Assessing Cardiovascular Disease Burden in Rural Uganda and Informing Future Interventions

by

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Program II Senior Thesis
Disease, Religion & Global Health Policy
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Durham, North Carolina

November 28th, 2017

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Senior thesis submitted in partial fulfillment of the
requirements for the degree of Bachelor of Arts in
Disease, Religion & Global Health Policy
in the Trinity College of Arts & Science

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Abstract

This senior thesis seeks to investigate cardiovascular disease (CVD) risk in a rural region in Uganda and to use insights from field experience and the literature to explore possible interventions. The thesis research involved a total of 232 participants, including village residents (142), market workers (50), religious leaders (20), and village health workers (VHTs) (20). The village sample data are part of a larger longitudinal study, conducted under the Community Health Collaboration project of the Student Research Training Program (SRT) at Duke University. Recruitment for the other three cohorts of market workers, religious leaders, and VHTs began with this current study, conducted in the summer of 2016. The current study continued the biometric assessments of CVD risk within the village cohort and extended the testing to market workers. A total of 192 individuals participated in these three biometric assessments of their body mass index (BMI), systolic and diastolic blood pressure, and fasting blood glucose. In addition, the research team conducted surveys using an interview format with all four cohorts. The survey assessed demographic information, lifestyle factors, CVD perceptions, and CVD knowledge, and religious influences on CVD. Overall, the biometric findings show substantial CVD risk in the village sample and the persistence of risk for individuals over time, as evidenced by the results from longitudinal, linear mixed-effect models. Beyond this high, persistent CVD risk for villagers, the market workers had even higher CVD risk as evidenced by elevated BMI and fasting blood glucose. The elevated CVD risk for market workers is possibly due to differences in lifestyle factors including diet and exercise that are associated with urbanization. The survey results show near unanimous agreement among participants that CVD is a problem in their community. Despite the overall concern, the findings expose inaccuracies in knowledge about CVD across all cohorts. Regarding the role of religion,

more than 90% of participants across all cohorts believe that religion can alleviate CVD symptoms. Further questioning about religion and CVD reflected a broad array of direct and indirect interpretations of the role of religion. Exploratory regression analyses, which link survey data to CVD risk indicators, yielded results that have implications for tailoring CVD interventions to rural Uganda. To further connect the findings to intervention strategies, the discussion summarizes the method and results of a literature review on possible CVD interventions. The literature review advances three principal categories of intervention: education, policy, and programming. For each of these categories, the study findings together with the literature review provide the basis for recommending three integrative strategy for CVD intervention: VHT CVD education programs, policy reform to address CVD medication stock-outs, and religiously-based CVD programs. The strategies have promise for reducing CVD risk and improving the lives of individuals in rural Uganda.

1 Introduction

1.1 Cardiovascular Disease

Cardiovascular disease (CVD) encompasses a multitude of diseases of the cardiac muscle and vital organs' vascular systems, most commonly ischemic heart disease, congestive heart failure, and stroke.[1] These diseases share many risk factors with other non-communicable diseases (NCDs), including physical inactivity, tobacco use, poor diet, excess alcohol consumption, blood lipids, hypertension, obesity, family history of CVD, diabetes, age, gender, and socioeconomic status.[2]

1.2 Cardiovascular Disease in Uganda

CVD remains the leading cause of death worldwide with 80% of these deaths occurring in low and middle income countries (LMICs).[3,4] CVD in LMICs is increasingly alarming given that CVD affects younger populations in LMICs than in high-income countries, thereby affecting individuals' peak productivity years.[5] Uganda, a low-income country, is currently undergoing this epidemiological transition, which refers to a shift in burden from primarily communicable disease to NCD.[6] Although communicable diseases still constitute the highest burden, the deaths and DALYs due to NCDs, including CVD, are continually rising in Uganda.[6] The Global Burden of Disease (GBD) study estimates that in Uganda, CVD is responsible for 10.24% of deaths and 4% of disability adjusted life-years (DALYs).[7] GBD estimates that the percentage of deaths and DALYs that CVD causes has steadily increased in Uganda since its earliest estimates in 1990.[7] Risk factors for CVD have been documented throughout Uganda although data indicates that they generally increase with increasing urbanization.[8]

