wastewater treatment technology. Identifying a target community and cultivating a new partnership would have been challenging for JVCI. However, by uniting with VIIDAI, JCVI was invited into a welcoming community and could utilize faculty and students for project assistance (Table 2.2).

IMPACT

VIIDAI has trained over 1,000 UABC, 250 UCSD, and 500 SDSU students since inception. Some trainees have returned as faculty members. Improvements in community health are signaled by patient complains shifting from infections[10] to chronic diseases[11] over the past decade. Moreover, community empowerment was achieved by training community members to sustain programs like the Bixby family planning intervention (Table 2.2).

LESSONS LEARNED

VIIDAI is suited for a stable community to ensure continuity of services. Exercising transparency during project planning, implementation, and evaluation ensures support from partners and local governing bodies. Furthermore, the dissemination of results by students and faculty through university-sponsored research symposiums, national research meetings,[7,8] and peer-reviewed publications[9–13] affords the opportunity to forge future partnerships.

CONCLUSION

VIIDAI is a synergistic, impactful model, with mutual benefits for community members, faculty, students, and NGOs, and serves as a prototype for replication in similar resource-limited communities.

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Chapter 2, in part, is being prepared for submission for publication. Moor M.A., Fraga M.A., Brodine S.K., Elder J.P., Garfein R.S.. Transcending borders with VIIDAI: a binational approach to public health education. The dissertation author was the primary investigator and author of this paper.

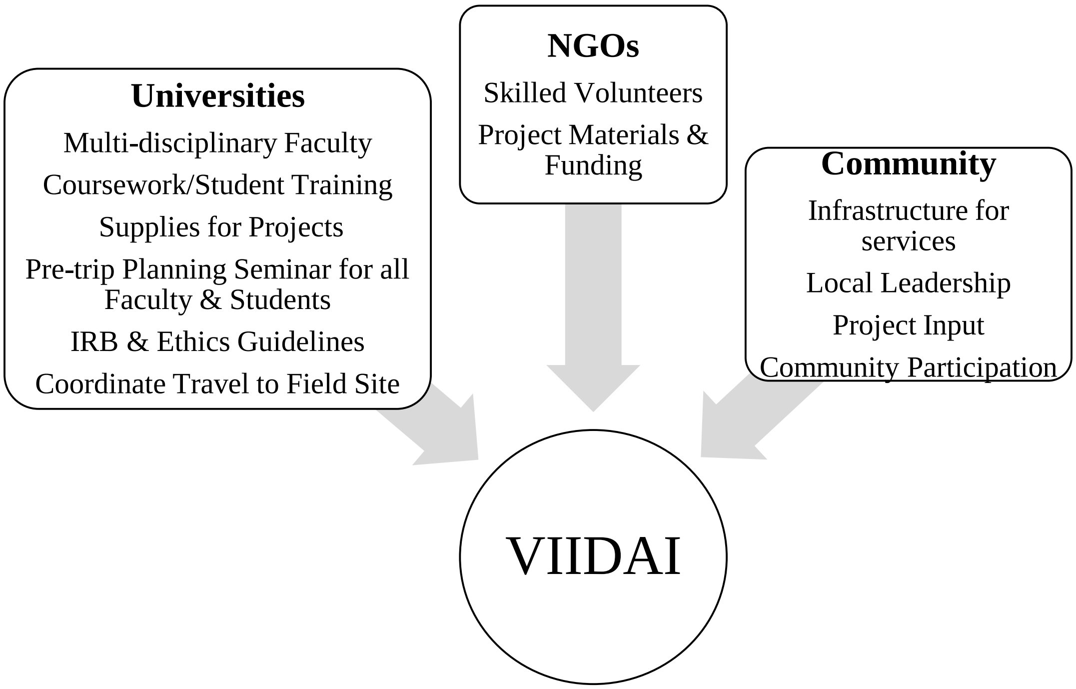

Figure 2.1 Structure of the VIIDAI program.

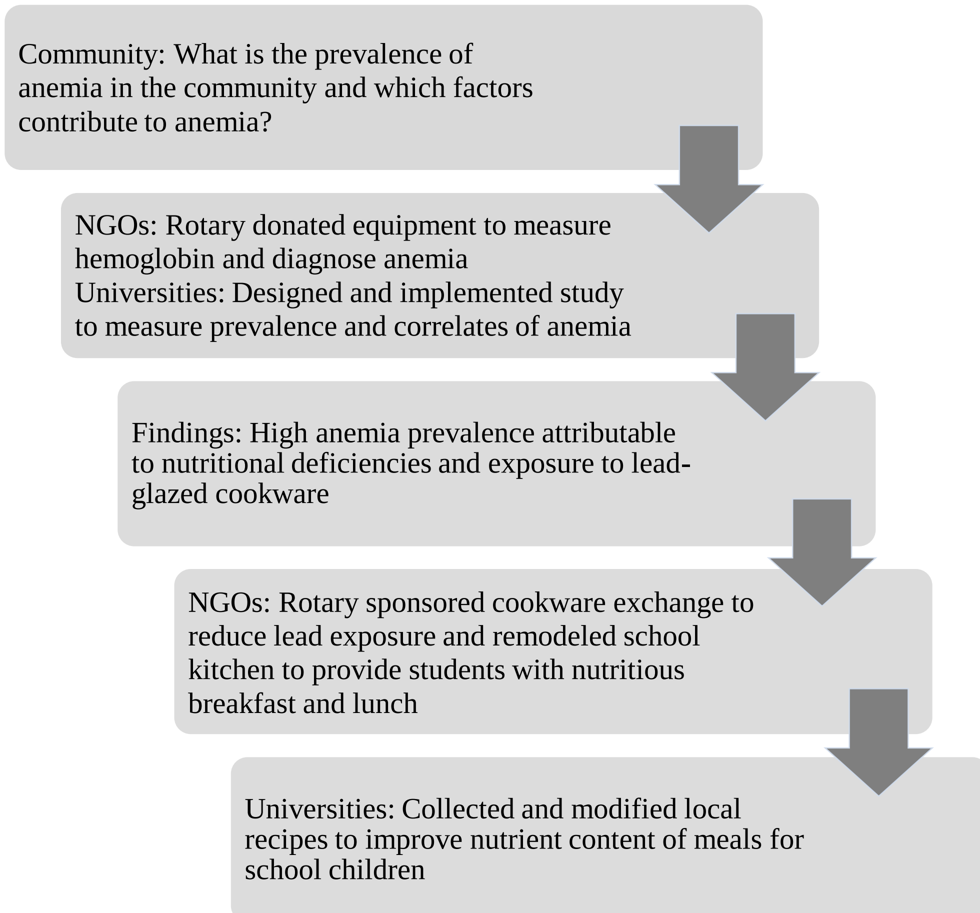

Figure 2.2. Synergistic example of VIIDAI's ability to addresses community problems through a CBPR model incorporating rapid assessments and interventions.

Table 2.1 Demographics of Colonia Residents

Demographic Variable	Median (IQR[a]) or %
Age of Adult Residents (yrs)[b]	35 (28-42.5)
Household Size[c]	5 (4-7)
Length of Residence in Colonia (yrs)[c]	14 (10-17)
Years of education completed[b]	4.1 (0-6)
Born in the state of Oaxaca, Mexico[b]	79.3%
Speaks Indigenous Language[b]	52.4%
Agricultural Worker[b]	46.3%
Weekly income ≤ $190 USD[d]	64.2%

[a]Abbreviation: interquartile range (IQR)
[b]Data obtained from a study including 133 adult residents, age 18 yrs or older[10]
[c]Data obtained from a study including 118 female residents[8]
[d]Data obtained from a study including 68 female residents[12]

Table 2.2 Special Projects Sponsored by VIIDAI

Year	Project	Purpose	Design	Subjects	Findings	Recommendations
2004-2005	Water Survey & Education	Inspect household water sources	Household convenience sample	90 households	Contamination of purchased purified water resulting from improper water storage	Rotary provided water storage containers & advised residents about safe storage.
2004	Family Planning Assessment	Examine reproductive health practices	Household and clinic sample	160 females	High parity and lack of family planning resources in the colonia.[7]	Implement family planning interventions funded by the Bixby Foundation.
2004-2005	Anemia Survey	Measured anemia prevalence and risk factors	Random household and clinic sample	201 women & 99 children	Anemia prevalence rates of 40% in women & 54% in children; found use of lead cookware & poor nutrition.[14]	Implement interventions to reduce exposure to lead-glazed cookware and improve nutrition.
2006-2008	Bixby Family Planning Intervention	Trained Student Promotoras (peer educators)	School leaders selected Promotoras	4+ Promotoras	Students had increased reproductive health knowledge after Promotoras implemented curriculum	Positive feedback warranted training of additional Promotoras.
2007-2008	Nutrition Survey and Intervention	Collected household recipes and examine dietary habits	Convenience sample	23 households	Local recipes were analyzed and modified to include nutritious ingredients.	Rotary funded school kitchen remodel to serve modified nutritious recipes to students.
2007	Lead-Glazed Cookware Exchange	Tested hand-painted cookware for lead.	Convenience sample	31 households	Lead-glazed cookware was exchanged for lead-free cookware, supplied by Rotary clubs.	Follow-up to see if families use new cookware.
2008	Diabetes & Metabolic Syndrome (MS)	Measured prevalence of MS and diabetes	Random household sample	107 adults	41% of adults had MS and 26% had diabetes.[11]	Provide MS and diabetes prevention education.
2008	Latent Tuberculosis Infection (LTBI)	Conducted LTBI blood tests	Random household & clinic convenience sample	133 adults	Prevalence of LTBI was 39.8%. Consumption of unpasteurized milk was associated with LTBI.[10]	Provide TB care and prevention.

Table 2.2 Special Projects Sponsored by VIIDAI (contd.)

