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An analysis of association between using solid fuel and anemia among reproductive age women, 15-49 years old in Timor-Leste

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An analysis of association between using solid fuel and anemia among reproductive age women, 15-49 years old in Timor-Leste.

by
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A Thesis Submitted to the Graduate Faculty
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Abstract

Introduction: In Timor-Leste, anemia affects approximately 21% of reproductive age of women. The established risk factor for anemia is poor nutritional status, but recently solid fuel use in the household has emerged as a possible risk factors. The association between solid fuel and anemia has been studied in children and pregnant women, but there hasn't been a study conducted to find the association among all reproductive age women from 15-49 years old.

Aim: The objective of this study is to determine if use of solid fuels (charcoal, wood, and straw/shrubs/grass) compared to cleaner fuels (electricity, LPG. natural gas, biogas, and kerosene) associate with the increasing of the prevalence of anemia among reproductive age women (15-49 years old) in Timor-Leste.

Methods: This study used data from the Timor-Leste Demographic Health Survey (TLDHS) 2009-2010. The data used was based on the individual level within household from 13 districts in Timor-Leste. Bivariable logistic regression analysis was performed to assess associations between each independent variable (type of fuels, age group, BMI group, residence, wealth index, education level and smoking behavior) and the outcome variable (anemia) and mutlivariable logistic regression model was also performed with significant covariates.

Results: The association based on the type of fuels showed that the odds ratio for anemia in women using solid fuels was 1.73 (OR: 95% CI: 1.49 - 2.01) compared to the women using cleaner fuels. After adjustment for other covariates, the odds ratio for anemia in women that use solid fuels was 1.43 (95% CI: 1.29-1.64) compared to women using cleaner fuels.

Discussion: Based on our study population, this study found that reproductive age women 15-49 years old in Timor-Leste who used solid fuel as a source of energy for cooking or heating activities in the household were at higher risk for anemia.

Keywords: Solid Fuel, Cleaner Fuel, Anemia, Reproductive Age of Women, Carbon Monoxide (CO), Demographic and Health Survey, Household, Household Energy, Wood.

Approval Page

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Author's Statement Page

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Signature of Author

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CHAPTER I

1. INTRODUCTION

1.1 Background

Every day both harmful and harmless substances are released into the atmosphere. They can be chemical, biological or physical, and these components can be emitted from different sources such as industrial facilities, power plants, motor vehicles, solid fuels. Still others are naturally occurring like volcanos, fire, and windblown dust (USEPA, 2015; IEA, 2015) . All of these substances released contribute to air pollution, and some have the potential to cause health effects (USEPA, 2015). The common air pollutants associated with health issues include particulate matter (PM), ground-level ozone (O_3), carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), lead (Pb), mercury (Hg), benzene, and polycyclic aromatic hydrocarbons (PAHs) (USEPA, 2015). Of all these chemicals, PM is the main contributor to the environmental health problems (Lim *et al.*, 2015). In fact, the World Health Organization (WHO) reported in 2010 that the average world level of PM_{10} in ambient air from 1600 cities in 91 countries was 71µg/mg3 with a range of 26-208 µg/mg3 per region. Approximately 3.7 million deaths globally (6.7%) were related to outdoor air pollution and even more, 4.3 million deaths, from indoor air pollution (Lim *et al.*, 2015). Indoor air pollution present in different forms, starting from chemicals present in the solid fuels combustion, which mostly seen in household in the developing countries, to chemicals compounds which can be in volatile and semi-volatile organic compounds forms present in the modern buildings (Zhang & Smith, 2003).

In developing countries, the main contributor to indoor air pollution is combustion from the solid fuels like wood, charcoal, animal dung, and crop waste which are used as energy for cooking and space heating (Bruce, Perez-Padilla, & Albalak, 2000; WHO, 2016a). Solid fuel is the primary choice of energy because it is affordable to most people, easy to use without vented cooking stoves, and widely available (Desai, Mehta, & Smith, 2004). According to the International Energy Agency (IEA), in 2015, approximately 2.5 billion people living in rural areas of developing countries continue to rely on solid fuel as the primary source of energy. Even though biomass fulfills the needs of many individuals in developing countries, the disadvantages are enormous and harmful to human health (IEA, 2015).

In terms of combustion efficiency and cleanliness, solid fuel is categorized into the lowest group in the energy group ladder, meaning that it is among the least efficient and dirtiest of fuels. In contrast, liquefied petroleum gas and electricity are more efficient and cleanest and are categorized into the highest group. (IEA, 2015). Solid fuel smoke contains pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), Carbon monoxide (CO), Nitrogen dioxide (NO_2), formaldehyde, benzene, 1,3 butadiene, polycyclic aromatic hydrocarbons (such as benzo[a]pyrene), and many other toxic organic compounds (USEPA, 2015).

Even though each type of solid fuels emits many chemicals which contribute to air pollution, CO and PM found to be common pollutants from solid fuels (IEA, 2015). The level of pollutant emitted from each is varies among them. In fact, a study measured the CO and PM released from solid fuels per meal in developing countries, they found that animal dung released 64 gram per mega joule (g/MJ) of CO and and 63 g/MJ PM per meal, Crop 60 g/MJ of CO and 14 g/MJ of PM and Wood 19 g/MJ of CO and 26 g/MJ of PM per meal. (Smith, Rogers, & Cowling, 2005)

These chemical compounds emitted have been associated with a number of health issues including pneumonia, stroke, ischemic heart disease, chronic obtrusive pulmonary disease (COPD), lung cancer, and anemia (WHO, 2016a; Mishra & Rutherford, 2007)

Anemia is the state in which someone's hemoglobin level falls below 11 g/dl. When this condition occurs, human body encounter a low oxygen concentration distributed throughout the body, which resulting in symptoms like dizziness, fatigue, lightheadedness, low blood pressure, malaise, or weakness, abnormal heart rate, headache, pallor and shortness of breath. (WHO, 2011). This phenomenon affects 1.62 billion people around the globe (Benoist, McLean, Egli, & Cogswell, 2009). In 2008, the WHO and Centre for Disease Control and Prevention (CDC) published a global report on anemia which stated that globally 47% of children under five years old, 42% of pregnant women and 30% of non-pregnant women age from 15-49 years were affected. These affected groups were seen highly in the Western Pacific, African and south-east Asian countries including Timor-Leste. (Benoist, McLean, Egli, & Cogswell, 2009)

The prevalence of anemia in Timor-Leste is approximately 21% in women of reproductive age (17.5% mild Anemia, 3.6 % moderate anemia and 0.3 % severe anemia) Among this group of women, 28% were pregnant and 19% were not pregnant, and 25% were breastfeeding (Lover, Hartman, Chia, & Heymann, 2014). This statistic clearly indicates that women in Timor-Leste are at risk of anemia. The risk factor for anemia in reproductive age women has been associated with poor nutritional status, but recently solid fuel has also been linked to and identified as risk factor for anemia (Mishra & Retherford, 2006; Page, Patel, & Hibberd, 2015). The association between solid fuel and anemia has been studied in children and pregnant women, but there hasn't been a study conducted to find the association among all reproductive age women (15-49 years old). Thus, this study sought to determine if use of solid fuels (Charcoal, Wood, and Straw/shrubs/grass) compared to cleaner fuels (Electricity, LPG. Natural Gas, Biogas, and Kerosene) associate with the increasing of the prevalence of anemia among reproductive age women (15-49 years old) in Timor-Leste.

1.2 Research questions

This study aimed to conduct exploratory analyses of the following questions:

1. What is the prevalence of anemia for women in Timor-Leste?
2. What proportion of the women who use solid fuels have anemia?
3. What other factors explain the prevalence of anemia, including age, education, region, urban or rural residence, wealth, literacy level, and smoking?

CHAPTER II

2. LITERATURE REVIEW

2.1 Brief overview of Air Pollution

The World Health Organization (WHO) describes air pollution as the indoor or outdoor atmosphere polluted by any chemical, physical or biological substances capable of altering the normal characteristics of the air in the environment (WHO, 2016a.) There are two common types of air pollution: ambient and indoor. Ambient air pollution is the contamination of the atmosphere in the outside environment which usually comes from mobile sources (Table 1) such as an automobile or stationary source like manufacturing facilities and power generators, forest fires, traffic, and volcanos (Abelsohn & Stieb, 2011). Indoor air pollution, on the other hand, is usually associated with substances released into the environment from inside the building or a house and the pollutants vary depending on the type of source (Bonjour *et al.*, 2013).