1.3 Religion in Uganda

Religion in Uganda is a central part of community organization and facilitates social cohesion and cultural identity; therefore it is an important element to consider in community health.[9] The religious breakdown in Uganda is 45.1% Protestant, 39.3% Roman Catholic, 13.7% Muslim, 1.6% Other (including traditional religions), and 0.2% None.[10] The low percentage of the population not identifying with a religion indicates the pervasiveness and importance of religious identity and practice in the country. Moreover, development programs, seeking to facilitate quality of life improvements, often rely on these strong ties to religion to engage and mobilize communities.[9]

1.4 Policy for CVD in Uganda

National policies in Uganda, as in many other countries, are inadequate to address the rising CVD and more broadly NCD burden. Uganda lacks many policies that help address increased CVD risk including food policies to reduce population salt consumption, saturated and trans fats availability, and other unhealthy diets.[11] The WHO also recommends that Uganda, among other countries, implement policies to address CVD risk factors, including policies to reduce alcohol consumption, lessen tobacco-use, and decrease physical inactivity.[11] Additionally, the WHO recommends a national strategic action plan to address CVD, which Uganda currently lacks.[11]

Policy also encompasses CVD funding, which falls more broadly under NCD funding. Despite a steady increase in the budget percentage allocated to health, total health spending still falls below 10% of the total budget and significantly misses the 15% goal outlined in the Abuja Declaration.[12] Moreover, the NCD programme in Uganda receives 0.01% of the total Ministry of Health budget, of which a smaller fraction is geared toward addressing CVD.[13]

1.5 Purpose and Paper Aims

The overall purpose of this project was to better understand CVD risk at a community level in a rural region in Uganda using qualitative and quantitative methods and to explore interventions to address the CVD burden, using insights from a field study and literature. To understand CVD risk, the study assessed the longitudinal level of CVD risk in a rural parish, the relative risk of a slightly more urban population, and the predictors of CVD risk in those communities. To inform potential interventions, the study explored knowledge and perceptions of CVD in this region and the influence of religion on those understandings. Finally, this project utilized the available literature to inform recommendations for CVD intervention in the local communities. The individual aims of the study appear below:

I. How has risk of CVD, as measured by Body Mass Index (BMI), blood pressure, and fasting blood glucose, changed longitudinally from 2013-2016 in the rural parish (village cohort)?

II. Are market workers (more urban cohort) or villagers (more rural cohort) more at risk of CVD, as assessed by the biometric indicators?

III. What knowledge levels exist surrounding CVD risk factors and how does knowledge vary between cohorts?

IV. How is CVD perceived and how does perception vary among cohorts?

V. How does religion inform local perceptions of CVD and how does the influence of religion vary between cohorts?

VI. What lifestyle factors, demographics, perceptions, and indicators are significant predictors of increased CVD risk?

VII. What are potential policies or programs within the local context to improve cardiovascular health among the population?

2 Fieldwork Methods

2.1 Study Setting

Data collection for this study on cardiovascular health focused on a rural parish in Mityana District of Uganda's Central Region, Mityana town, which is a small town in the same district, and the surrounding areas. The parish is located approximately 75 miles west of the capital city, Kampala. Data collection was composed of two main geographical sources, the parish and Mityana town. Within the parish, two groups were sampled: (1) the 'village sample,' sampled longitudinally starting in 2013 and (2) the village health workers (VHTs), sampled for the first time in 2016. The parish encompasses 14 villages, which each have an average population of 601 people and 105 households. Data collection in Mityana town involved a cohort of market workers from the food market located at the center of the town. The market has 98 regular workers who live in Mityana town or surrounding areas, primarily outside of the rural parish. The final cohort, the religious leaders, lived in the parish, Mityana town, and surrounding areas.