Year	Project	Purpose	Design	Subjects	Findings	Recommendations
2009-2010	Rocky Mountain Spotted Fever (RMSF)	Assessed knowledge of RMSF and risk factors	Random household and clinic sample	163 adults	33% reported seeing a tick at home, with sightings more common among households with a dog.	Supplied community with vector prevention tools and educated community members about RMSF.
2009-2010	Influenza Survey	Determine community prevalence and knowledge of influenza	Random household and clinic sample	152 adults	49.7% reported flu symptoms $\leq$ 3 months; symptoms correlated with belief that physical contact does not spread influenza.	Provided hygiene, hand-washing, flu prevention, and transmission education interventions
2010	Drug-Scene Familiarity & Gang Violence	Assessed presence of gangs and drugs	Random household and clinic sample	164 adults	39% reported drug-scene familiarity and 42% indicated exposure to gang violence.[13]	Rotary sponsored team sports to increase physical activity & started a school library with computers and Internet to promote learning.
2011-2012	Anemia Survey II	Measured anemia prevalence and determined etiology	Random household and clinic sample	146 women & 77 children	22% of women and 20.5% of children were anemic & iron deficiency was the primary etiology.[8]	Provide additional nutritional education interventions.
2012	Intimate Partner Violence (IPV) Survey	Examine risk factors for IPV among residents	Random household & clinic convenience sample	62 women	94% believe IPV is a community-wide problem.[12]	Educate residents on resources available to those suffering from IPV
2014-2017	Wastewater Treatment	Assess water quality; gauge support for using Microbial Fuel Cells (MFCs) to treat wastewater	Collected local water samples; Community focus group	19 water samples & 21 adults	Bacteria and high levels of total dissolved solids present in water revealed colonia is a good candidate for MFC installation; community supports MFC project	Provide community education regarding MFCs; Funding has been secured to begin construction and instillation of MFCs at the local school.

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CHAPTER 3

Decreased Anemia Prevalence Among Women and Children in Rural Baja California, Mexico: A Six-Year Comparative Study

ABSTRACT

Anemia is a public health problem in Mexico. This study sought to determine the prevalence and correlates of anemia among women and children residing in a rural farming region of Baja California, Mexico. An existing partnership between universities, non-governmental organizations, and an underserved Mexican community was utilized to perform cross-sectional surveys in 2004-2005 (Wave 1) and in 2011-2012 (Wave 2) among women (15-49 years) and their children (6-59 months). In each wave, participants were randomly selected and completed a survey containing demographic, socioeconomic, health, and dietary characteristics and provided a capillary blood sample for anemia testing. Blood smears were obtained to from Wave 1 participants to identify etiology. Nutrition education interventions and clinical health evaluations were offered between waves. Participants included 201 women and 99 children in Wave 1, and 146 women and 77 children in Wave 2. Prevalence of anemia decreased from 42.3% to 23.3% between Waves 1 and 2 in women ($p<0.001$), from 46.5% to 30.2% in children 24-59 months ($p=0.066$), and from 71.4% to 45.8% in children 6-23 months ($p=0.061$). Among women in Wave 1, consumption of iron absorption enhancing foods (green vegetables and fruits high in vitamin C) was protective against anemia ($p=0.043$). Women in Wave 2 who ate $\geq$ 4 servings of green, leafy vegetables per week were less likely to be anemic ($p=0.034$). Microscopic examination of blood smears in Wave 1 revealed microcytic, hypochromic red blood cells in 90% of anemic children and 68.8% of anemic women, consistent with iron deficiency anemia.

INTRODUCTION

Anemia is a primary health concern for individuals living in developing countries. The World Health Organization estimates that one in four people suffer from anemia, with disproportionately higher rates occurring in resource-poor areas.[1] Women and children, in particular, are at highest risk for developing anemia because of their increased iron requirements.[1–3]

A high prevalence of anemia, especially among women and children, is an ongoing public health problem in Mexico. National statistics from 2012 indicate an anemia prevalence of 11.6% in non-pregnant women, 17.9% in pregnant women,[4,5] 18.8% in children 24-59 months, and 38.8% in children 12-23 months.[4] Slightly higher prevalence of anemia has been found among non-pregnant women and children 12-59 months who live in rural areas, those who reside in southern Mexico, and are indigenous.[5,6] Low socioeconomic status (SES)[5,7] and nutritional deficiencies[6] have also been shown to be associated with anemia. Other studies report similar findings[8,9] and suggest that the etiology of anemia among Mexican women and children has many origins. Anemia is most commonly attributable to nutritional deficiencies in iron, vitamin B12, and folate;[6,8,10] however, lead toxicity has also been implicated as a cause of anemia, particularly among indigenous individuals.[11,12]

While the epidemiology of anemia in the general population of Mexico has been extensively studies, little is known about anemia among marginalized populations such as agricultural workers and their families. Many indigenous Mexicans migrated from states in the south to northern Mexico for agricultural work. Beginning in the 1970's, working in the agricultural fields of Baja California offered some relief from the poverty and unemployment experienced by those living in southern Mexico.[13] Job security encouraged many agricultural laborers to settle and raise families in the region. These migrant families from southern Mexico have multiple risk factors for anemia which include indigenous heritage, low SES, and rural living conditions,[13,14] yet the prevalence of anemia in this population is unknown. Furthermore, these families typically have poor access to and utilization of healthcare services;[14,15] thus, many health conditions, including anemia, may go undetected or untreated.

We sought to investigate the prevalence and correlates of anemia among women and children living in rural agricultural communities in northern Baja California. We utilized VIIDAI ([Viajes Interinstitucional de Integración, Docente, Asistencia y de Investigación, or Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research], a binational public health and clinical training program conducted collaboratively by three universities (Universidad Autónoma de Baja California [UABC], San Diego State University [SDSU], and the University of California San Diego [UCSD]) who had an existing partnership with a rural agricultural community in Baja California to perform the study. Data for the present study in 2004-2005. Results revealed a high prevalence of anemia; thus, in 2005, community interventions were initiated to improve health and decrease anemia prevalence. Non-governmental organizations, specifically Rotary clubs from San Diego, CA and Ensenada, Mexico, working in collaboration with VIIDAI, provided funding to implement these interventions. The kitchen at the local school was remodeled and enlarged in order to have the capacity to offer school-aged children nourishing meals for breakfast and lunch. Recipes were also collected from community residents and modified to include locally available, nutritious ingredients with greater amounts of iron and vitamin C; these adapted recipes were subsequently shared with the community. The modified recipes were also provided to school chefs to use as a guide for preparing meals in the new school kitchen. Because lead from painted cookware can be ingested and may contribute to anemia, a collaborating NGO sponsored a community cookware exchange. Households that were willing to give up their lead-glazed ceramic cookware were offered new ceramic cookware. Public health students in the VIIDAI program also designed community health promotion campaigns to educate residents. A variety of educational topics were offered in conjunction with the VIIDAI program and included: healthy eating, anemia prevention, and proper hygiene and hand-washing techniques. Lastly, VIIDAI medical faculty and students offered free weekend health clinics twice per year where community residents could receive preventive care, anemia testing, and access to personalized nutritional counseling. The objective of this study was to determine if there were significant decreases in anemia prevalence following the implementation of these community health interventions and services, and to identify correlates of anemia in this population to inform future interventions.

METHODS

This study utilized a serial cross-sectional design with four data collection periods. Each survey took place over a two-day period in October 2004, March 2005, October 2011, and April 2012. Data were combined from the earlier two surveys (Wave 1) and compared to data from the two later surveys (Wave 2). Institutional Review Boards at SDSU, UCSD, and UABC approved the study. Informed consent for participation was obtained from all participants.

Study Setting

The town of San Quintín is situated in a rural agricultural region of northern Baja California, approximately 200 miles south of the United States (US)/Mexico border. Because few people lived in this area initially, the growth of the region as a major agricultural area relied on the import of inexpensive laborers, predominantly from southern Mexico. Many *colonias* (small settlements) are situated in close proximity to San Quintín, and these communities are primarily populated by indigenous peoples who migrated to the area for employment as agricultural laborers, but many have since established permanent residency as a result of job stability. One *colonia* of approximately 3800 individuals [16] has been the focus of ongoing VIIDAI public health activities for the past decade and was the site for this study.

Sampling Techniques

The target population consisted of females between the ages of 15 and 49 years (hereafter referred to as women) and children between the ages of 6 and 59 months (hereafter referred to as children). Study participants in each wave were recruited using two methods: 1) eligible individuals who attended a free, two-day VIIDAI medical clinic were selected through random sampling while waiting in line to see a provider; and 2) individuals living in randomly selected households within the *colonia* were approached to participate. For household selection, a map of the *colonia* was used to randomly select blocks of homes and then a survey team systematically approached households in these blocks to recruit study participants. Contact was attempted at each household in the designated block, beginning at the northeast corner and continuing in a clockwise manner. Individuals were eligible for the study if they were female between the ages of 15-49 years and able to speak Spanish (or have a translator bilingual in Spanish and their indigenous language available). One woman and up to two children per household (one child 6-23 months and one child 24-59 months) were eligible for participation. If more than one woman or more than one child in each age group were eligible, the eligible individual(s) rolled a pair of dice, and the person (or child) who rolled the highest number was included in the study. Persons who did not reside in the *colonia*, or did not meet the age requirements, were excluded from participation. We enrolled as many eligible individuals as possible during each two-day data collection period.

Survey Instruments

All female participants enrolled in the study were interviewed in Spanish by a trained interviewer using a structured questionnaire. If necessary, indigenous translation was provided by a member of the household, or by the interviewer, if he or she spoke both Spanish and the indigenous language. No individuals were excluded due to language barriers. Questions regarding age, demographics, education, indigenous background, reproductive history, breastfeeding, and diet were assessed among all participants in Waves 1 and 2. Questions pertaining to children were answered by the child's mother or caregiver.

A proxy score for socioeconomic (SES) was created by summing the number of household characteristic questions the participants responded affirmatively to, which included having electricity and ownership of a vehicle, radio, television, and refrigerator. Households with an SES score of 0-2 on the 5-point scale were considered to be low SES.

Education and SES questions were not included for participants surveyed in 2005. In Wave 1 and in the first half of Wave 2 data collection (occurring in 2011), subjects were asked about foods consumed in the previous 48 hours. Participants were asked to respond yes or no regarding their consumption of foods rich in heme iron (meat, fish, and poultry), foods enhancing iron absorption (fruits and leafy, green vegetables containing vitamin C), and foods inhibiting iron absorption (grains, legumes, dairy, coffee, and tea). However, serving amount was not obtained. Thus, in the second half of Wave 2 data collection in 2012, dietary intake was expanded and participants were asked to indicate the number of servings consumed during a 7-day period for each of the individual food items included on the previous dietary survey.