Table 1. Major sources of indoor air pollution.

Source	Key Pollutants
Household solid fuels from cooking and heating	$PM_{2.5}$ or PM_{10}, CO, PAHs, NOx, VOCs, semi-VOCs, sulfur oxides arsenic, fluorine, aldehydes
Tobacco smoke	$PM_{2.5}$ or PM_{10},, CO, PAHs, VOCs, semi-VOCs
Cleaning, Incense and mosquito coil	$PM_{2.5}$ or PM_{10}
Consumer products	VOCs, semi-VOCs, pesticides
Construction materials used in remodeling or demolition	VOCs, semi-VOCs, aldehydes, asbestos, lead, radon

Building characteristics related to moisture, ventilation, and furnishings	Biologic pollutants (fungal spores, mites, cockroaches, endotoxins, glucans)
Soil, rock, and water sources under building	Radon

Abbreviations: $PM_{2.5}$ = Particulate matter with 2.5 micrometer less than in diameter, PM_{10} = Particulate matter with 10 micrometer less than in diameter, CO= Carbon monoxide, NOx =Nitrogen oxide (NO2), PAHs = polycyclic aromatic hydrocarbons, VOCs = Volatile Organic Compounds.

Source : Bonjour et al., 2013.

Of all the pollutants mentioned in Table 1 only six pollutants (Ozone (O3), Particulate matter ($PM_{2.5}$ or PM_{10}), Carbon monoxide (CO), Nitrogen dioxide (NO2), Lead (Pb) and Sulfur Dioxide (SO2) are currently regulated by the United States Environmental Protection Agency (USEPA) under its national ambient air quality standards (NAAQS) (USEPA, 2015).

These chemicals possess the threat to human health. The burden of the adverse impact of air pollution has become a significant environmental problem. In 2010, the global burden of disease or comparative risk basement project estimated that the burden from air pollution accounted for approximately 4.3 million deaths by household air pollution and 3.7 million death from ambient air pollution (Lim *et al.*, 2015). These burdens are seen highly in developing regions like South Asia, East Asia, Southeast Asia, and African countries, where PM from solid fuel is used as the primary source of pollution. WHO, 2016a; Chafe *et al.*, 2014).

2.2 Overview of solid fuel.

Generally, in developing countries, households engage a single or combination type of energies for cooking, heating and lighting (IEA, 2016). Energy used consists of electricity, gas fuels (natural and methane gas), liquid fuels (kerosene, ethanol and methanol, and liquefied petroleum gas), and solid fuel. Solid fuels refer to the type of fuel that produce energy from solid materials such as coal, lignite, charcoal, wood, straw, shrubs, grass, agricultural crop and animal dung (Sood, 2012; IEA, 2016). In developing countries where people have restricted access to the cleaner forms of energy such as electricity, LPG. natural gas, biogas, and kerosene, solid fuels become the primary choice as the source of energy in the households because they are readily available and affordable to most people (IEA, 2016).

The use of solid fuel in developing countries is mostly for cooking and indoor heating carried out by women as well as children, but rarely men (Sood, 2012;) The population most affected by solid fuel smoke is commonly associated with women and children because they spend most of the time in the domestic arena, specifically, in the kitchen cooking. Children usually tag along or are carried on their mothers' back as the mother performs these activities (Sood, 2012; IEA, 2016). The cultural practice of women spending more time in the kitchen and caring for children while cooking introduces them into greater risk of health problems associated with solid fuels. Because not only the due to the time spend in the kitchen, but during cooking they also used solid fuel on unimproved cooking stoves and unventilated kitchen, which increase the risk or exposure (Legros *et al.*, 2009). While in developed countries, solid fuel is used for residential heating to which men, women, and children are exposed, the concentration of pollutants released during heating is lower than cooking. (IEA, 2016; Legros *et al.*, 2009)

Solid fuel used in households has declined drastically over the past decades. In fact, a study conducted by Bonjour *et al.* (2013) estimated that the solid fuel use in households for cooking alone among 150 countries around the world from the year of 1980 – 2010 declined from 61% to 41%. Despites it decline over decades, the change is seen in developed countries and not in developing countries, because the transition from free and affordable solid fuels to cleaner fuels depends on the socioeconomic status of the country and people living in the household (IEA, 2015; Legros et all, 2009). A WHO report in 2013 indicated that solid fuel use in the household was less than 10% seen in developed countries such as the United States and European countries, while it was higher among Africa regions (79 %) and 60% of Southeast Asia regions (WHO, 2016c).

Among Southeast Asia regions, Timor-Leste is the highest user of solid fuels in households. The statistics show that 93% of the population still relies on solid fuel and it accounts for 95% of population living in the rural and 81% of the urban area. In addition to Timor-Leste, in Vietnam 47% of the population still depends on the solid fuel (61% urban and 16 % rural), Indonesia 39 % of the population (65% rural and 16 % urban), and Thailand 23% of the population (31 % from rural and 13 % urban) (WHO, 2016c; World Bank, 2007).

2.3 Health effects associated with pollutants from solid fuels

Many studies within the literature report strong association between solid fuel use and health effects. Most derive from epidemiologic studies and toxicological studies in animals. Acute lower respiratory infection(ALRI) in association with solid fuel use is found in children less than five years old. (Sood, 2012). This group is susceptible because of their lower immune system and probably lack of proper hygiene, and spending more time with their mother in the kitchen (Sood, 2012). In fact, a case-control study conducted in Nepal found that children in the case group where their house used solid fuel like wood and coal as a source of energy showed a significant association with ALRI (Bates *et al.* 2013). Similarly, a meta–analysis compiled 24 studies from Africa, Latin American and China, also found that children less than five years old living in the household that used solid fuel indicated a significant correlation relationship with ALRI (Dherani *et al.*, 2008). Both authors argued that ALRI in children is mostly due to their time spent in the kitchen with their mothers and proximity to the stove while the cooking activities were ongoing.

Additionally, solid fuel use was found to be the single risk factor for chronic obstructive pulmonary disease (COPD) in less economically developed countries. As pointed out by Kurmi and colleagues (2010) on a meta-analysis that adult women who exposed to solid fuel had approximately 3 times more to have COPD (95% CI:1.85-4.0) as compared to cleaner fuel, and wood as fuel choice which had 4.29 times more significant risk to acquire COPD (95% CI 1.35 - 13.70) than another type of fuel.

Moreover, some systematic reviews and meta-analysis have also been conducted to link both developed and developing countries. These studies selected solid fuel (wood and coal) for cooking and heating as the primary exposure and correlated the development of lung cancer. The first study was based on data from the International Lung Cancer Consortium (ILCCO) and represented North America, Asia, and Europe and revealed that women exposed to solid fuel showed higher risk of lung cancer than men and that Asian populations had a greater risk than whites or other groups (Hosgood *et al.*, 2010). Besides ILCCO findings, a case control study carried out among women in India also reported that women who exposed to solid fuel were more susceptible to the development of lung cancer than unexposed women (Behera & Balamugesh, 2005).

2.4 Anemia

Anemia is a public health problem across developing countries, and mostly women and children are affected. Anemia is defined as a lack of red blood cells in the blood or person having hemoglobin level below 11 g/dl which results in low oxygen content and restricted blood flow across organs in the body. (Benoist, Mclean, Egli & Cogswel, 2009). This condition is commonly seen in women in of reproductive age worldwide. Anemia affects 24.8 % of populations in developing countries, about 47.4 % are children under 5 years old, 41% pregnant women and 30.2% are non-pregnant women, and iron deficiency anemia, which is common subtype form of anemia seen among these group. (Balarajan *et al.*, 2011).

The risk factors for anemia are varied among women; it can be due to a person's poor diet, ability to absorb iron, pregnancy, blood loss or genetic diseases (Benoist *et al.*, 2009). However, recent studies have linked solid fuel exposure as a risk factor for anemia (Mishra & Rutherford, 2006; Page, Patel, & Hibberd, 2015).

2.5 Mechanisms of solid fuel exposure and anemia.

The notion of solid fuel use causing anemia in women and children is very new and the mechanism is not well known. The mechanism is believed to take place as certain chemicals present in solid fuel combustion enter the human body and induce the hemoglobin process (Blumenthal, 2001; Dutta, Ray,& Banerjee 2012). There are numbers of pollutants released from solid fuel combustion, but the most common pollutant that has potential binding capability to hemoglobin (Hb) and ability to cause anemia is carbon monoxide (CO). CO is a colorless, non-irritant, and odorless gas. It results from incomplete combustion of solid fuels, petrol, natural gas and kerosene. CO is also one of the pollutants in ambient air that is regulated by USEPA. USEPA set an 8 hour exposure limit of 9 part per million (ppm) and an hour exposure limit of 35 ppm from the environment. This exposure level should not be exceeded more than once per year (USEPA, 2015; Dutta, Ray, & Banerjee 2012).