2.2 Participants

2.2.1 Village Sample Participants

The village sample is a continuation of the CVD dataset of the Community Health in Rural Uganda project, established by Dr. Sumedha Ariely and Dr. Christopher Kigongo and sponsored by the Student Research Training (SRT) program at Duke University. The research team first recruited participants in 2013 for a study on cardiovascular health. The team surveyed 121 adult women and measured their blood pressure and BMI. The recruitment of women for this initial study followed a systematic strategy. From the VHTs' registers, nine houses in each village were selected randomly, except for Village N in which only 4 houses were selected.

Random selection occurred through numbers drawn from a bag containing the number of houses in the village. To qualify, at least one adult woman needed to inhabit the house. If no adult woman was home when the surveyors visited the house, they redrew a number from the bag to identify a replacement house.

In 2014, the research team surveyed 156 new and re-recruited participants and measured their blood pressure, BMI, and blood glucose. To incorporate men into the study, houses were randomly selected from VHTs' registers in each village using a random number generator. From the registry, the research team chose the oldest male in each house, for a total of 5 males and 5 alternate males. Additionally, the team randomly selected 5 of the women from the 2013 sample from each village using a random number generator with the remaining women listed randomly as alternates. For Village N, the recruitment included all 4 women who participated in 2013 plus 6 women randomly selected from the registry; this yielded 1 additional participant and 5 alternates.

In 2015, the research team surveyed 148 new and re-recruited participants and measured blood pressure, BMI, and blood glucose. VHTs attempted to re-recruit all 2014 participants in their village from a list the researchers provided. To maintain sample sizes of approximately 10 participants per village, if the number of willing participants of each gender in their village was below five, the VHTs recruited new participant(s) of their choosing who were the same gender in the village.

In 2016, the research team surveyed 142 new and re-recruited participants and measured their blood pressure, BMI, and blood glucose. VHTs recruited participants based on a list of all previous participants, prioritized by the recent participation (2015 then 2014 then 2013). VHTs recruited 10 participants using the prioritization for alternates.

Every year, VHTs instructed participants to meet early in the morning at a central location in their village on the day of testing. For years that included blood glucose testing, VHTs also instructed participants not to eat late in the evening or the morning of the testing. If participants did not arrive at the agreed location, VHTs would call participants or walk to their houses to see if they still wanted to participate. The number of participants sampled consecutive years is detailed in Appendix A1.

2.2.2 Market Worker Participants

In 2016, for the first time, the research team surveyed 50 market workers and measured their blood pressure, BMI, and blood glucose. The research team chose participants using a random number on a list of all individuals working in the market, which was complied with the help of the market supervisor. When individuals were missing, or declined participation, the team used a number generator to select an individual for replacement.

2.2.3 Village Health Worker Participants (VHTs)

In 2016, the research team surveyed 20 VHTs but did not measure any biometric indicators. The research team selected the VHTs to recruit using a random number generator on a complete list of VHTs, which the Head VHT provided.

2.2.4 Religious Leader Participants

In 2016, the research team recruited and surveyed 20 religious leaders based on nomination and convenience sampling. Therefore, the religious leader cohort results cannot be generalizable to all religious leaders in the parish, Mityana town, and surrounding areas. All VHTs provided the names and phone numbers of any religious leaders in the villages or surrounding areas. The research team then recruited from these contacts. Recruited religious leaders also identified and recommended additional religious leaders in the villages or surrounding areas for possible recruitment.

2.3 Procedure

This section will detail procedures for all cohorts including consent, survey tools, biometric measurement procedures, measurement classifications for biometrics, and the ethics statement. The final section (2.3.6) details cohort specific procedures.