Testing of Cookware

Traditional cookware from southern Mexico is often decorated with lead-based paint or glaze. If the cookware is improperly cured, lead may leach into prepared foods.[11] To check for lead exposure, painted cookware was tested for lead in a sample of households who participated in Wave 1 and Wave 2 (n=34 and n=10, respectively). Individuals who completed the survey and reported using painted cookware were randomly selected and asked to allow interviewers to test their cookware for lead using LeadCheck Swabs (3M, St. Paul, MN).

Collection of Blood Samples

All women and children in Waves 1 and 2 had blood samples taken and tested for anemia. Using a capillary blood sample obtained by finger prick, hemoglobin levels were measured using a portable HemoCue photometer (HemoCue AB, Angelholm, Sweden).

Additionally, at the beginning of Wave 1 in 2004, a thin peripheral blood smear was obtained in a randomly selected subset of women (n=38) and children (n=25) who participated in the study. Peripheral blood smear slides were prepared, stained, and examined microscopically.

Anemia Determination

Anemia was diagnosed according to established WHO guidelines and defined as having a hemoglobin concentration below the following levels: 12.0 g/dl for non-pregnant women, and 11.0 g/dl for children and for pregnant women. Anemia was further classified as *mild* (≥11.0 g/dl and <12.0 g/dl for non-pregnant women; ≥10.0 g/dl and <11.0 g/dl for pregnant women and children), *moderate* (≥8.0 g/dl and <11.0 g/dl for non-pregnant women; ≥7.0 g/dl and <10.0 g/dl for pregnant women and children), and *severe* (<8.0 g/dl for non-pregnant women; <7.0 g/dl for pregnant women and children).[17] All participants diagnosed with anemia, along with all pregnant women in this study, were provided with vitamin supplements containing iron and advised on proper use and dose.

Study Sample

A total of 256 women and 131 children were enrolled in Wave 1; however, 55 women and 32 children were excluded because blood samples were not obtained (either due to subject refusal or inability to obtain enough blood). Thus, the final sample in Wave 1 included 201 women and 99 children. A total of 158 women and 86 children were enrolled in Wave 2; however, 12 adults and 9 children were excluded because blood samples were not obtained (either due to subject refusal or inability to obtain enough blood). Thus, the final sample in Wave 2 included 146 women and 77 children. Waves 1 and 2 did not examine the same group of women and children; however, it is possible that some women included in Wave 1 were also randomly selected to participate in Wave 2.

Statistical Analysis

Descriptive statistics including means and frequencies were calculated for all variables and data were checked for normality. Chi-square and independent sample t-tests were conducted to assess differences in anemia prevalence and anemia risk factors, as appropriate. To determine whether health status improved over time, anemia prevalence and severity were compared between Waves 1 and 2. Because participants in each wave were not linked, we examined participant characteristics with respect to anemia status and controlled for potential confounders. Data were analyzed using PASW Statistics version 18 (SPSS Inc., Chicago, IL). All statistical tests were two-tailed and a p-value of less than 0.05 was considered statistically significant.

RESULTS

Prevalence and Severity of Anemia

The prevalence of anemia decreased from Wave 1 to Wave 2 in all three age groups (Table 3.1), with the greatest reduction occurring among women (42.3% vs. 23.3%, $p<0.001$). The prevalence of anemia also decreased by one-third among both children age 24-59 months (46.5% vs. 30.2%, $p=0.066$) and children age 6-23 months (71.4% vs. 45.8%, $p=0.061$). A reduction in anemia severity was also noted in all three age groups, with fewer cases of moderate and severe anemia observed in Wave 2 compared to Wave 1. The greatest decrease in severity was detected among children 6-23 months, where the proportion of moderate and severe anemia decreased from 55% in Wave 1 to 9.1% in Wave 2, and from 5% to 0%, respectively ($p=0.013$).

Demographic and Socioeconomic Characteristics

The mean age of all women who participated in the study was 29.8±9.0 years. Women surveyed in Wave 1 exhibited a significant association between anemia and living in a low SES household (p=0.024, Table 3.2). However, the percentage of low SES households did not change significantly between Wave 1 (19.8%) and Wave 2 (13.8%) (p=0.223, data not shown). A longer length of residence within the *colonia* was significantly associated with anemia among participants in Wave 2 (p=0.003), but not in Wave 1 (p=0.632). However, the significant increase in length of residence in the *colonia* between Wave 1 (10.1±6.4 years) and Wave 2 (12.7±8 years; p=0.006) shows the population did not relocate during the course of the study. Among Waves 1 and 2 combined, working in an agricultural occupation was significantly associated with being anemic (p=0.009). However, this association was not apparent when stratified by time of testing (Wave 1 vs. Wave 2), and upon further review, it was evident that significantly more women reported working in the agricultural industry in Wave 1 compared to Wave 2 (82.0% vs. 32.4%, respectively, p<0.001, Table 3.2). Education level and literacy were not associated with anemia, although significant increases occurred in both between Waves 1 and 2 (data not shown).

Maternal and Reproductive Characteristics

Anemia prevalence decreased among pregnant women between Waves 1 and 2 (33.3% vs. 12.5%, respectively, data not shown). Pregnancy rates did not differ among anemic and non-anemic women in both Wave 1 and Wave 2 (Table 3.3). There were no significant associations between anemia and parity, menstruation, childbirth, or breastfeeding (Table 3.3).

Health and Nutrition Characteristics

In Wave 1, consumption of foods that enhance iron absorption in the past 48 hours was protective against anemia (66.7% among anemic vs. 79.5% among non-anemic, p=0.04). In 2012 of Wave 2, women who ate four or more servings of vegetables per week were significantly less likely to be anemic than women who consumed less than four servings of vegetables per week (p=0.03). However, eating four or more servings of meat (including fish, and poultry) was not associated with anemia status (p=0.48). Seasonal variation of foods in the spring versus the fall did not appear to be associated with anemia status (Table 3.2).

Childhood Characteristics

Among children 24-59 months, having diarrhea in the preceding two weeks was significantly association with being anemic (p=0.007, Table 3.4). Among children 6-23 months, living in a household with fewer people was significantly associated with being anemic (p=0.017). No other significant associations between anemia and maternal or socioeconomic factors were observed among children (Table 3.4).

Cookware

In Wave 1, 34 glazed, painted cookware items were tested for lead and 12 (35.2%) tested positive. During Wave 2, 10 glazed cookware items were tested for lead and all tested negative.

Microscopic Examination of Blood Samples

Microscopic examination of blood samples collected in Wave 1 from a subset of 38 anemic women and 25 anemic children showed that 97.4% of the women's samples and 100% of the children's samples contained microcytic red blood cells, with a differential diagnosis that included nutritional iron deficiency, blood loss-induced iron deficiency, anemia of chronic diseases, thalassemia, or lead toxicity. However, the absence of basophilic stippling in the red blood cells and the lack of target red blood cells made lead toxicity or thalassemia as an underlying cause, respectively, less likely. In contrast, the presence of hypochromic microcytic red blood cells in 90% of the children's samples and 68.8% of the women's samples were suggestive of iron deficiency. The red blood cells in the remaining samples were not hypochromic.

DISCUSSION

Anemia prevalence rates are a public health concern in this community. In Wave 1, anemia prevalence rates were twice as high as the corresponding national averages among women[18] and children.[7] The microcytic characteristics of the thin blood smears collected in Wave 1 were consistent with nutritional iron deficiency anemia, and dietary evidence in both Waves 1 and 2 corroborated this finding. On a positive note, a dramatic reduction in anemia prevalence was observed in Wave 2 compared to Wave 1. This decrease may be partially attributable to the implementation of community nutrition interventions and access to health care provided by the VIIDAI program, although no data exists to directly correlate participation in VIIDAI community interventions and clinics to anemia status.

Evidence from a dietary study among women living in rural Central Mexico revealed that the Mexican diet typically consists of iron absorption-inhibiting foods (phytate, fiber, legumes, calcium, tannins) and is relatively low in the consumption of bioavailable iron and iron absorption enhancing foods. Their results also indicated that increased iron levels were associated with increased intake of vitamin C.[19] Our study similarly showed the consumption of iron absorption enhancing foods rich in vitamin C were protective against anemia among women. Thus, nutrition interventions, which included the modification of local recipes, the construction of a school kitchen to prepare nutritious meals, community education, and personalized nutritional counseling following anemia diagnosis implemented after Wave 1 encompassed methods for increasing iron and vitamin C intake.

The reported use of painted ceramic cookware, which has the potential to contain lead-based paint, discloses the potential for lead exposure in this *colonia*. Lead exposure can be a primary cause of anemia, but it can also exacerbate anemia severity by increasing heavy metal absorption in individuals with existing iron deficiency anemia.[20] Furthermore, lead poisoning can hinder brain,[21,22] central nervous system,[22,23] kidney and organ development in children.[22] Mexican families frequently use lead-glazed ceramic cookware made with lead-based paints. If not properly cured, lead from the paint can transfer to foods cooked or stored in the cookware, contributing to lead poisoning.[11,12,24] In Wave 1, 34.4% of the study population reported using painted ceramic cookware. Thirty-four cookware items were subsequently tested for lead and 12 (35.2%) tested positive. Though stippling was not observed in any of the thin blood smears, the high prevalence of anemia in Wave 1 and the widespread use of lead-based painted cookware prompted VIIDAI to sponsor a cookware exchange in 2006 to replace existing glazed cookware with new ceramic cookware. During Wave 2, 10 glazed cookware items were tested for lead and all tested negative; furthermore, decreased use of painted ceramic cookware was also noted between Waves 1 and 2.

In Wave 1, anemia was significantly more common in women from low SES households, which is consistent with other published studies.[5,6] Compared to national household economic standards in Mexico, most households in the *colonia* are considered very low SES.[25,26] We also discovered that women residing in the *colonia* who reported working in agriculture were more likely to be anemic. The disproportionate anemia rates among female agricultural workers may be due, in part, to the fact that agricultural labor is a job that is often occupied by people of low SES.[25,27,28] Higher anemia prevalence among agricultural workers may be a reflection of higher anemia prevalence rates among individuals of low SES.

Because many *colonia* residents are of low SES, they may not be able to afford to purchase fresh produce, which typically commands a higher cost than other foods. Although many residents of the *colonia* are employed as manual laborers in the agricultural industry, the majority of produce grown in the fields around the *colonia* is exported to the United States, as the profit margin is substantially higher when selling produce in the U.S. compared to Mexico.[29] High prices and limited availability of produce may contribute to the high prevalence of anemia within the *colonia*.