When people are exposed, they inhale many pollutants including CO, which is the main contaminant chemical. When CO is inhaled from solid fuel combustion, it dissolves in the blood and immediately binds to adults' hemoglobin in their red blood cells and forms carboxyhemoglobin (COHb). The binding speed or affinity of CO to Hb is faster compared to oxygen, and CO bonding with Hb tends to bond longer than oxygen in the Hb binding site. Thus, as the CO concentration increases in the bloodstream, it reduces the oxygen storage function of hemoglobin and the oxygen transportation function of COHb which results in less oxygen being delivered to the tissues (Blumenthal, 2001). When there is limited oxygen in the tissue, the hemoglobin production also decreases which leads to anemia.

In the oxygen dissociation curve (Figure 1), when oxygen saturation in the human body is low due to high concentration of CO, the curve of the graph to shifts to the left (Figure 1) which is similar if a person is anemic. The curve of patient also shifts to the left with low concentration of oxygen content and partial pressure of oxygen.

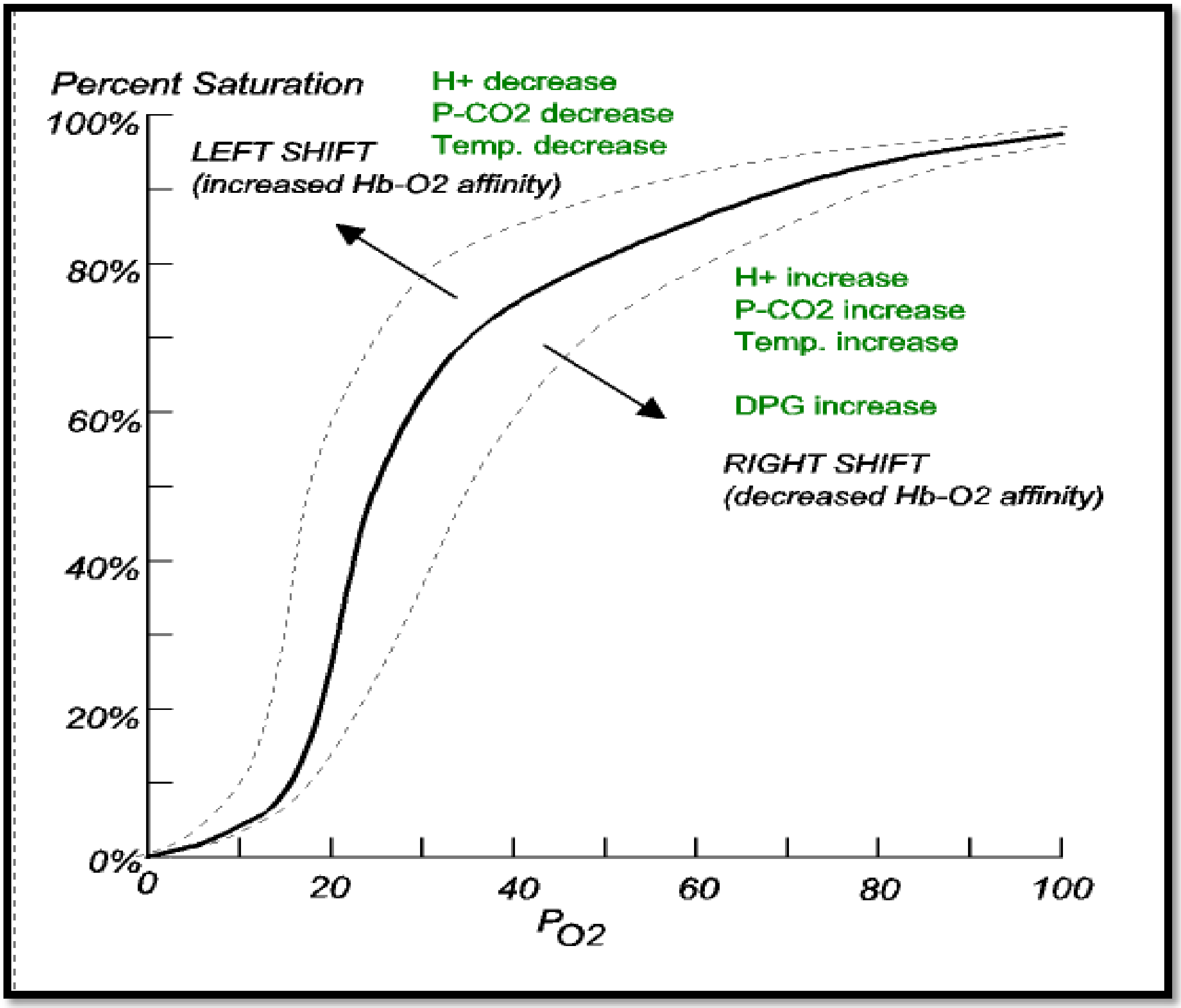


Figure 1. Oxygen disassociation curve

(Source : http://www.acbrown.com/lung/Lectures/RsBldg/RsBldgOxgnNoteB5y.htm)

Another way that combustion gases from solid fuel cause anemia is believed through triggering systemic inflammation. Chemicals such as CO, transitional metals, ultrafine particles (UFP, < 0.1 µm in diameter), $PM_{2.5}$, and PM_{10} are capable of inducing systemic inflammation (Page at al, 2015; Dutta, Ray, & Banerjee, 2012). It occurs when people are exposed to gases, systemic inflammation is trigger by mediator by inflammatory cytokines like tumor necrosis factor alpha (TNF-α), interleukin-1 (IL-1), interleukin-6 (IL-6), and interferon- γ (IFN-γ) initiated. As soon as the systemic inflammation is activated, it causes the inflammatory cytokines levels to increase. In fact, Dutta, Ray and Banerjee (2012) insist that women who are exposed to solid fuel tend to have a high level of inflammatory cytokines like alpha (TNF-α), interleukin-1 (IL-1) and interleukin-6 (IL-6) (Dutta, Ray, & Banerjee, 2012). Thus, when the inflammatory cytokines level is raised, it causes dysregulation of iron hemostasis, impairs proliferation of erythroid progenitor cells, reduces erythropoietin response, and shortens the red blood cells' life span. All of which contribute to developing anemia (Ying-Ying *et al.*, 2014; Dutta, Ray, & Banerjee, 2012).

2.6 Evidence of association of solid fuel exposure and anemia

The association of solid fuel exposure and anemia among women in their reproductive years is understudied. So far only a handful of studies have been conducted and have found exposure to solid fuel combustion among pregnant women and children which associated with anemia. We discuss studies and their findings regarding the exposure to solid fuel resulting in anemia in women. First, the most vulnerable group is pregnant women. In developing countries, the risk of multiple diseases is high among the population living in rural areas with low socioeconomic status. Page, Patel and Hibberd (2015) conducted a prospective cohort study with rural pregnant women in Nagpur, India and recorded their pregnancy outcomes until six weeks' post-partum from May 2011 to June 2013. They evaluated solid fuel use as an independent risk factor for anemia among pregnant women. They found that of the 56 percent of all women who used solid fuel 90.5 percent were anemic. Of this number 43.1 percent were mildly anemic and 47.4 had moderate to severe anemia. They argue that pregnant women who were using solid fuel for cooking might have an increased risk of anemia because the chemical from the combustion triggered systemic inflammation which resulted in anemia. In addition to pregnant women, anemia in children has also been linked to combustion from solid fuel. A study based on the national level of child anemia of 29 developing countries year 2003-2007 used cross-sectional DHS to determine the association between solid fuel smoke exposure and childhood anemia. The study reported that 79% of children age 0-49 months who were exposed to solid fuel at home had a strong association with mild and moderate to severe anemia, 24% and 39 % respectively. Similarly, a study led by Mishra and Rutherford (2014) used data from India's second National Family Health Survey (NFHS-2) year 1998-1999 to examine the association of using solid fuel and anemia among children age 0-35 months. The study revealed that of the 71 % of children, 23% were mildly anemic and 48% were moderate to severely anemic. Both studies on children revealed the same notion that affected children spent more time with their mothers during cooking activities.