2.3.1 Consent

In all cohorts, regardless of year, the research team acquired informed consent before any data collection. To acquire consent, the translator read the oral consent form to the participants before they signed and dated the written consent form. The research team obtained approval from the Duke IRB and local officials, detailed in the Ethics Statement below.

2.3.2 Ethics Statement

Duke University Institutional Review Board (#C0393) and Dr. Fred Lwasampijja, the head of Uganda's Mityana District Health Office, approved this study. All participants gave oral and written consent after a trained translator read the IRB-approved consent form in the local language, Luganda. Participants had the opportunity to ask questions and decline participation. For participants who could not write, they indicated consent using an "X" mark.

Across all years, agreement to participate was high, despite a reasonably high level of effort required for participation. This high level of consent is likely because the VHTs, who helped recruit participants, are trusted members of the community, the Duke Student team is known and liked in the parish, and the community is interested in cardiovascular health. In 2016, all village participants, VHTs, and religious leaders, whom the researcher and translator met in person, consented to participate. With regards to the two individuals in the market sample who declined participation, we thanked them for their time and invited two other randomly selected participants. Additionally, for the village sample, this high participation likely resulted from the fact that VHTs recruited participants ahead of time; therefore, those that agreed and showed up on the day of testing were self-selecting and knew that they wanted to participate. For the VHTs and religious leaders, this is likely also a result of not acquiring biometric data and therefore requiring less of a commitment to participate.

2.3.3 Survey Tools

The research team developed the research surveys administered to the village and market worker cohorts in 2016 utilizing CVD literature, advice from a Ugandan physician from the study community, and input from the local community translators and coordinators working with the team. Participants answered questions regarding demographics, diet, income, lifestyle habits, past medical history, symptoms of CVD, CVD medication use, perceptions of CVD, knowledge of CVD, and perceptions of the influence of religion on CVD. Prior to surveying, the student researchers examined the survey, written in English, with the local translator. Together they clarified the intent of each question, practiced administration procedures, and discussed the importance of direct participant back translation. The local translator has worked with the SRT team every year since 2014, participating each year in retraining on IRB approved procedures and best practices in translation and survey administration. The trained translator administered the survey in the local language, Luganda, in real time. The translator then relayed the participants' responses in English to the student researcher, who recorded the responses. The average survey took 10 to 15 minutes to complete.

2.3.4 Biometric Sampling

The study utilized biometric indicators that are predictors of CVD risk and are minimally invasive including blood pressure, blood glucose, and BMI. During consent acquisition, participants sat for at least 10 minutes, which helped to better ensure accurate measurements. Next, the 2016 research team assessed the biometric CVD risk indicators. To avoid effects of mobility or anxiety on the reading, the team first measured blood pressure using an automated machine (ReliOn BP100 Upper Arm Blood Pressure Monitor). To insure accurate blood glucose assessment, the team next reviewed procedures described in recruitment and follow-up reminders that required overnight fasting. The team emphasized that if they had not fasted, it was okay, but it was important to know for test validity. For the one participant in the village sample in 2016 who had indicated having forgotten to fast, the glucose data were omitted. After sufficient training, the local translator tested the blood glucose of participants using standard procedures with single-use lancets and the Bayer's Contour Blood Glucose Monitoring System. The team verified accuracy using a control solution for the monitoring system prior to field use. Last, the team recorded weight and height to assess BMI with a mechanical, spring-powered scale placed on a flat surface and a tape measure adhered to a vertical surface. For this assessment, participants removed their shoes and stood on the scale with their backs against a vertical structure. The team calculated the BMI immediately after the measurements using the standard formula of weight in kilograms divided by the square of height in meters (kg/m^2). The team attempted to conduct the assessments quickly, knowing that the participants had fasted and needed to resume their daily work.