Diarrhea was a significant correlate of anemia among children 24-59 months. Prolonged diarrhea can result in nutrient depletion, and in some cases, blood loss. Anemia in children can cause decreased immune function and result in the acquisition of an infectious disease which can lead to diarrhea,[17] thus compounding the problem. The risk of a diarrheal disease increases with poor sanitation,[30] and the *colonia* has limited sanitation services, which is indicative of poor economic conditions. One of the community interventions offered by VIIDAI focused on hygiene and hand-washing techniques to prevent the transmission of infectious agents that may cause diarrheal episodes.

There were several limitations in this study. First, this was not a cohort study; determining if the anemia status of individual participants changed over the six-year study period was impossible. However, given the stability of the *colonia* population between the two waves, it is likely that the women and children included in each wave of data collection had been permanent residents of the *colonia* during both data collection periods. Thus, it is probable that the populations tested at each time point were similar and were exposed to the same VIIDAI health interventions and free health clinics. Another limitation of this study is that participant enrollment was limited by the two-day data collection period. Within each wave, sample sizes were relatively small, especially among children. However, pooling data from each wave of data collection increased the power to identify factors associated with anemia for some variables (see Tables 3.2, 3.3, 3.4). Lastly, individual involvement in each of the community interventions and attendance at the free clinics was not assessed, thus, it was not feasible to identify a direct correlation between participation in health activities and anemia status.

CONCLUSION

A substantial decrease in anemia prevalence and severity was observed in our study, which may be attributable, in part, to the free clinics, nutritional counseling, vitamin supplements, as well as the community interventions such as the cookware exchange, recipe modifications, and the enhancement of the school kitchen. Nevertheless, the high prevalence of anemia observed in both women and children in Wave 2 indicates that anemia remains a public health problem in this *colonia* and that nutritional iron deficiency appears to be the underlying cause.

While the implementation of multiple community interventions likely contributed to the substantial reduction in anemia among women and children, a broader exploration of the factors contributing to anemia is necessary so mechanisms can be implemented to further reduce prevalence. We know the consumption of fresh produce is low among community residents and future directions may include the development of a nutrition education curriculum, improved access to nutritious foods (specifically foods enhancing iron absorption), and an exploration of community and government assistance programs available to low SES *colonia* residents. Integrated efforts are necessary to combat this public health problem.

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Decreased anemia prevalence among women and children in rural Baja California, Mexico: A six-year comparative study. The dissertation author was the primary investigator and author of this paper.

Table 3.1 Comparison of Anemia Prevalence and Severity in Women (15-49 years old) and Children (6-59 months old) in Waves 1 and 2

	Women 15-49 yrs			Children 24-59 mos			Children 6-23 mos		
	Wave 1 (n=201) *n* (%)	Wave 2 (n=146) *n* (%)	p	Wave 1 (n=71) *n* (%)	Wave 2 (n=53) *n* (%)	p	Wave 1 (n=28) *n* (%)	Wave 2 (n=24) *n* (%)	p
Anemic[a]	85 (42.3)	34 (23.3)	*<0.001*	33 (46.5)	16 (30.2)	0.066	20 (71.4)	11 (45.8)	0.061
Severity[b]			0.207			1.0			*0.013*
Mild	40 (47.7)	22 (64.7)	-	23 (69.7)	12 (75.0)	-	8 (40.0)	10 (90.9)	-
Moderate	40 (47.7)	11 (32.4)	-	9 (27.3)	4 (25.0)	-	11 (55.0)	1 (9.1)	-
Severe	5 (5.9)	1 (2.9)	-	1 (3.0)	0 (0)	-	1 (5.0)	0 (0)	-

[a]Anemia was classified by using HemoCue Hb results. Non-pregnant women (15-49 yrs) with Hb <12.0 g/dL were considered anemic. Pregnant women (15-49 yrs) and children (6-59mos) with Hb <11.0 g/dL were considered anemic.

[b]Anemia severity was further classified by Hb measurement. For non-pregnant women, the following categories were used: Mild Anemia = 11.0-11.9 g/dL, Moderate Anemia = 8.0-10.9 g/dL, Severe Anemia = < 8.0 g/dL. For pregnant women (15-49 yrs) and children (6-59 mos), the following categories were used: Mild Anemia = 10.0-10.9 g/dL, Moderate Anemia = 7.0-9.9 g/dL, Severe Anemia = < 7.0 g/dL.

Table 3.2 Bivariate Analysis of Demographic, Socioeconomic, and Health Characteristics by Anemia Status in Women (15-49 yrs) in Waves 1 and 2

	Wave 1			Wave 2			Total (Waves 1+2)		
	Anemic (n=85)	Non-Anemic (n=116)		Anemic (n=34)	Non-Anemic (n=112)		Anemic (n=119)	Non-Anemic (n=228)	
Variable	*n*±SD or n(%)	*n*±SD or n(%)	p	*n*±SD or n(%)	*n*±SD or n(%)	p	*n*±SD or n(%)	*n*±SD or n(%)	p
Age	29.9±10.0	30.2±8.9	0.850	30.5±9.5	29.1±8.3	0.393	30.1±9.9	29.6±8.6	0.672
Years of Residence[ab]	9.7±6.6	10.4 ± 6.4	0.632	16.1 ± 7.0	11.7 ± 7.7	*0.003*	12.6±7.4	11.3±7.4	0.203
Household Size[b]	5.6±2.7	5.2±2.4	0.384	5.5±1.7	5.9±2.6	0.295	5.6±2.3	5.7±2.6	0.765
Indigenous[a]	48 (57.8)	66 (60.6)	0.704	12 (35.3)	43 (38.7)	0.717	60 (51.3)	109 (49.5)	0.761
Low SES[b]	13 (29.5)	5 (10.6)	*0.024*	4 (11.8)	16 (14.4)	1.000	17 (21.8)	21 (13.3)	0.095
Occupation[ab]			0.146			0.328			*0.009*
Agricultural	37 (88.1)	36 (76.6)	-	12 (36.4)	35 (31.3)	-	49 (65.3)	71 (44.7)	-
Homemaker	2 (4.8)	1 (2.1)	-	17 (51.5)	71 (63.4)	-	19 (25.3)	72 (45.3)	-
Other	3 (7.1)	10 (21.3)	-	4 (12.1)	6 (5.4)	-	7 (9.3)	16 (10.1)	-
Education Completed[ab]			0.401			0.971			0.469
None	11 (25.0)	15 (32.6)	-	7 (20.6)	21(18.8)	-	18 (23.1)	36 (22.8)	
Primary	29 (65.9)	24 (52.2)	-	18 (52.9)	61 (54.5)	-	47 (60.3)	85 (53.8)	
Secondary	4 (9.1)	7 (15.2)	-	9 (26.5)	30 (26.8)	-	13 (16.7)	37 (23.4)	
Literacy[ab]	33 (75.0)	31 (67.4)	0.426	27 (81.8)	94 (83.9)	0.774	60 (77.9)	125 (79.1)	0.834
Season tested			0.114			0.791			0.366
Fall	44 (51.8)	47 (40.5)		20 (58.8)	63 (56.3)		64 (53.8)	110 (48.2)	
Spring	41 (48.2)	69 (59.5)		14 (41.2)	49 (43.8)		55 (46.2)	118 (51.8)	
Food Intake ≤ 48hrs[a]									
Heme Iron (meat)	52 (61.9)	75 (67.0)	0.463	15 (75.0)	46 (73.0)	0.861	67 (64.4)	121 (69.1)	0.416
Iron Absorption Enhancing Foods	56 (66.7)	89 (79.5)	*0.043*	17 (85.0)	53 (84.1)	1.000	73 (70.2)	142 (81.1)	*0.035*
Iron Absorption Inhibiting Foods	82 (97.6)	109 (97.3)	1.000	28 (93.3)	102 (99.0)	0.127	110 (96.5)	211 (98.1)	0.455
Use Painted Cookware[ab]	18 (40.9)	13 (28.3)	0.207	3 (8.8)	21 (19.3)	0.195	21 (26.9)	34 (21.9)	0.398
Diarrhea ≤ 2 wks[a]	7 (9.2)	6 (5.6)	0.350	4 (11.8)	16 (14.3)	0.785	11 (10.0)	22 (10.0)	0.990

[a]Variables with missing data: Years of residence (Wave 1 N=86, Wave 2 N=145), Indigenous (Wave 1 N=192, Wave 2 N=145), Occupation (Wave 1 N=89, Wave 2 N=145), Education (Wave 1 N=90, Wave 2 N=145), Literate (Wave 1 N=90, Wave 2 N=145), Food intake (Wave 1 N=196, Wave 2 (only 2011) N=83), Painted cookware (Wave 1 N=90, Wave 2 N=143), Diarrhea ≤ 2 wks (Wave 1 N=183).

[b]Data not available for 2005 for these variables. For variables without missing data: Wave 1 N=91 (44 anemic, 47 not anemic).

Table 3.3 Bivariate Analysis of Maternal Characteristics by Anemia Status in Women (15-49 yrs) in Waves 1 and 2

Variable	Wave 1 Anemic (n=85) *n*±SD or n (%)	Wave 1 Non-Anemic (n=116) *n*±SD or n (%)	p	Wave 2 Anemic (n=34) *n*±SD or n (%)	Wave 2 Non-Anemic (n=112) *n*±SD or n (%)	p	Total (Waves 1+2) Anemic (n=119) *n*±SD or n (%)	Total (Waves 1+2) Non-Anemic (n=228) *n*±SD or n (%)	p
Parity	3.8±2.8	3.7±2.9	0.803	3.4±2.3	2.8±1.9	0.162	3.7±2.7	3.3±2.5	0.125
Currently Pregnant	4 (4.7)	8 (6.9)	0.565	1 (2.9)	7 (6.3)	0.681	5 (4.2)	15 (6.6)	0.367
Currently Breastfeeding[a]	17 (21.8)	22 (20.4)	0.814	2 (5.9)	23 (20.7)	0.067	19 (17.0)	45 (20.5)	0.435
Currently Menstruates[a]	74 (91.4)	98 (89.1)	0.605	28 (84.8)	82 (75.2)	0.247	102 (89.5)	180 (82.2)	0.080
Gave birth < 6 mos[a]	7 (9.0)	5 (4.7)	0.248	2 (5.9)	7 (6.3)	1.000	9 (8.0)	12 (5.5)	0.378

[a]Variables with missing data: Currently breastfeeding (Wave 1 N=186, Wave 2 N=145), Currently menstruates (Wave 1 N=191, Wave 2 N=142), Gave birth < 6 mos (Wave 1 N=184, Wave 2 N=145).