2.6 Social Economic Status and Anemia

Socio-economic status (SES), such as wealth and level of education, play a major role in achieving a healthy life style among most women. Many women of reproductive age in developing countries who live in rural areas and have low SES encounter difficulties in maintaining their health status. (Page *et al.*, 2015). Anemia is one of the common health issues correlated with women in low SES households and with high illiteracy. This situation is clearly seen in India, where women who lived in urban and rural areas with a low standard of living or poor wealth index had high prevalence of mild (33.9% vs 42.0%), moderate (14.9% vs 17.7%), and severe (2.2% vs 2.8%) anemia when compared to other women who lived with medium and high standards of living (Bentley & Griffiths, 2003). In another part of Asia, anemia among girls aged 10-18 years old in Korea was associated with living in low income households (Ying-ying *et al.*, 2014). Both studies revealed that these women live in difficult situations to maintain their health status because the household needs are far more important than their personal needs.

In term of level of education, illiterate women or women with no formal education were more likely to have anemia than those who had a formal education. Bentley and Griffits (2003) indicated in their study that 96% of illiterate pregnant women were shown to have anemia from mild to very severe levels with an approximation of 56 percent in the severe anemia group. Their study argued that this phenomenon occurred due to limited information or lack of awareness about anemia.

2.7 Demographics and Anemia

According to the WHO, women's anemia can be determined through demographic variables such as age, BMI, and smoking. When looking at women's age in relationship with anemia, women aged 25-60 and beyond 60 are more affected compared to younger women aged 15-25 years old (Morsy &ALhays (2014). In a study among non-pregnant, ever-married women conducted in Bangladesh , women age 30 – 49 years had higher percentages of anemia (43.6%) than younger women (38.6%) (Kamruzzaman *et al.,* (2015). The authors argued that a majority of women age 30-49 have young children who are dependent on them for needs. This situation restricts them from prioritizing their health needs and instead focusing on their children, which may result in anemia. Similarly, in Gazira state region, Sudan women age 35 – 49 were more vulnerable to anemia because of the lack of proper focus on health needs (Morsy &ALhays (2014).

Additionally, women categorized as underweight, overweight and obese women are more likely to have anemia than normal weighted women (Qin *et al.*, 2013; Thankachan *et al.*, 2007;

Lukanova, 2004). The authors explain that these women were prone to anemia because of lack of nutritional intake like serum ferritin, iron, vitamin B12, folates, as well as increased level of estrogen which may contribute to the reduction of red blood cell production (Qin *et al.*, 2013; Thankachan *et al.*, 2007; Lukanova, 2004).In fact, a study conducted among young women from low SES in Bangalore, India indicated a significant prevalence of anemia and iron deficiency anemia, 39% and 62% respectively were due to a lack of iron supplements.

Furthermore, approximately 250 million women smoke worldwide, with 9 percent accounted for women from developing countries, which most of them are of reproductive age and about 22 percent from developed countries (WHO, 2016d). Smoking has been identified as a risk for many health issues including cancer, chronic disease and anemia. (EPA, 2015) Anemia tends to develop among those who have active and long-term exposure to cigarettes. (Leifert, 2008). Cigarette burning releases CO which is known to bind to Hb. The mechanism of CO causing anemia from smoking would similar to that of CO inhaled from solid fuel (Leifert, 2008; Blumenthal, 2001).

2.9 Timor-Leste

2.9.1 Demographics

Timor-Leste is a newly independent country having achieved independence from Indonesia in 2002 (National Statistics Directorate, 2013). It's located in Southeast Asia, and shares a land border with Indonesia archipelago. The eastern side of the country is located close to the northwest of Australia. The country has a population of 1.2 million which occupies the land of 14,919 km2. The proportion of population based on sex is distributed equally and approximately 43 percent are under 14 years old. Timor-Leste (Figure 4) is divided into 13 municipalities, 65 administrative posts, 422 villages and 2,225 hamlets. The majority of Timor-

Leste's population lives in rural area, approximately 70%, and only 30% in urban areas. The capital of Timor-Leste is Dili and Tetun, and Portuguese is the official language while English and Indonesia are working languages (National Statistics Directorate, 2013).

Looking at the economy of the country, the gross domestic product (GDP) of Timor-Leste was estimated approximately US$4,941 million and US$4,361.6 million for GDP per capita. The poverty in Timor-Leste is mostly seen in the rural areas as opposed to urban due to low agriculture productivity and limited access to the roads and transportations. The rate of urbanization is relatively low (4.25% annually) and approximately 40% of the population is illiterate. (IMF, 2012).

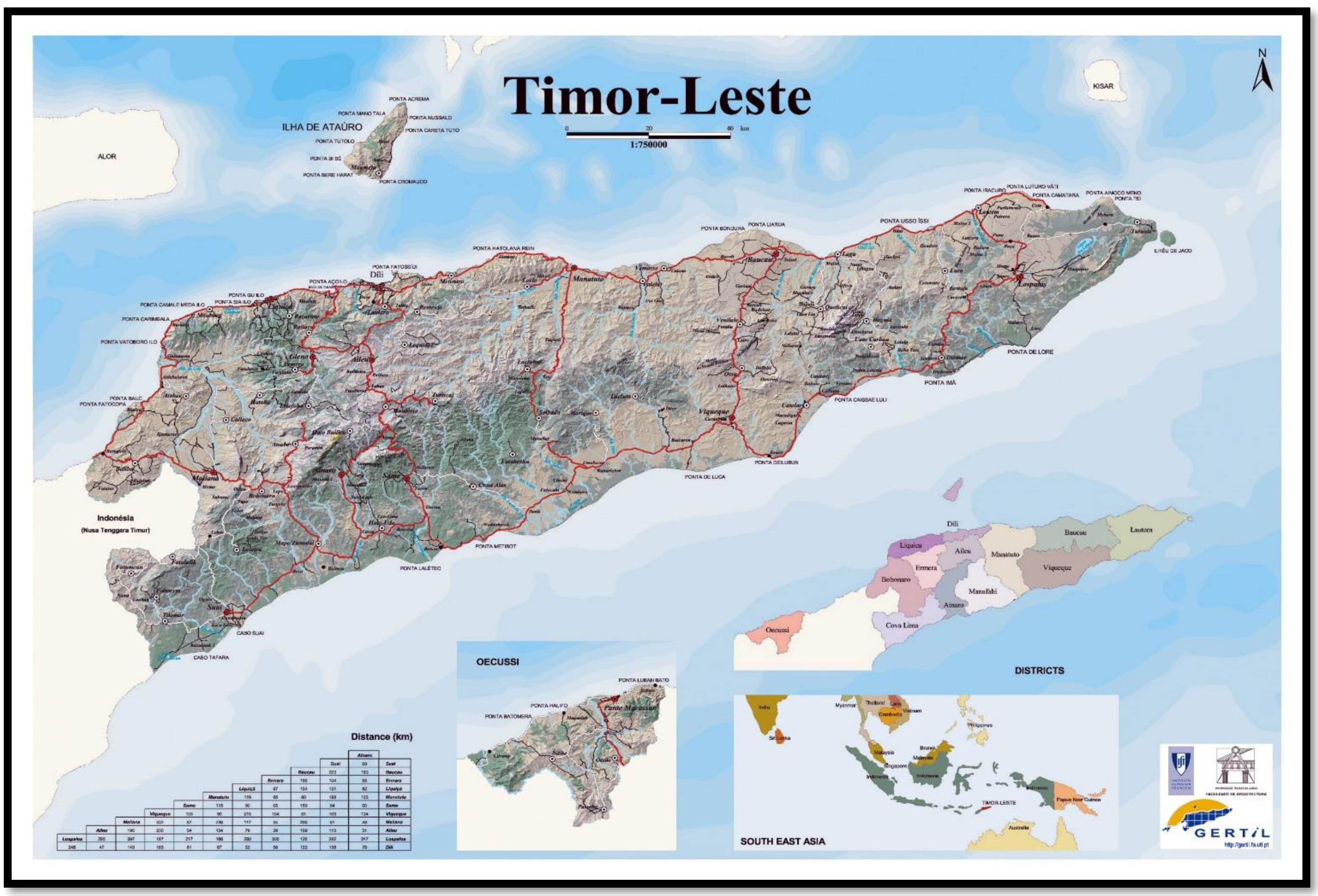


Figure 2. Map of Timor-Leste. (Source : http://www.maps-of-the-world.net/maps/maps-of-asia/maps-of-east-timor/large-detailed-map-of-Timor-Leste-with-relief-roads-and-cities.jpg)

2.9.2 Household energy for cooking situation in Timor-Leste.

Timor-Leste's main source of fuel for power generation is fossil fuel. However, wood fuel is still is the main fuel for cooking and heating activities almost all households (The World Bank, 2010). Approximately 98% of all the households in both rural and urban areas used wood fuel as the main cooking fuel. In the rural area, about 80 percent of households obtain and collect the wood from the nearest forest while 60 percent of households in urban areas purchase the wood. Approximately 600,000 tons/year of wood fuel is consumed in Timor-Leste (WHO, 2016b; The World Bank, 2010).