2.3.5 Measurement Classification

BMI was categorized using the World Health Organization's (WHO's) international classification of adult underweight, overweight, and obese (Appendix B1).[14] Blood pressure was categorized using the European Society of Hypertension and the European Society of Cardiology's (ESH/ESC)[15] classifications of optimal, normal, high-normal, stage 1, stage 2, and stage 3 hypertension (Appendix B2), which the WHO endorses.[16] Fasting blood glucose was categorized using the American Diabetes Association's classifications of normal, pre-diabetic, and potential diabetic (Appendix B3).[17]

2.3.6 Cohort Specific Procedures

2.3.6.1 Village Sample Participants

In the first year of data collection (2013), the student researcher, local translator, and VHT visited each participant's home, attained informed consent, and surveyed and obtained biometric indicators for each participant. In 2014, 2015, and 2016 the VHT organized the recruited participants from their village to meet a specific morning at a central location. Following their training, VHTs carefully instructed participants not to eat before the sampling to maintain the integrity of the fasting blood glucose test. Upon arrival, the VHTs helped organize the participants. The researcher and translator attained informed consent from all participants, took biometric measurements of all participants, and administered the survey to all participants, in that order. The whole procedure lasted from approximately 9am to 11am for each village tested.

2.3.6.2 Market Worker Participants

The researcher and translator identified the market workers randomly selected for participation (via random number generation from the list of workers) using the help of the market supervisor and other workers within the market. Once identified, the translator explained the study to the prospective participant. After receiving verbal information about consent to participate, individuals who volunteered then completed the written consent form and the survey. The team member then reminded the participant to avoid eating after midnight before the assessments. The following morning the participant had all biometric measurements measured in the same fashion as detailed for the villager cohort.

2.3.6.3 Village Health Worker Participants

The translator called the randomly selected VHTs using the phone numbers provided by the Head VHT and arranged a time for the researcher, translator, and VHT to meet. At the meeting, the researcher provided information about the study and consent. All VHTs volunteered to participate, completed the written consent, and then completed the survey. Chronologically, all VHT sampling occurred after the completion of sampling the villager and market worker cohorts.

2.3.6.4 Religious Leader Participants

The translator called the religious leaders who the VHTs and other religious leaders had identified, using the phone numbers these sources provided. When a phone number was lacking, the translator and researcher went to the home or work of that individual to explain the study and inquire about participation. If the participant was interested, the research team acquired informed consent and administered the survey. If the participant spoke English, the student researcher conducted the interview. This was the only cohort in which some participants were fluent in English. Chronologically, all religious leader sampling occurred after the completion of sampling the villager and market worker cohorts.

3 Fieldwork Results

3.1 Longitudinal Risk

The longitudinal component of this study involved only the village sample cohort as detailed in the methods section. This component sought to assess the level of CVD risk in pursuit of the broader aim of better understanding CVD risk in the rural parish and to the specific aim of addressing the following:

I. How has risk of CVD, as measured by Body Mass Index (BMI), blood pressure, and fasting blood glucose, changed longitudinally from 2013-2016 in the rural parish (village cohort)?

Prior to statistic modeling, we sought to present results regarding longitudinal risk descriptively. Following this preliminary analysis, we used linear mixed-effects models (LMMs) to explore the data. For these models, the analyses include subsamples which had complete, consecutive data: (a) across all four years, 2013-2016 or (b) across the most recent three years, 2014-2016. Given difficulties inherent in following participants over time and variety in recruitment priorities, there were limited numbers of individuals within these two subsamples. Also, the overall study began collecting blood glucose in the second year (2014), so analyses involving fasting blood glucose cover three years (2014-2016).