Table 3.4 Bivariate Analysis of Demographic, Health, and Socioeconomic Characteristics by Anemia Status in Children (6-59 months) in Waves 1 and 2

	Children 24-59 mos Waves 1 and 2			Children 6-23 mos Waves 1 and 2		
	Anemic (n=49)	Non-Anemic (n=75)		Anemic (n=31)	Non-Anemic (n=21)	
Variable	*n*±SD or n (%)	*n*±SD or n (%)	p	*n*±SD or n (%)	*n*±SD or n(%)	p
Age of Mother	26.6±7.0	28.4±7.0	0.161	26.2±8.2	25.4±6.9	0.727
Anemic Mother[a]	17 (35.4)	17 (22.7)	0.123	12 (41.4)	4 (20.0)	0.136
Indigenous[a]	22 (52.4)	39 (53.4)	0.914	13 (43.3)	10 (47.6)	0.762
Household Size[b]	5.8±2.4	5.8±2.2	0.955	5.8± 2.7	8.1±2.8	*0.017*
Low SES household[b]	6 (18.2)	10 (18.5)	0.969	8 (36.4)	3 (18.8)	0.296
Breastfeeding[a]	-	-	-	10 (60.0)	8 (38.1)	0.124
Diarrhea ≤ 2 wks[a]	15 (34.9)	9 (13.2)	*0.007*	9 (33.3)	9 (47.4)	0.337
Maternal Occupation[b]			0.119			0.587
Agricultural	18 (54.5)	29 (53.7)	-	11 (50.0)	8 (53.3)	-
Homemaker	9 (27.3)	22 (40.7)	-	9 (40.9)	7 (46.7)	-
Other	6 (18.2)	3 (5.6)	-	2 (9.1)	0 (0)	-
Maternal Education[b]			0.357			0.284
None	11 (33.3)	11 (20.4)	-	8 (36.4)	2 (12.5)	-
Primary	14 (42.4)	30 (55.6)	-	9 (40.9)	8 (50.0)	-
Secondary	8 (24.2)	13 (24.1)	-	5 (22.7)	6 (37.5)	-
Maternal Literacy[ab]	29 (90.6)	43 (79.6)	0.235	13 (61.9)	8 (38.1)	0.050
Season Tested			0.976			0.397
Fall	26 (53.1)	40 (53.3)		17 (54.8)	9 (42.9)	
Spring	23 (46.9)	35 (46.7)		14 (45.2)	12 (57.1)	
Use Painted Cookware[ab]	6 (18.2)	13 (24.1)	0.519	3 (15.0)	4 (26.7)	0.672

[a]Missing data for children 24-59 months: Anemic mother (N=123), Indigenous (N=115), Breastfeeding (N=116), Diarrhea ≤ 2 wks (N=111), Maternal literacy (N=86). Variables with missing data for children 6-23 months are as follows: Anemic mother (N=49), Indigenous (N=51), Breastfeeding (N=51), Diarrhea ≤ 2 wks (N=46), Maternal literacy (N=37), Use Painted cookware (N=35).
[b]Data not available for 2005 for these variables. For variables without missing data, among children 24-59 months, N=87 (33 anemic, 54 not anemic). For variables without missing data, among children 6-23 months, N=38 (22 anemic, 16 not anemic).

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CHAPTER 4

Individual and Community Factors Contributing to a High Prevalence of Nutritional Anemia Among Women and Children Living in Rural Baja California, Mexico

ABSTRACT

A high prevalence of anemia exists among women and children in rural Baja California, Mexico. This study examined the etiology and factors contributing to anemia in women and children. A cross-sectional study of 118 women (15-49 years) and 25 children (24-59 months) was performed in rural Baja California, Mexico in 2012. Participants completed a survey and provided a capillary blood sample. A portable HemoCue was used to measure hemoglobin and diagnose anemia. Anemic participants provided a venous blood sample for laboratory testing to elucidate the etiology of anemia. Prevalence of anemia was 22% in women and 20% in children. Women from low SES households and women enrolled in the government assistance program *Prospera* were significantly more likely to be anemic (OR=3.48, 95% CI 1.35-8.98 and OR=2.49, 95% CI 1.02-6.09, respectively). Vitamin supplementation was protective against anemia (OR=0.12, 95% CI 0.02-0.94). Iron deficiency anemia was the primary etiology in 100% of children and 80.8% of women, followed by vitamin B-12 deficiency (11.5%) and combined iron and vitamin B-12 deficiency (7.7%). Implementing programs designed to improve nutrition and health literacy, in conjunction with ensuring access to nutritious foods, might reduce nutritional anemia within the community.

INTRODUCTION

Anemia is a significant public health problem in developing countries, and occurs more frequently in pre-school age children and women of childbearing age.[1,2] National studies show the prevalence of anemia in Mexico has decreased in the past decade[3–6] and is currently 11.6% among non-pregnant women, 17.9% among pregnant women,[4,5] and 23.3% among children 12-59 months of age.[5] Some of the reduction in anemia prevalence has been ascribed to the implementation of government programs.[6] Of particular relevance is a national Mexican program, *Prospera* (formerly called *Oportunidades*), which provides food subsidies, cash incentives, and healthcare services to impoverished families in designated communities to improve quality of life.[7,8] Enrollment in *Prospera* has been associated with decreased anemia prevalence,[3,8,9] with one study indicating that children who received assistance from *Prospera* were 25.5% less likely to be anemic than children who did not receive benefits from the program.[10]

While programs have been implemented to improve the health of rural, marginalized Mexican citizens, anemia rates still remain higher among Mexicans residing in rural areas than in urban environments.[11] In a prior study conducted by our institutions, we examined anemia prevalence among women and children living in a rural, farming *colonia* (small settlement) in Baja California, Mexico. Results revealed an anemia prevalence rate of 23.3% among women and 30.2% among children in 2012, which is substantially higher than the national average.[12] However, the study provided only limited information concerning the etiology of anemia. Evidence from dietary recall and blood smears collected in the previous study showed that iron deficiency was the probable cause; however, other contributing factors could not be dismissed. While iron deficiency is the most common cause of anemia,[2,13] studies show that nutrient deficiencies including vitamin B-12 and folate,[14,15] as well as lead toxicity due to use of lead-glazed painted cookware,[16] may contribute to anemia among Mexicans. The purpose of this study was to determine the etiology of anemia, and to identify the individual and community factors contributing to a high prevalence of anemia among women and children in rural, Baja California, Mexico.

METHODS

A cross-sectional study was conducted during a two-day period in October 2012 in a rural *colonia* located near San Quintín, Baja California, Mexico. This study was performed in conjunction with VIIDAI (Viajes Interinstitucional de Integración, Docente, Asistencia y de

Investigación/ Inter-institutional Field Experiences for Integration, Teaching, Medical Service, and Research), a binational public health training program between San Diego State University (SDSU), University of California San Diego (UCSD), and Universidad Autónoma de Baja California, Tijuana (UABC).[12,17,18] VIIDAI affords students an opportunity to provide supervised clinical and public health services to underserved communities. Approval for this study was granted by the SDSU, UCSD, and UABC Institutional Review Boards. Informed consent was obtained from all study participants.

Study Setting

San Quintín is located in an agricultural region of Baja California, approximately 200 miles south of the California, USA/Baja California, Mexico border. Several small, rural, *colonias* are located near San Quintín that are populated primarily by indigenous peoples who migrated from southern Mexico to work in the agricultural fields[19] and have since established permanent residency in the region due to the consistent availability of work. As of the 2010 census, approximately 3800 individuals reside in the *colonia* where this study was conducted.[20]

Sampling Techniques

The study population included women of childbearing age (15-49 years) and their young children (24-59 months). Participants were recruited in one of two settings: the VIIDAI clinic or the participant's home. In the clinic setting, random sampling was performed to screen individuals for study participation among women waiting in line to see a provider. For household enrollment, a map of the *colonia* was used to randomly select blocks of homes in the *colonia* for inclusion in the study. Each household in the designated block was approached for study participation, beginning at the northeast corner and continuing in a clockwise manner until all houses on the block were approached. Individuals were eligible for the study if they were women between the ages of 15-49 years with the ability to speak Spanish. One woman and one child between the ages of 24-59 months per household were allowed to participate in the study. If more than one child was eligible, the eligible individuals rolled a pair of dice, and the child who rolled the highest number was included in the study. Persons were not eligible if their primary residence was in a different community or they did not meet the age criteria. We enrolled as many participants as possible during the two-day data collection timeframe.

Survey Instrument

An English questionnaire containing demographic, socioeconomic, and health factors putatively related to anemia was developed, translated into Spanish, and then back translated into English to confirm accuracy. The Spanish survey was then pilot tested among indigenous persons to ensure comprehension. Administration of the survey among study participations occurred via face-to-face interviews at the clinic or in the participants' homes. Ownership of specific household items including a refrigerator, vehicle, radio, television, and phone were used to create a socioeconomic status (SES) score, with one point given for ownership of each item. Thus, SES scores ranged from 0-5; a score of 0-2 was considered low SES. Dietary intake data was based on a yes or no response to a 48-hour recall of the consumption of specific food items and beverages. Occupation was categorized in three ways: 'agricultural' referred to a person employed as a field laborer, a 'homemaker' was a female not currently working outside of the home, and 'other' included business owners or women employed outside of the home, but not working in the agricultural industry. Literacy was defined by an individual's self-reported ability to read a newspaper and write a letter. Additional questions concerning attendance at the VIIDAI medical clinics and participation in government assistance programs were also asked. All surveys were conducted in Spanish.