Solid fuel use predominantly become major source of energy fuel in Timor-Leste for various reason. First, it's the cheapest and accessible type of fuel to most household. Second, majority of population living in the rural area have limited access to electricity which leaves them with wood as the only choice. Third, nearly half of the population living under the poverty line with an estimated income of $0.88 per capita per day. Other fuels like electricity and LPG are available in the country but mostly seen in the capital city Dili in commercial sectors such as hotels and restaurants (IMF, 2012; The World Bank, 2010).

CHAPTER III

3. METHODOLOGY

3.1 Data Source

This study will use data from the Timor-Leste Demographic Health Survey (TLDHS) 2009-2010. The data was obtained from the United States Agency for International Development (USAID) website http://dhsprogram.com/data/dataset/Timor-Leste_Standard-DHS_2009.cfm?flag=0

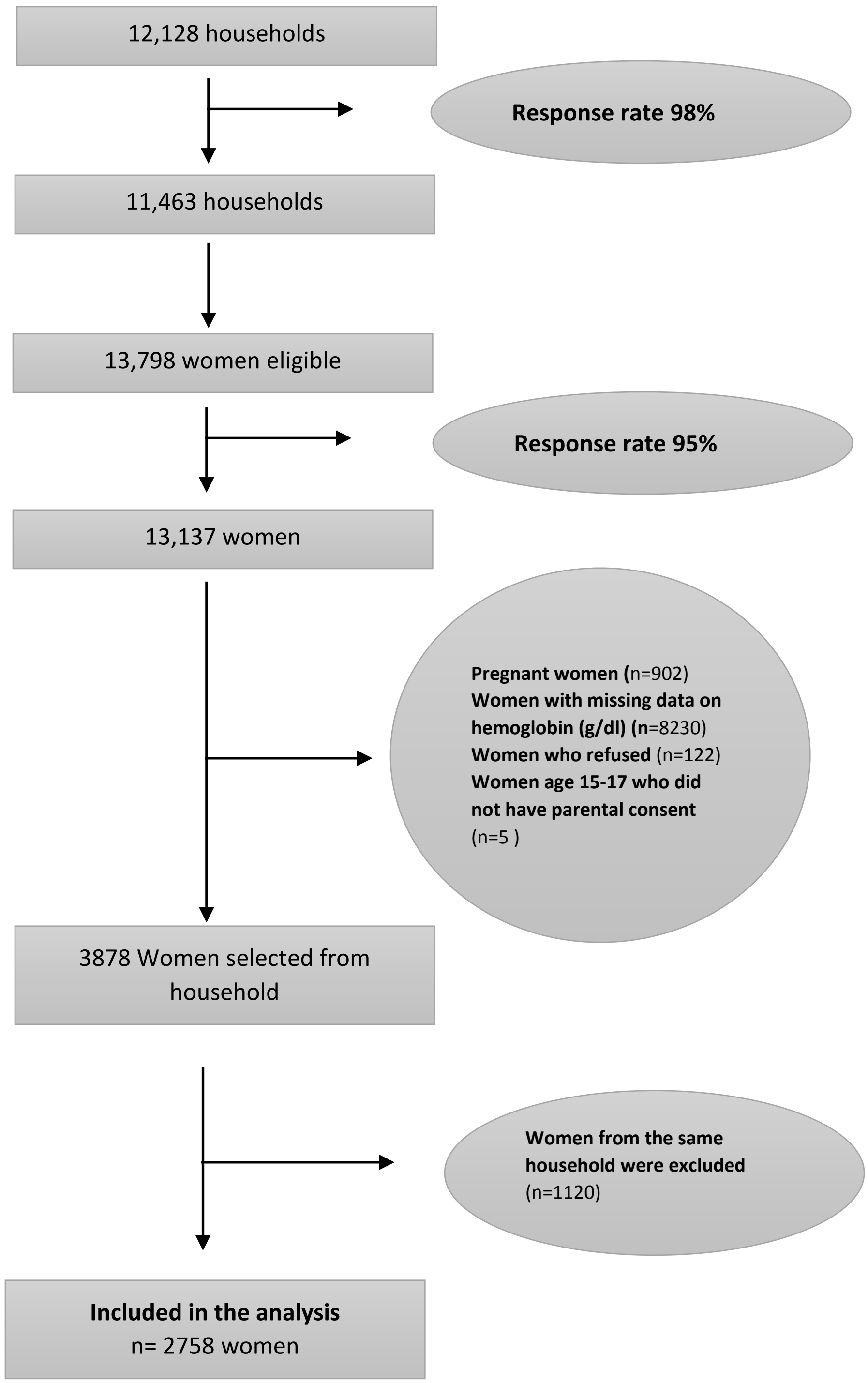
The target population for sampling was men and women age 15-49 years old, and the data was collected by administrating a survey at both the household and individual levels. The main objective of the survey was to estimate demographics and health conditions at national and regional levels (13 districts).

3.2 Study design and participants

This study used a cross-sectional study design, and the sample was selected based on a stratified two-stage cluster design. A flow diagram of the selection process is presented in figure 3. In the first cluster, 455 enumeration areas were selected consisting of 116 urban and 339 rural areas. In the second stage, a systematic random sampling of households from each cluster was selected, and the final sample was 12,128 households. The selected households were then visited and 98% of households participated (N= 11,463). Then eligible women 15-49 were randomly selected and interviewed from one-third of the households selected with a total of 13,798 women. The response rate among eligible women was 95% totaling 13,137 participants.

There are some exclusions from the dataset before analysis. Firstly, participants who were pregnant (n=902) when the study was conducted were excluded. Secondly, participants or women with missing data on hemoglobin (n=8,230) were excluded. Thirdly, those women who refused to participate in hemoglobin testing (n=122) and women age between 15 – 17 years, who did not provide parental consent (n=5) were excluded from the analysis. Lastly, since this study used an individual dataset from the household, the probability of participants selected from the same household were likely to occur. Hence, only one participant from a household was selected for this study (n=1120). The final dataset for analysis contains 2,758 observations, and all women provided informed consent **(**figure 3).

Figure 3. Sampling flow diagram of participants in the study.



3.3 Variable Characterization

3.3.1 Type of fuel.

Exposure to combustion from cooking fuel is the exposure of interest and is estimated by looking at fuel type. The types of cooking fuels recorded were electricity, liquefied petroleum gas (LPG), natural gas, biogas, kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crop, and animal dung. The fuels were then categorized into two groups. The first group was the cleaner fuel which consisted of electricity, liquefied petroleum gas (LPG), natural gas, biogas, and kerosene. The solid fuel was the second group which consisted of coal /lignite, charcoal, wood, straw/shrubs/grass, agricultural crop, and animal dung (National Statistics Directorate, 2010).

3.3.2 Anemia

The anemic status of women participants was based on hemoglobin (Hb) concentrations in grams per deciliter(g/dl) . The measurement of hemoglobin concentration was performed using HemoCue® Hb 301 system among women who agreed and signed the consent letter (National Statistics Directorate, 2010). The Hb level was categorized as women not having anemia with Hb greater than 11 g/dl and having anemia with Hb less than 11 g/dl (WHO, 2011).

3.3.3 Other predictor variables.

Anemia among women of reproductive age may also be influenced by other factors including their age, body mass index (BMI), residence type (rural vs. urban), wealth index, education level and smoking behaviors. The variable age was categorized into four groups including the groups of 15-24, 25-34, 35-44 and 45-49 years of age. BMI was categorized as Normal (BMI = 18.5 - 24.99), Underweight (BMI < 18.5), Overweight (BMI 25.00-29.99) and Obese (BMI > 30). The residence type was then grouped into rural and urban.

Moreover, the socioeconomic status of participants like wealth index and educational attainment were also re-categorized. Those women who were in the poorest and the poor class was treated as Low Wealth Index; middle-class women treated as Middle Wealth Index, and the rich and the richest classes as High Wealth Index. Educational attainment was categorized as No education, Primary level (incomplete and complete primary), Secondary level (incomplete and complete secondary) and Higher level. Furthermore, smoking behavior was categorized based on interview results either Yes or No response if they had smoked in the preceding 24 hours when the survey was conducted.

Table 2. Description of variables used in the study.

No	Variable description	Dependent / Independent	Variable name	Data type
1	**Hemoglobin Level**	Dependent	V456	Categorical
2	**Type of Cooking Fuel**	Independent	V161	Categorical
3	**Age**	Independent	V012	Categorical
4	**Type of place of residence**	Independent	V102	Categorical
5	**Educational Attainment**	Independent	V149	Categorical
6	**Wealth Index**	Independent	V190	Categorical
7	**Smoking Cigarettes**	Independent	V463A	Categorical
8	**Body Mass Index**	Independent	V445	Categorical

3.4 Statistical analysis

Statistical analysis in this study was performed using the Statistical Analysis System (SAS) Version 9.4. The measure of association is the Odds Ratio with 95% confidential intervals, and $\alpha = 0.05$ will be considered significant. The descriptive analysis of all the independent variables was performed to examine the frequency distribution of each variable. The outcome variable was classified as binary outcomes. Thus, the logistic regression model has been performed to examine the association between the independent variables and outcomes of interest.

Since DHS data used a complex sampling method, sampling weights as applied to each analysis performed. The reason for using weight was to account for probabilities of differential misclassification and inclusion for individuals in the study sample. The sampling weight variable was based on the recommendation from DHS that sample weight (V005) should be divided by 1,000,000 (National Statistics Directorate, 2010).

In the analysis, there will be two model stages of analysis. In the first stage, a bivariable logistic regression analysis was performed to assess associations between each independent variable (Type of fuels, Age group, BMI group, residence, wealth index, education level and smoking behavior) and the outcome variable (Anemia). In the second stage of the analysis, a mutlivariable logistic regression model was performed. Those variable found to be significant in the bivariable analysis were included in the mutlivariable analysis.

<u>**CHAPTER IV**</u>

4. RESULTS

4.1 Descriptive Statistics

This study used Timor-Leste DHS data from 2009-2010. A total of 2,758 women aged 15 – 49 years old were included in the study. The characteristics of participants delineated by anemia is presented in Table 3. Of all the women who participated in this study, 23% women were anemic and 77% women were not. When observed anemia among women based on the type of fuel which the main analysis for this study, those women who used solid fuel in the household were the largest group affected as opposed to those who used cleaner fuel (96 % and 4% respectively). On the other hand, those women who were normal and used solid fuel were 94% and 6% were cleaner fuel.

By women's age, among those were affected with anemia, the 35-44 age group had the highest proportion of women affected with anemia (35%) followed by 25-34 age group (28%), 15-24 age group (23% and the 44-49 age group were the least affected (14%). When compared to those women who were not affected, 25-34 age group had 33%, 35-44 age group had 31%, 15-24 age group had 25% and the least was 45-49 age group with 11% were affected.

In terms of the women's residence, women who were affected and lived in urban areas had a higher percentage of anemia than women who lived in rural areas (80% and 20%, respectively). While those women who weren't affected by anemia, still those who lived in the rural areas were greater that urban areas (72% and 28%, respectively).

Moreover, by looking at wealth index, the low wealth index women had the highest anemia proportion (43%) compared to the highest index (38%) and middle index (19%) among affected group. When comparing to women who didn't have anemia, rich wealth index was the highest (43%) than poor and middle (38% and 19% respectively).

When examining anemia among women based on the level of education, women who were affected by anemia and without a formal education background was the group most affected by anemia (43%), followed by secondary level of education (32%), primary level of education (23%) and highest level of education group (2%). On the other hand, those women who were not anemic, secondary level of education were the highest (38%) followed by those who didn't have formal education (33%), primary level of education (25%) and higher education level (4%).

Additionally, in term of women's body mass index, women with a normal BMI had 63% of anemia, underweight women had 30%, overweight women had 5%, and 2% of obese women had anemia. When compared to normal or anemia free group of women in this study, normal BMI still had the highest proportions (69%), followed by underweight (24%), overweight (6%) and obese women (1%).

Furthermore, women who did not smoke had the highest proportion of anemia compared to those who did smoke (3%). On the other hand, among those women who were not anemic, those who didn't smoke (96%) and smoker were 4%.

Table 3. Characteristics of participants in the Timor-Leste DHS delineated by anemia.

Independent Variables	**Anemia**		
	Normal N (%)	**Anemic N (%)**	**Total N (%)**
	2121(77%)	637(23%)	2758 (100%)
Age			
15-24	531 (25%)	158 (23%)	689(24%)
25-34	678 (33%)	180(28%)	858(32%)
35-44	673 (31%)	215(35%)	888(32)
45-49	239(11%)	84(14%)	323(12%)
Residence			
Urban	535 (28%)	117 (20 %)	652(26%)
Rural	1586 (72 %)	520 (80%)	2106(74%)
Wealth Index			
Low	877 (38%)	288(43%)	1165(39%)
Middle	424 (19%)	123(19%)	547(19%)
High	820 (43%)	226(38%)	1046(42%)
Smoking			
No	2011 (96%)	604(96 %)	2615(96%)
Yes	110(4 %)	33 (4%)	143(4%)
BMI			
Normal	1461 (69%)	413 (63%)	1874 (68%)
Underweight	505(24%)	193(30 %)	698(25%)
Overweight	122 (6%)	22 (5%)	144(6%)
Obese	21 (1%)	8 (2%)	29(1%)
Level of education			
No education	734 (33%)	269 (43%)	1003(36%)
Primary	557(25%)	158 (23%)	715(24%)
Secondary	783 (38%)	201(32%)	984(37%)
Higher	47 (4%)	9(2%)	56(3%)
Type of Fuels			
Cleaner fuels	73 (6%)	11(4 %)	84(5%)
Solid fuels	2036(94%)	623 (96%)	2743(95%)

***BMI** = Body Mass Index.*

***DHS** = Demographic Health and Survey*

4,2. Variability of hemoglobin results among participants

In our study population, approximately 2/3 of data were excluded from the final data set due to lack of hemoglobin results. This condition will likely to introduce variability among covariate in this study. Hence, we also conducted test to observe the similarities and differences for those individuals observed and missing data for each covariate included in this analysis presented in Table 4.

We found that the differences between women with hemoglobin and without hemoglobin were significantly different from each level for each type of covariate in this study. Age has p value = 0.0027, residence has p value = 0.005), wealth index has p value = <.0001, BMI has = <.0001) and type of fuel has p value = <.0001.

On the other hand, there were not significantly different among women with hemoglobin and without hemoglobin found on the level of education (p value = 0.3422) and smoking group (p value = 0.9345).

Table 4. Similarities and differences among those individuals observed and excluded from dataset.

Independent Variable	Women with hemoglobin Vs without Hemoglobin Chi-squared Test. ***P value***
Age	0.0027
15-24	
25-34	
35-44	
45-49	
Residence	0.0050
Urban	
Rural	
Wealth Index	<.0001
Low	
Middle	
High	
Smoking	0.9345
No	
Yes	
BMI	<.0001
Normal	
Underweight	
Overweight	
Obese	
Level of education	0.3422
No education	
Primary	
Secondary	
Higher	
Type of Fuels	<.0001
Cleaner fuels	
Solid fuels	

4.2 Bivariable analysis

Table 5 displays results of weighted bivariable logistic regression analyses explaining prevalence of anemia in women aged 15-49 in Timor-Leste between 2009 and 2010. When analyzing the association based on the type of fuels, the odds ratio for anemia in women using solid fuels was 1.73 (95% CI: 1.49 - 2.01) compared to women using cleaner fuels. By age group, both 35-44 and 45-49 age group were 1.30 and 1.39 times as likely to have anemia compared to the 15-24 age group.

By residence, the odds ratio for anemia among women living in the rural areas was 1.5 (95% CI: 1.43-1.64) compared to women living in urban areas. In addition to residence, the odds ratio of women's wealth index showed that both middle and rich classes were 0.88 and 0.80 times less likely to anemia than those women in the poor class.

Moreover, in term of level of education, women who had primary, secondary and higher level of education had the lower odds ratio (0.70, 0.65 and 0.37 respectively) of having anemia compared to those women without any formal education.