Collection of Blood Samples & Diagnosis of Anemia

Anemia testing was performed among all participants. Each study participant provided a capillary blood sample obtained by finger prick. The initial diagnosis of anemia was performed by measuring hemoglobin (Hb) with a portable HemoCue photometer (Hemocue AB, Angelholm, Sweden). Non-pregnant women 15-49 years of age with Hb levels of less than 12.0 g/dl, and pregnant women and children with Hb levels of less than 11.0 g/dl were considered anemic (WHO 2011). A sample of venous blood was collected from women and children diagnosed with anemia, and blood smears were also prepared. The blood was collected in vacutainer tubes and kept refrigerated until delivery to a laboratory where complete blood count (CBC) with differential, serum iron, iron saturation, total iron binding capacity (TIBC), transferrin, unsaturated iron binding capacity (UIBC), ferritin, vitamin B-12, folate, and lead tests were performed. A hematopathologist reviewed blood smears and laboratory results to classify anemia and determine etiology. *Mild anemia* was defined as Hb levels of 11.0-11.9 g/dl for non-pregnant women, and 10.0-10.9 g/dl for pregnant women and children. *Moderate anemia* was defined as 8.0-11.0 g/dl for non-pregnant women, and 7.0-10.0 g/dl for pregnant women and children. *Severe anemia* was defined as Hb levels below 8.0 g/dl for non-pregnant women, and below 7.0 g/dl for pregnant women and children.[21] Blood lead levels were tested in all anemic individuals and values of greater than 19 ug/dL in adults and greater than 5 ug/dL in children were used to diagnose lead poisioning. Isolated iron deficiency anemia was diagnosed by low serum iron (below 35 ug/dL), low transferrin saturation (below 15%), low ferritin (below 13 ng/mL), high TIBC (above 450 ug/dL), or high UIBC (above 375 ug/dL). Anemia due to vitamin B-12 deficiency was defined as having vitamin B-12 levels below 211 pg/mL. Folate deficiency was defined as folate levels below 3.1 ng/mL. In cases where some laboratory parameters may have appeared within normal limits, participants were evaluated for chronic diseases and/or early iron deficiency anemia.

Individuals diagnosed with anemia received a consultation from a medical professional that included education about the causes and prevention of anemia and were provided with vitamin supplements.

Grocery Store Assessments

Observational *tienda* (small, local convenience/grocery store) assessments served as a mechanism to examine the quantity and quality of food available for consumption by community residents. There are no supermarkets located within the *colonia*, and the closest supermarket is over 5 miles away, so many residents, especially those without a vehicle, utilize *tiendas* as their primary source to purchase food. In addition to the *tiendas*, residents have the ability to purchase food and other goods during a weekly swap meet held in the community. There are approximately 15 *tiendas* situated within the *colonia*. To ascertain the types of foods available for purchase, 6 (40%) of these *tiendas* were randomly selected and visited. Data collected included store size, capacity, and food items available for purchase. The size of the store was classified by the number of aisles and registers; small stores had 2 aisles or less, medium stores had 3-4 aisles, and large stores had at least 5 aisles. Stores were also considered large in size if they contained more than one cash register. Approval to survey the store was obtained from the individual who was responsible for overseeing the store on the day of the visit. A total of 6 *tiendas* were approached for study inclusion and all agreed to participate.

Statistical Analysis

Continuous variables were checked for normality and descriptive statistics were calculated for all variables. Chi-square tests were used to examine categorical variables and independent sample t-tests were used to examine continuous variables to assess the differences in anemic and non-anemic individuals. Unadjusted odds ratios (OR) with 95% confidence intervals (CI) were computed to determine associations with anemia status.

A separate stratified analysis was performed to determine if enrollment in *Prospera* was an effect modifier for dietary intake and anemia status. We elected to perform this evaluation because participation in *Prospera* increases a household's income; thus, enrolled households may have additional money to purchase food or vitamin supplements.

A multivariate logistic regression analysis was also performed and included variables that were significantly associated with anemia status during bivariate analysis. All statistical tests were two-tailed; p-values less than 0.05 were considered statistically significant. Data were analyzed using PASW Statistics version 18.0 (SPSS Inc., Chicago, IL). A post-hoc power analyses was also calculated using G*Power version 3.1.6 (Franz Faul, Kiel University, Kiel, Germany).

RESULTS

Participant Characteristics

A total of 118 women (9 (7.6%) of whom were pregnant) and 25 children completed the anemia survey and underwent anemia testing; 40 (35%) of the women and 6 (24%) of children were enrolled from the clinic, the remaining individuals were enrolled from community households. The mean age of women in the study was 29.7±9.0 years and the mean age of children was 3.3±0.98 years. Results showed that the overall anemia prevalence was 22% among both pregnant and non-pregnant women (Table 4.1). There was no significant difference in prevalence of anemia by location of enrollment (Table 4.2). Among those women who were anemic, the majority of cases were mild or moderate in severity (Table 4.1). Anemia prevalence was 20% among children, with most cases (75%) defined as mild (Table 4.1).

Demographic Characteristics

Demographic and household characteristics were compared between anemic and non-anemic women. Anemic women were more likely (OR=3.48, 95% CI 1.35-8.98) to reside in a low SES household than women who were not anemic (Table 4.2). No differences were found between clinic and household participants with respect to demographic or SES characteristics (data not shown). Other comparisons between anemic and non-anemic participants are shown in Table 4.2.

Maternal Characteristics & Participation in Health Programs

With respect to participation in health programs, anemic women were more likely (OR=2.49, 95% CI 1.02-6.09) to be enrolled in the government program *Prospera*, as compared to non-anemic women (Table 4.2). Attendance at a VIIDAI clinic within the past 5 years was 66.1% among all women regardless of anemia status. However, no differences in VIIDAI clinic attendance rate were found between anemic and non-anemic women (Table 4.2). Overall, 66.9% of females reported receiving nutrition education either from VIIDAI programs intended to decrease anemia or from outside sources such as *Prospera*, but nutrition education was not associated with decreased likelihood of being anemic (Table 4.2).

Twelve (48%) of the 25 children in our study were enrolled in *Prospera*. Among children, there was no association between anemia and enrollment in *Prospera* (OR=0.21, 95% CI 0.19-2.17).

Dietary Characteristics

Dietary intake was compared between anemic and non-anemic women. Vitamin use was protective against anemia, with significantly lower rates of anemia among those reporting vitamin use (OR=0.12, 95% CI 0.02-0.94, Table 4.2). Vitamin use was 66.7% among pregnant women and 16.5% among non-pregnant women (p=0.002). Of note, vitamin use was not associated with participation in *Prospera* (p=0.512) or visiting a VIIDAI clinic (p=0.583). The consumption of citrus juice (containing vitamin C), which enhances the body's ability to absorb iron, approached significance as being protective against anemia (OR=0.44, 95% CI 0.18-1.07, Table 4.2). While no statistically significant differences in food and drink intake were found among anemic and non-anemic women, consumption of citrus juice and green vegetables (sources of vitamin C), and beef (a source of iron and vitamin B-12) were somewhat higher among non-anemic women (Table 4.2). There was no significant difference in food intake based on enrollment in *Prospera* (data not shown).

Multivariate Results

Logistic regression simultaneously examining the associations of SES, enrollment in *Prospera*, and vitamin supplement use showed that after adjusting for the remaining variables, each variable was independently and significantly associated with anemia. Women from low SES households were more likely (OR=4.37, 95% CI 1.51-12.60) to be anemic compared to women from higher SES households. Odds of being anemic were 3.59 times higher (95% CI 1.32-9.78) among women enrolled in *Prospera* compared to women not enrolled in *Prospera*. Vitamin supplement use was protective against anemia; the odds of being anemic were lower (OR=0.11, 95% CI 0.01-0.90) among women who used vitamin supplements compared to those who did not use vitamins (Table 4.3). No significant interactions were found between the variables.

Laboratory Findings

Twenty-six women were anemic and laboratory blood tests showed 18 cases of microcytic anemia, four cases of macrocytic anemia, and four cases of normocytic anemia.

Seventeen of the 18 cases of microcytic anemia showed clear evidence of iron deficiency anemia, and the remaining case exhibited both iron deficiency and vitamin B-12 deficiency. No peripheral blood smear or laboratory evidence of concomitant thalassemia was noted in the iron deficient individuals. Three of four cases of macrocytic anemia had vitamin B-12 deficiency, and one case had a vitamin B-12 deficiency and iron deficiency. In all four of the normocytic anemia cases, ferritin was on the lower end of the reference range and TIBC was on the higher end of reference range, which is consistent with early iron deficiency anemia. Among women, iron deficiency accounted for 65.4% of anemia cases, vitamin B-12 deficiency was implicated in 11.5% of anemic women, 7.7% of females had both iron and vitamin B-12 deficiencies, and 15.4% of anemia cases were attributed to early iron deficiency anemia (Table 4.4). Etiology of anemia among the two pregnant women was iron deficiency and vitamin B-12 deficiency. Microcytic anemia was present in all cases of anemia in children. Subsequent iron studies showed decreased iron stores, indicating that iron deficiency was the principal cause (Table 4.4). No cases of elevated blood lead levels were found among women or children.

Grocery Store Assessments

Assessments were performed in six *tiendas* (1 small, 2 medium, and 3 large). Five *tiendas* had one cash register, and one *tienda* had two cash registers. General characteristics of the capacity and departments of the *tiendas* are as follows: all stores had refrigerator doors (range 1-9 doors), four stores had freezer doors (three stores had one freezer door, one store had two), all stores sold produce, and three stores sold raw meat (only 2 of these had a butcher service counter). None of the stores sold prepared foods or had vending machines. Dry food items were available for purchase at all *tiendas* and included fortified dried cereal, legumes, and enriched pasta. Perishable goods including milk and eggs were available for purchase at all stores; however, meat selection (sources of iron and vitamin B-12) was limited with four stores selling chicken, three stores offering beef and turkey, and two stores selling pork. No fresh fish, frozen fish, or organ meats were found in any of the stores, but canned sardines and tuna were available for purchase at all stores. While produce containing vitamin C was available at all stores, the selection was limited; at least one variety of citrus fruit was offered at each store, potatoes (another good source of vitamin C) were also available at all stores; however, leafy green vegetables were only available for purchase at one store. A wide assortment of pre-packaged, high caloric, low nutrient 'junk food' items were also available for purchase at all stores.

DISCUSSION

With anemia prevalence nearly double the national average among non-pregnant women,[4,5] anemia is a public health concern in this *colonia*. Low SES and enrollment in *Prospera* were significantly associated with anemia among women, whereas vitamin supplement use was protective against anemia. These findings suggest that poverty, in conjunction with limited nutritious food available for purchase at local *tiendas*, contribute to the high prevalence of nutritional anemia in this community. While the presence of *Prospera* in the *colonia* implies that government support is available to improve the health and SES of qualifying households, its effectiveness is unclear. Our findings suggest that improving the penetration of *Prospera*, promoting nutritional education and health literacy, and enhancing access to nutritious foods, may decrease the prevalence of anemia in this *colonia*.