Looking into the women BMI's, obese (1.93) and underweighted women (1.39) had a higher chance of having anemia compared to those women with a normal BMI. On the other hand, the odds ratio of having anemia among overweight women was lower (0.87) compared to those women with a normal BMI.

Furthermore, in term of smoking behaviors, there was no statistically significant difference in anemia comparing women who smoke to those that do not ; 1.01 (95% CL: 0.88 - 1.16).

Table 5. Bivariable analysis of risk factors for anemia in women age 15-49 years in Timor-Leste, 2009–2010.

Independent Variables	COR (95% CIs)
Type of Fuels	
Cleaner fuels	Reference
Solid fuels	**1.734 (1.498 - 2.016)***
Age	
15-24	Reference
25-34	0.970 (0.897 – 1.050)
35-44	**1.304 (1.208 - 1.407) ***
45-49	**1.394 (1.264 - 1.538) ***
Residence	
Urban	Reference
Rural	**1.533 (1.431 - 1.644) ***
Wealth Index	
Low	Reference
Middle	**0.879 (0.813 – 0.951) ***
High	**0.808 (0.759 – 0.861) ***
Smoking	
No	Reference
Yes	1.014 (0.881 - 1.163)
BMI	
Normal	Reference
Underweight	**1.389 (1.302 - 1.481) ***
Overweight	**0.868 (0.762 - 0.985) ***
Obese	**1.933 (1.529 – 2.425) ***
Level of education	
No education	Reference
Primary	**0.703 (0.653 – 0.757) ***
Secondary	**0.646 (0.604 – 0.690) ***
Higher	**0.372 (0.303 – 0.453) ***

***** *Indicates statistically significant association result.*
COR *= Crude or Unadjusted Odds Ratio with 95% Confidential Intervals with significant level = 0.05.*
BMI *= Body Mass Index.*

4.3 Multivariabe Analysis.

Table 6 illustrates the result of a mutlivariable logistic regression model which included all the independent variables (Type of fuel, Age, Residence, Wealth Index, BMI, and Level of education) that were significantly associated with anemia in the bivariable analysis. After inclusion in single model predictors remained significant.

After adjustment for other variables, the odds ratio for anemia for women that use solid fuel was 1.43 (95% CI: 1.29-1.64) compared to the cleaner fuel users. When examining the age group of users, the odds ratio for both age groups 45-49 and 35- 44 (1.17 and 1.16 times respectively) were more likely to have anemia than age group 15-24.

Moreover, for women who live in the rural areas, the odds ratio for having anemia was 1.42 (95% CI: 1.31 – 1.55) compared to those lived in the urban areas. Obese women had 2.12 times higher odds of anemia and underweight women a 1.36 higher odds of anemia compared to women of normal weight. Overweight women did not have a difference in risk compared to normal weight women (0.96 [95% CI: 0.84-1.09]).

Furthermore, in term of level of education, after the adjustment for the other variables, the odds ratio for women with formal education including Primary, Secondary and Higher level of education (0.74, 0.73, and 0.59 times respectively) were less likely to have anemia when compared to women without any formal education.

Table 6. Adjusted odds ratio from weighted mutlivariable analysis of risk factors for anemia in women age 15-49 years in Timor-Leste, 2009–2010.

Independent Variables	**AOR (95% CIs)**
Type of Fuels	
Cleaner fuels	Reference
Solid fuels	**1.431 (1.296 - 1.644)***
Age	
15-24	Reference
25-34	0.942 (0.869 - 1.023)
35-44	**1.158 (1.066 - 1.258)***
45-49	**1.169 (1.049 - 1.303)***
Residence	
Urban	Reference
Rural	**1.424 (1.312 - 1.547) ***
BMI	
Normal	Reference
Underweight	**1.356 (1.271 - 1.447) ***
Overweight	0.961 (0.840 - 1.097)
Obese	**2.126 (1.678 - 2.681) ***
Level of education	
No education	Reference
Primary	**0.736 (0.681 - 0.795) ***
Secondary	**0.733 (0.677 - 0.794) ***
Higher	**0.594 (0.475 - 0.737) ***

*** Indicates statistically significant association result.*
***AOR** = Adjusted Odds Ratio results were controlled for type of fuels, age, residence, smoking behaviors, BMI, level of education.*
***CIs**= Confidential Intervals with significant level = 0.05.*
***BMI** = Body Mass Index.*
***AIC =** 40657.536*

4.4 Bivariable and multivariable analysis of risk factors for hemoglobin as continues variable among women age 15-49 years in Timor- Leste, 2009–2010.

Table 7 displays bivariable linear regression model of anemia as continues variable. The study found that only BMI and level of education were associated with anemia. In term of BMI, underweight and overweight women (p- value, 0.008 and 0.033 respectively) were statistically significantly associated with anemia. When looking into level education, only primary and secondary level of education women (p- value, 0.017 and 0.001 respectively) found to be associated with anemia.

Moreover, the multivariable analysis of linear regression presented in Table 8. The table only displayed the variable that found statistically significant in the bivariable analysis. Women with BMI level identified as underweight and overweight (p- value, 0.013 and 0.043 respectively) were statistically significantly associated with anemia. In addition to BMI, women with the primary and secondary level of education (p- value, 0.021 and 0.002 respectively) remained as the group found to be significantly associated with anemia even adjusted for variables.

Table 7. Bivariable analysis of linear regression for hemoglobin as continues in women age 15-49 years in Timor-Leste, 2009–2010.

Independent Variables	R-Squared	Parameter	t-value	p-value
Type of Fuels				
Cleaner fuels	0.000373	12.965	92.15	<.0001
Solid fuels		-0.125	-0.87	0.385
Age				
15-24	0.002799	12.885	230.30	<0.001
25-34		0.047	0.60	0.548
35-44		-0.114	-1.44	0.150
45-49		-0.144	-1.35	0.176
Residence				
Urban	0.000091	12.823	186.84	<0.001
Rural		0.031	0.41	0.680
Wealth Index				
Low	0.001959	12.858	279.14	<0.001
Middle		0.101	1.18	0.240
High		-0.074	-1.10	0.270
Smoking				
No	0.000013	12.847	409.22	<0.001
Yes		-0.025	-0.19	0.851
BMI				
Normal	0.0077	12.877	348.512	<0.001
Underweight		**-0.182**	**-2.62**	**0.008**
Overweight		**0.327**	**2.13**	**0.033**
Obese		-0.432	-1.56	0.118
Level of education				
No education	0.005255	12.708	252.88	<0.001
Primary		**0.190**	**2.38**	**0.017**
Secondary		**0.255**	**3.30**	**0.001**
Higher		0.157	0.86	0.387

Bold *Indicates statistically significant association result.*

Table 8. Mutlivariable analysis of linear regression for hemoglobin as continues in women age 15-49 years in Timor-Leste, 2009–2010.

Independent Variables	R-Squared	Parameter	t-value	p-value
BMI				
Normal	0.0125	12.747	228.88	<0.001
Underweight		**-0.173**	**-2.49**	**0.013**
Overweight		**0.318**	**2.03**	**0.043**
Obese		-0.461	-1.67	0.095
Level of education				
No education		-	-	-
Primary		**0.185**	**2.31**	**0.021**
Secondary		**0.220**	**3.07**	**0.002**
Higher		0.055	0.30	0.765

Bold *Indicates statistically significant association result.*

CHAPTER V

5. DISCUSSION AND CONCLUSION

5.1 Predictor variables and anemia

This study to our knowledge is the first study conducted using the dataset from Timor-Leste DH, between year 2009-2010 with the focus on the association of solid fuel use and anemia among women age 15-49 years old in Timor-Leste. Our analysis showed consistency with our study hypothesis that women who are exposed to solid fuels are at greater risk for anemia.

Our study confirms that approximately 23% of women age 15-49 years old in Timor-Leste during the year of 2009 – 2010 had anemia. This study found that women who used solid fuel as a source of energy for cooking or heating activities in the household were at increased risk for anemia compared to women who used cleaner fuel, even after adjusting for other predictors. When looking into the household energy use in Timor-Leste with approximately 600,000 tons of wood per year, this may have variety of health implications for reproductive age women because of the time spent in performing domestic tasks in the household.

Our results replicate the finding of a similar cross-sectional study conducted by Page *et al.* (2015), upon which our hypothesis and analysis were based. The difference between the studies was that the Page study focused on pregnant women while this study focused on non-pregnant women of reproductive age. Even though the sample population was different, the risks of anemia when exposed to solid fuel combustion in our study population and theirs were similar after adjusting for other covariates. The relative risk ratio in the Page study was 1.38 (95% CL: 1.19 -1.61) and the odds ratio in our study was 1.431 (95% CL: 1.296 - 1.644).

The analysis of the association of solid fuel and anemia has also been studied in children and reported to have a strong relationship with the mild and moderate/severe anemia even after they adjusted for other covariates (Kyu *et al.*, 2010). The biological plausibility of the association of solid fuel and anemia is still understudied. But through literature review, we believed that exposure to combustion byproducts from solid fuel has the potential to cause anemia. The chemicals emitted from combustion have the ability to reduce oxygen delivery to the tissues and also cause systemic inflammation which is mediated by inflammatory cytokines to interrupt erythropoietin process which resulting in anemia (Blumenthal, 2001; Weiss and Goodnough, 2005; Ying-Ying *et al.*, 2014).

Also, our study found that women in the age group of 35- 49 were at greater risk of having anemia compared to 15-35 group of age. Our result surprisingly resembles the finding presented by Morsy and ALhays (2014) in which they found that women at the age of 36- 50 years were more at risk when compared to other younger age groups. This phenomenon is seen in this age group because they tend to focus more on the household needs and abandon their personal needs which puts them at risk of having health problems (Morsy & ALhays, 2014) . In fact, in Timor-Leste a majority of women in reproductive age seem to have more responsibilities including taking care of young children, elderly and other siblings in the household because of cultural beliefs and traditions (Lover *et al.*, 2014; IEA, 2015).

In looking into women's residence, our study found that those women who live in the rural areas are more susceptible to anemia compared to those who live in the urban areas even after it was controlled for other covariates. Considering 70% of the total the Timor-Leste population residing in the rural area and living under the poverty line, the finding of our study reflect the vulnerability of Timor-Leste women to anemia (IEA, 2015). This situation was also identified by Bentley and Griffits (2003) highlighting that women in India who lived in the rural area with a low standard of living were the most susceptible group to anemia. Hence, women who lives in the impoverished conditions, the likelihood of having health problems especially anemia is higher among them.

Moreover, our study also indicated that obese women were two times more likely to have anemia as compared to normal weighted women. The result is consistent with studies which looked into the association between anemia and BMI's of women among women in China and girls in North India (Qin *et al.*, 2013; Peter *et al.*, 2012). Both studies argued that these women or girls had anemia because of their age, socioeconomic condition, low food intake, and hormonal changes. In addition to obese women, after adjusted to other predictors, underweight women also still found to be associated with anemia. This could be due to the fact that majority of women in Timor-Leste have limited access to proper nutrient in daily life which made prone to anemia (Qin *et al.*, 2013; Peter *et al.*, 2012).

Wealth index and level of education in our study both showed an association with anemia. Our finding also seems to present the same results as studies from India, which identified that women without formal education who live in low income or wealth index households have a higher tendency to have health problems. Because these group of women were believed to have limited knowledge on the nutritional requirements in their reproductive age (Morsy & ALhays, 2014; Bentley & Griffits, 2003).

5.2 Strengths and limitations

Our study has several limitations that we found along the process. First, our independent variable of interest which was the type of fuel variable: solid fuel (96%) and cleaner fuel (5%). The proportion of both groups have anemia showed large differences in terms of a type of fuel use. This differences might contribute to overestimation or underestimation of the result in determining the risk of having anemia from this study population. Second, in our study the measurement of solid fuel exposure among participants might be imprecise, because DHS used survey questions to determine whether or not a participant was exposed. Thus, it may lead to exposure misclassification in this study. Additionally, since solid fuel emits various concentration of pollutants, it requires a direct measurement to examine the association accurately. Third, the mechanism in which pollutant form solid fuel combustion caused anemia is still largely unknown, thus further studies are needed to explore more on the mechanism of disease development. Last but not least, our study used DHS data from a survey based on the cross-sectional study design. The cross-sectional study design only allows analysis of the association between predictors and outcome variables and not a causal relationship.

Fourthly, there were also significantly differences found in most of covariates based on the hemoglobin results among those women who were observed and excluded from this study (table 4). Those differences would affect the final result and impact generalizability of our study to women in Timor-Leste.

Lastly, this study could be improved by considering other potential confounders in the association of solid fuel use with anemia. One of the main potential confounders is women's nutritional status of iron, vitamin B12, and folate levels. Nutritional status plays a vital role in the determination of anemia (WHO, 2012). The DHS dataset only had information on nutritional status for pregnant women, which means that we could not evaluate its effect in our population.

Despite the limitations, the main strength is that we have a sample that represents individuals from households across 13 municipalities in the country which makes our finding generalizable to populations across the country. Since our study is the first to explore the association between solid fuel use and anemia in Timor-Leste among reproductive age of women of whom a majority are living in the rural areas, this study could serve as a baseline for information to enhance the evidence worldwide on the importance of using of cleaner fuel instead of solid fuel among women living in rural areas in developing countries. This study also can be used by Ministry of Health and Ministry of Environment of Timor-Leste to have a better approach, implement and evaluate a program to reduce the use of solid fuels and improve the health status of Timorese women.

5.3 Policy Implications and Recommendations

Many interventions to reduce health effects related to indoor air pollution especially from solid have been introduced in developing countries. In fact, WHO recommended three levels of interventions. First, intervention at the source of pollution by switching to alternative fuels (liquid petroleum gas (LPG), biogas, electricity and solar power) and using improved stoves. Second, intervention to the cooking and living area in the household by creating better house ventilation including chimneys, smoke hoods, eaves spaces enlarged and cooking window. Third, intervention to user behaviors by keeping children away when cooking or using dried fuel wood for cooking. (WHO, 2016a; WHO, 2016b)

Of all the interventions recommended by WHO, many of these interventions have been found to successfully reduce risk to indoor air pollution. For instance, improved cooking stove in Mexico, people used Patsari cook stove which is the latest improvement type of cooking device. This device help reduce indoor air pollution which resulting in less impact of solid fuel smoke to human health (Romieu *et al.,* 2009).

Our findings from this study have demonstrated some important implications for the Timor-Leste government especially the Ministry of Environment and Ministry of Health in Timor-Leste. From our result, a majority of participants were poor, resided in rural areas and used solid fuel as primary source of energy for cooking and heating. These may put them at risk for anemia and other health problems. Thus, the Ministry of Environment in Timor-Leste should consider purposing alternative interventions that could help minimize the risk of exposure to combustion from solid fuel. One way to start is to introduce improved cooking stoves or switching to a cleaner and less pollutant option like liquid petroleum gas, kerosene and electric.

The adverse impacts of indoor air pollution to public health have been proven. Therefore, the Ministry of Health in Timor-Leste, especially the public health division, should create an awareness program that helps to educate women, children and other potential population at risk on the importance of considering alternative methods of using solid fuels or switching to cleaners fuel. This program might incorporate directly with individuals in the household because we believe that the majority of individuals in Timor-Leste still have limited knowledge regarding the indoor air pollution, especially from solid fuel.

Since exposure to solid fuel from our study was measured indirectly and used a cross-sectional study design, future studies are needed to explore in depth the relationship between solid fuel use and anemia among women who are directly exposed to combustion. The study should include variables such as the type of solid fuel, measurement of time, distance, type of cooking devices, kitchen or house ventilation and specific pollutants that women are exposed to during cooking and heating activities. The future studies that incorporate all the variables mentioned may uncover the clear relationship between solid fuel combustion and anemia.

5.4 Conclusion

As newly independent country, Timor-Leste encounters many difficulties in all sectors. One of the sectors that seems to have minimum focus is household energy used for cooking across the nation. In South East Asia, Timor-Leste is the country where approximately 98% of the population still relies on solid fuel as the main source of energy (WHO, 2016c; World Bank, 2007). Solid fuel has been proven to be associated with related health problems like ALRI in children, COPD, lung cancer and recently with anemia in both women and children.

This study has examined the association between solid fuel use in the household and anemia among reproductive age of women in Timor-Leste, age 15-49 years old. The study found that solid fuel use with adjustment of other covariates significantly correlated with anemia in reproductive age of women. The finding suggests that exposure to combustion from solid fuel. Hence, alternative interventions such introducing improved cook stoves or switching to cleaner fuel and public health awareness programs regarding solid fuel must be implemented to minimize the risk of developing anemia and other health effects in both women and children. Future studies are also needed to explore in depth the relationship between solid fuel use and anemia among women who are directly exposed to combustion.

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