Iron deficiency was the primary cause of anemia in all of the children and 80.8% of women in our study. This is consistent with other studies delineating iron deficiency as the primary etiology of anemia in Mexico.[15,22] Because nutritional deficiencies were the primary cause of anemia, it is not surprising that the use of vitamin supplements was protective against anemia in this community. A previous study reported that vitamins are used by 18% of Mexican women and are protective against anemia.[23] Prevalence of vitamin use among women in our study was similar (20.3%), and we also found vitamins to be protective against anemia. Previously, we have shown that women in the community who consumed four or more servings of leafy green vegetables per week (a good source of vitamin C which enhances the body's ability to absorb iron) were less likely to be anemic.[12] While poor diet is clearly the primary contributing factor to being anemic within this community, no significant associations were evident between food items consumed within the past 48 hours and anemia status. This could be due to the fact that serving sizes and amounts were not assessed, as well as the fact that the study was underpowered to detect dietary differences. A study measuring dietary intake among women from central Mexico showed that iron deficiency was not necessarily due to low iron intake, but instead attributed to lower intake of foods containing non-heme iron (vegetables, grains, and nuts) and foods containing vitamin C (which enhances the body's ability to absorb iron).[24] An intervention conducted in central Mexico which included the twice-daily addition of 25 mg of vitamin C to meals found that iron absorption improved from 6.6% at baseline to 22.9% after 2 weeks.[24] Interestingly, in our study the consumption of citrus juice (a source of vitamin C) was much higher among non-anemic women (72.8%), as compared to anemic women (53.8%). This finding suggests that increasing vitamin C intake, and encouraging the simultaneous consumption of iron and vitamin C, may be a feasible method for improving iron absorption and decreasing iron deficiency anemia.

Contrary to previous studies that found enrollment in *Prospera* was protective against anemia among children;[3,8] our study found that women enrolled in the program were significantly more likely to be anemic. There are several plausible explanations for this finding. First, the duration of enrollment in *Prospera* was not obtained; thus, the females in our study who were also enrolled in *Prospera* may not have received monetary and health benefits for a long enough time period to show tangible improvement in health measures such as anemia.

Secondly, we found that the poorest households in the community were not necessarily the households that were enrolled in the *Prospera* program. Long-term program enrollment may have helped the lowest SES households to move higher on the SES spectrum as a result of stipends received from participation. Unfortunately, the amount of money each household received from their enrollment in *Prospera* was also unknown among participants in this study. Public data indicates the stipends range from $10 to over $150 USD per month based on maternal characteristics (i.e. currently pregnant or lactating), as well as the age, gender, and education level of children living in the household.[25]

We were unable to account for the lack of differences in food consumption and anemia status based on *Prospera* enrollment, but speculate that women enrolled in *Prospera* may not be using their stipends to purchase nutritious foods which may result from the limited availability of nutritious food available for purchase. Grocery store surveys revealed limited availability of fresh produce within the community; thus, it is possible that the money provided to households from *Prospera* is not used to purchase nutritious foods. One study found that improvements in nutrition as a result of enrollment in *Prospera* may actually be due to intake of fortified food supplements, as opposed to dietary changes in food consumption within the home.[26]

Despite many community members working in the agricultural industry, most fresh fruits and vegetables are not consumed locally because they are exported to the United States for consumption.[27] Mexico is the second largest supplier of agricultural goods to the US, with fresh vegetables and fruit accounting for the majority of agricultural exports.[27] Since produce commands a higher market price in the US, it is more profitable for them to be exported rather than sold locally within Mexico. Similar to other studies,[6,11] we found that women of low SES were more likely to be anemic than women of higher household SES, which may indicate that price, as well as availability, of fresh produce make regular consumption more difficult. Our study showed no difference in dietary intake based on enrollment in *Prospera*, suggesting that the ability to consume nutritious foods may be a result of limited food availability in the community. Even with the additional income provided by *Prospera*, if local *tiendas* do not sell fresh produce, being enrolled in *Prospera* may not improve one's diet. Perhaps creating government partnerships with agricultural corporations to provide subsidized produce to local *tiendas* is a means to improve access to nutritious food for impoverished households.

Although this study successfully identified factors associated with anemia in a community with a history of a high prevalence of this disease, it has several limitations. The two-day data collection period resulted in a small overall sample size. While the study found significant associations between anemia and SES, *Prospera* enrollment, and vitamin consumption, the precision of these measures was limited by the small sample size. Furthermore, the study was underpowered to detect differences among some variables, particularly dietary characteristics. Post-hoc power analyses showed that 80% power was not achieved for any of the examined associations between the dietary intake variables and anemia status. The cross-sectional design impeded the exploration of causal relationships between the duration of enrollment in *Prospera* and anemia status, as well as the extent to which the *Prospera* stipend improves SES and the consumption of nutritious foods. We also do not know how many of the households in our study met the inclusion criteria for the *Prospera* program, but were not enrolled. Furthermore, the *Prospera* program is primarily designed to benefit children; however, our study was underpowered to evaluate the effects of the program among children due to the small sample size. Another potential shortcoming of the study is recall bias, specifically for dietary intake. Because participants were asked to report food and beverages consumed in the past 48 hours, recall inaccuracies may have impacted the ability to distinguish associations between food consumption and anemia. Despite this weakness, there were dietary trends supporting the laboratory evidence of anemia due to nutritional deficiencies. Obtaining venous blood samples from all participants, rather than just anemic individuals, would have been beneficial in uncovering the overall prevalence of nutrient deficiencies in the community and revealing if all community members, not just anemic individuals, would benefit from future nutritional interventions.

In summary, while vitamin supplements are effective in preventing anemia, they may not be a long-term solution. Following households who are beneficiaries of *Prospera* and measuring their health metrics over a period of time would be one way of determining if the program is effective in this community. In the meantime, more readily introduced health literacy interventions may include providing additional nutrition education, particularly to those enrolled in *Prospera*, emphasizing the importance of consuming iron and vitamin C together, and identifying and labeling nutrient-rich foods at local *tiendas* to promote the purchase of healthy foods by community members.

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Table 4.1 Prevalence and Severity of Anemia in Women and Children Living in a Rural Farming Community in Baja California, Mexico [2012]

	Non-Pregnant Women (n=109) n (%)	Pregnant Women (n=9) n (%)	Children (n=25) n (%)
Anemic[a]	24 (22.0)	2 (22.2)	5 (20.0)
Severity[b]			
Mild	7 (29.2)	1 (50.0)	4 (75.0)
Moderate	15 (62.5)	1 (50.0)	1 (25.0)
Severe	2 (8.3)	0 (0)	0 (0)

[a]Anemia was classified as having Hb of <12.0 g/dL among non-pregnant women and <11.0 g/dL among pregnant women and children 24-59 mos.

[b]Anemia severity among non-pregnant women (15-49 yrs) was classified as follows: Mild Anemia = 11.0-11.9 g/dL, Moderate Anemia = 8.0-10.9 g/dL, Severe Anemia = < 8.0 g/dL. For pregnant women (15-49 yrs) and children (24-59 mos), the following anemia classifications were used: Mild Anemia = 10.0-10.9 g/dL, Moderate Anemia = 7.0-9.9 g/dL, Severe Anemia = < 7.0 g/dL

Table 4.2 Associations between Demographic, SES, and Health Variables and Anemia Status in Women Living in a Rural Farming Community in Baja California, Mexico [2012] (n=118)

Variable	Anemic (n=26) mean±SD or n (%)	Not Anemic (n=92) mean±SD or n (%)	OR (95% CI)	p
Demographic Characteristics				
Age	30.3 ± 9.0	29.5 ± 9.1	1.01 (0.96-1.06)	0.681
Survey Location[a]				0.403
Home[b]	18 (72.0)	56 (62.9)	-	
Clinic	7 (28.0)	33 (37.1)	0.66 (0.25-1.75)	
Occupation				0.141
Agriculture[b]	10 (38.5)	34 (37.0)	-	
Homemaker	16 (61.5)	46 (50.0)	1.18 (0.48-2.92)	0.717
Other	0 (0)	12 (13.0)	-	
Low SES	11 (42.3)	16 (17.4)	3.48 (1.35-8.98)	*0.010*
Speak Indigenous Language	7 (26.9)	27 (29.3)	0.89 (0.33-2.5)	0.810
Education Completed				0.811
None[b]	4 (15.4)	12 (13.0)	-	
Primary	16 (61.5)	53 (57.6)	0.91 (0.26-3.20)	0.878
Secondary or more	6 (23.1)	27 (29.3)	0.67 (0.16-2.80)	0.580
Literacy	23 (88.5)	81 (88.0)	1.04 (0.27-4.05)	0.954
Uses painted cookware[a]	2 (8.0)	6 (6.7)	1.22 (0.23-6.44)	0.817
Maternal & Health Characteristics				
Number of Pregnancies	2.6 ± 1.7	3.0 ± 2.3	0.91 (0.73-1.13)	0.385
Currently Pregnant	2 (7.7)	7 (7.6)	1.01 (0.20-5.19)	0.989
Gave Birth ≤6 months	2 (7.7)	5 (5.4)	1.45 (0.27-7.95)	0.669
Currently Breastfeeding[a]	3 (13.0)	15 (16.9)	0.74 (0.20-2.81)	0.658
Enrolled in *Prospera*	16 (61.5)	36 (39.1)	2.49 (1.02-6.09)	*0.046*
Visited VIIDAI clinic ≤5yrs	19 (73.1)	59 (64.1)	1.52 (0.58-3.99)	0.397
Received nutrition education	17 (65.4)	62 (67.4)	0.94 (0.37-2.29)	0.848
Dietary Characteristics				
Foods Consumed ≤48 hrs				
Fish	8 (30.8)	33 (35.9)	0.80 (0.31-2.03)	0.630
Beef	19 (73.1)	77 (83.7)	0.53 (0.19-1.48)	0.224
White Meat	22 (84.6)	78 (84.8)	0.99 (0.30-3.30)	0.983
Eggs	25 (96.2)	83 (90.2)	2.71 (0.33-22.45)	0.355
Cereal	19 (73.1)	63 (68.5)	1.25 (0.47-3.30)	0.653
Nuts	6 (23.1)	21 (22.8)	1.01 (0.36-2.85)	0.979
Legumes	26 (100)	91 (98.9)	-	-
Dried Fruit	7 (26.9)	21 (22.8)	1.25 (0.46-3.37)	0.665
Grains, tortillas, pasta	25 (96.2)	91 (98.9)	0.28 (0.02-4.55)	0.367
Green, leafy vegetables	10 (38.5)	49 (53.3)	0.55 (0.23-1.34)	0.186
Beverage Intake ≤48 hrs				
Tea	12 (46.2)	40 (43.5)	1.11 (0.47-2.67)	0.808
Coffee	19 (73.1)	66 (71.1)	1.07 (0.40-2.84)	0.893
Citrus Juice	14 (53.8)	67 (72.8)	0.44 (0.18-1.07)	0.069
Alcohol	1 (3.8)	2 (2.2)	1.80 (0.16-20.67)	0.637
Vitamin Supplement Use	1 (3.8)	23 (25.0)	0.12 (0.02-0.94)	*0.043*

[a]Data were missing for some variables and the total sample size for each variable is as follows: currently breastfeeding (n=112), survey location (n=114), use of painted cookware (n=115)

[b]Indicates reference category

Table 4.3 Multivariate Logistic Regression Analysis of Demographic, SES, and Health Variables Associated with Anemia in Women Living in a Rural Farming Community of Baja California, Mexico [2012] (n=118)

Variable	Odds Ratio	95% CI	P
Low SES	4.37	1.51-12.60	0.006
Enrolled in *Prospera*	3.59	1.32-9.78	0.012
Vitamin Supplement Use	0.11	0.01-0.90	0.039

Table 4.4 Etiology of Anemia among Women and Children in a Rural Farming Community of Northern Baja California, Mexico [2012]

	Women (15-49 yrs) (n=26) n (%)	Children 24-59 mos (n=4)[a] n (%)
Iron deficiency	17 (65.4)	4 (100)
Early Iron deficiency	4 (15.4)	0 (0)
B-12 deficiency	3 (11.5)	0 (0)
Iron + B-12 deficiency	2 (7.7)	0 (0)
Lead	0 (0)	0 (0)

[a]A blood sample could not be obtained from 1 of the 5 anemic children.

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CHAPTER 5

Discussion and Conclusions

Overview

This dissertation was undertaken to address the following objectives: 1) To describe the development of VIIDAI as a binational public health training program and illustrate how the collaboration of universities, NGOs, and community members creates a synergistic effect in conducting rapid health assessments, implementing intervention projects, and obtaining long-term outcome information, 2) To compare the prevalence and correlates of anemia among women and children in a rural, Mexican *colonia* over a six year timespan to determine if there were significant decreases in anemia prevalence following the implementation of community health interventions, and 3) To determine the etiology of anemia among women and children living in a rural Mexican *colonia* and to identify the individual and community factors that contribute to anemia.

VIIDAI: A Framework for Collaborative Binational Research

As the field of public health has become increasingly complex, students must receive cross-cultural, multidisciplinary training in order to be equipped to address emerging global health problems. VIIDAI was established to meet this demand by allowing students to engage in a skill-building, collaborative, binational public health field experience. Consisting of a partnership between universities, NGOs, and a rural, indigenous Mexican *colonia*, VIIDAI employs a CBPR model to create an environment in which all stakeholders participate equitably. Studies show that the trusting relationship of CBPR yields improved community support and participation.[1] Key elements of VIIDAI's success include the engagement of community members in identifying and prioritizing health needs, ensuring the capacity to execute projects effectively, and receiving constructive program evaluation. Furthermore, all entities benefit from the collaboration. Community members receive access to free primary and specialty health care services, along exposure to tailored public health interventions.

University faculty oversee clinical and public health services, receive teaching credit, offer mentorship for dissertation and thesis projects, and have the opportunity to develop grant-funded projects. Students gain cultural awareness, clinical and/or public health knowledge, and develop field research skills required to serve as future responders for global humanitarian, disaster, and outbreak efforts. NGOs contribute to community empowerment by supporting the delivery of health interventions and sponsoring community development projects.

The framework of the synergistic VIIDAI partnership combines the resources required to jointly address community health needs. Community-requested rapid health assessments are conducted during the 4-day field experience, with findings used to implement sustainable solutions over successive trips. This structure is conducive to initiating and evaluating long-term community health projects. The examination of anemia within the community is an example of a VIIDAI public health study that follows this format.

Prevalence and Correlates of Anemia in Mexico

Results from the initial assessment of anemia in Wave 1 revealed a prevalence rate of 42.3% among women, 46.5% in children 24-59 months, and 71.4% among children 6-23 months, which was more than double the respective national averages among women[2] and children.[3] Microscopic evaluation of the thin blood smears collected in Wave 1 was consistent with nutritional iron deficiency anemia, and dietary evidence corroborated this finding. Consequently, community education, nutrition interventions, and clinical evaluations were offered to residents as a mechanism to decrease anemia prevalence.

Findings from the Wave 2 assessment conducted six years after Wave 1 revealed that anemia prevalence rates decreased by nearly half among women and one-third among children. It is plausible that this decline could be attributable, in part, to the community interventions and health services; however, no data exists for confirmation.

Analysis of dietary practices revealed the consumption of iron absorption enhancing foods (specifically fruits and green leafy vegetables high in vitamin C) was protective against anemia among women in Wave 1. This discovery is in line with other studies that show improvement in iron absorption with increased vitamin C intake.[4,5] Thus, community nutrition interventions, which included the modification of local recipes, the construction of a school kitchen to prepare nutritious meals, community education, and personalized nutritional counseling following anemia diagnosis focused on promoting iron and vitamin C intake.

Low SES also appeared to be associated with anemia among women in Wave 1, and this relation has been documented in several studies.[6–8] Low SES households in Mexico may not have the means to purchase nutritious foods, may be subject to poor living conditions, and have limited utilization of health care services.[9] In an effort to improve the health of all community residents, regardless of SES, free health clinics were offered twice yearly at the local elementary school. Health services were initiated prior to Wave 1 of data collection and extended beyond Wave 2.

Anemia occurred more frequently among children 24-59 months of age who experienced at least one diarrheal episode in the two weeks prior to the study. Prolonged diarrhea can result in nutrient depletion, and in some cases, blood loss, both of which can lead to the development of anemia. Furthermore, children with anemia may have decreased immune function, which could lead to the acquisition of an infectious disease, which in turn, may cause diarrhea,[10] thus compounding the problem. Poor sanitation may also be a cause of diarrhea,[11] and basic measures may prevent the spread of infectious agents. Thus, one of the community interventions offered by VIIDAI focused on hygiene and hand-washing techniques.

Self-reported use of painted cookware was a concern in this community, because of the potential for lead exposure through lead-based paint. Testing of painted cookware in Wave 1 revealed that lead was present in 35% of cookware examined. Studies show that lead exposure through food prepared and consumed in lead-containing cookware can contribute to anemia.[12,13] Although stippling was not observed in thin blood smears, the high prevalence of anemia in Wave 1 and the widespread use of lead-based painted cookware prompted VIIDAI to sponsor a cookware exchange in 2006 to replace existing painted cookware with new ceramic cookware. During Wave 2, 10 glazed cookware items were tested for lead and all tested negative; furthermore, fewer survey respondents reported using painted cookware.

Although significant decreases in anemia prevalence were observed among women and children in the *colonia*, anemia remains a public health concern and further efforts are needed to continue to decrease prevalence rates. The identification of variables associated with anemia during the course of this study provides a foundation upon which to create and implement future anemia projects.

Etiology and Factors Contributing to Anemia Among Women and Children

Laboratory findings revealed iron deficiency anemia was the primary etiology in 100% of children and 80.8% of women, followed by vitamin B-12 deficiency (11.5%) and combined iron and vitamin B-12 deficiency (7.7%), with no evidence of lead toxicity. These results are in accordance with other studies that report iron deficiency as the primary etiology of Mexican women and children.[14,15] Furthermore, laboratory evidence of nutritional deficiency anemia was corroborated by dietary findings that vitamin supplement use was protective against anemia among women. Observations of local *tiendas* also revealed limited availability of fresh produce available for purchase, which suggests that community nutrition advocacy, in addition to improved individual dietary choices, may be required to address the problem of anemia in this community.

Low SES and enrollment in the government assistance program *Prospera* were also associated with anemia among women. Multiple studies have shown low SES as a risk factor for anemia;[6–8] however, other evaluations of the *Prospera* program report positive associations between *Prospera* enrollment and improved anemia prevalence rates.[16,17] While the presence of *Prospera* in the *colonia* implies that government support is available to improve the health and SES of qualifying households in this community, its effectiveness is unclear. It is not possible to draw conclusions about the program given the lack of community data regarding the number of families eligible for program participation, duration of enrollment, amount of financial support received, or how the *Prospera* stipends are spent. Because *Prospera* targets the lowest SES households, and low SES households have higher anemia prevalence rates, it is reasonable to postulate that poverty, in conjunction with poor dietary habits, contributes to anemia in this community.

VIIDAI has implemented many interventions to assist individuals to adopt healthy eating practices; however, concerted efforts are required to eliminate community barriers. Vitamin supplementation appears to be a temporary, yet effective measure for preventing anemia on an individual basis, but it is not a sustainable long-term solution. Other viable options must be explored, such as initiating partnerships with agricultural corporations to provide subsidized produce to local *tiendas* for purchase by local residents, streamlining the process of identifying and enrolling qualified low SES households into assistance programs such as *Prospera*, and developing nutrition education curriculum for the local elementary school.

Conclusions

This dissertation reflects the health achievements of nearly a decade of public health activities within a rural Mexican *colonia*, and the findings from this work have many implications. First, the high anemia prevalence rates identified in the *colonia* reveal that anemia is significant health problem among this community and it may also be a problem in neighboring communities. Secondly, the reduction in anemia prevalence rates among *colonia* residents suggests that interventions and health clinics established by VIIDAI may have contributed to improving community health and may have the potential to be successful in decreasing anemia prevalence in similar communities. Finally, the collaborative, investigational, and interventional efforts employed by VIIDAI exemplify the power of multi-institutional partnerships and how the VIIDAI program could serve as a prototype for replication by other universities and NGOs in resource-limited communities.

In summary, this dissertation provides the conceptual framework for uniting universities, NGOs, and communities to work together to improve health in limited-resources settings. Results from the community anemia assessments and interventions reveal the profound role that VIIDAI has played in helping to decrease anemia prevalence in an underserved community. Findings from this dissertation will serve as the foundation to develop further interventions to decrease anemia prevalence and address associated public health problems.

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