3.1.1 Longitudinal Risk Results

Table 1 presents results from the longitudinal sample as raw numbers of individuals in each risk level category for all biometric indicators in all years. Given the longitudinal nature of the study, counts across years are not independent samples. Therefore, only some counts across years represent the same individual. The number of participants sampled in consecutive years appear in the demographic table in Appendix A1. The WHO's risk categories for BMI were used: 0 for underweight, 1 for normal weight, 2 for overweight, and 3 for obese (Appendix B1).[14] The European Society of Hypertension and European Society of Cardiology's risk categories for blood pressure were used: 0 for optimal, 1 for normal, 2 for high-normal, 3 for stage 1 hypertension, 4 for stage 2 hypertension, and 5 for stage 3 hypertension (Appendix B2).[15] The American Diabetes Association's risk categories for blood glucose were used: 0 for hypoglycemic, 1 for normal, 2 for pre-diabetic, and 3 for potential diabetic (Appendix B3). [17]

Table 1

Number of Unique Individuals within each year with Different CVD Risk in Village Sample (2013-2016)

	Cases by Year			
CVD Variable Risk Group	2013	2014	2015	2016
Body Mass Index Risk Group				
= 0	8	12	18	17
= 1	67	95	85	74
= 2	28	30	25	25
= 3	16	15	19	25
Total Valid BMI	119	152	147	141
	2013	2014	2015	2016
Blood Pressure Risk Group				
= 0	18	18	24	17
= 1	25	22	25	22
= 2	36	25	24	18
= 3	25	43	40	36
= 4	8	27	23	24
= 5	7	18	12	25
Total Valid Blood Pressure	119	153	148	142
	2013	2014	2015	2016
Blood Glucose Risk Group				
= 0	na	20	7	36
= 1	na	110	75	91
= 2	na	13	52	4
= 3	na	6	11	10
Total Valid Blood Glucose	na	149	145	141

Note. This table presents the counts of individuals in each risk category from the village cohort across all years. The table is for reference purposes. Because the participation and missing data vary across years, statistical analysis from these results cannot yield reliable inferences regarding risk distributions.

These exploratory results indicate that there is a substantial portion of the cohort each year at risk for BMI, blood pressure, or blood glucose. Within the 2016 village sample, 35% of the sample was overweight or obese, 60% in the stages of hypertension, and 10% pre-diabetic or potentially diabetic. These results are concerning and hint that CVD risk is high in this cohort. As explained in the methods section, this study does not comprise a completely random sample, therefore we cannot generalize to the rest of the rural parish; however, given these results, further investigation of CVD risk in the rural parish at large seems warranted. Moreover, the high CVD risk burden within the 2016 villager cohort indicates the need for intervention.

In addition to 2016 risk level, we are interested in how the cohort has changed overtime with increasing or decreasing risk level. For that reason, Table 2 visualizes the change in risk group status for all participants with two consecutive years of data. Participants included for two consecutive years may or may not have two other years of consecutive data points. Therefore, participants may or may not appear in the table more than once. The number of participants sampled in greater than 2 consecutive years appears in Appendix A1.

Table 2

Change in Risk Group Status Across Adjacent Years by Risk Indicator: Body Mass Index, Blood Pressure, Blood Glucose (2013-2016)

	Change in Risk Group Status			
Risk Indicator (Year)	Increasing	Stayed the same	Decreasing	Total
Body Mass Index				
2013-2014	4 (9.76%)	32 (78.05%)	5 (12.20%)	41
2014-2015	8 (9.64%)	59 (71.08%)	16 (19.28%)	83
2015-2016	17 (14.78%)	89 (77.39%)	9 (7.83%)	115
Total	29	180	30	
Blood Pressure				
2013-2014	18 (43.90%)	12 (29.27%)	11 (26.83%)	41
2014-2015	15 (17.65%)	36 (42.35%)	34 (40.00%)	85
2015-2016	49 (41.88%)	49 (41.88%)	19 (16.24%)	117
Total	82	97	64	
Blood Glucose				
2014-2015	41 (50.00%)	32 (39.02%)	9 (10.98%)	82
2015-2016	11 (9.57%)	41 (35.65%)	63 (54.78%)	115
Total	52	73	72	

From this table, it appears that in two consecutive years, most people stay within the same risk category with regards to any biometric indicator, particularly BMI. The observation that most participants over two years have stable risk is not surprising given that the risk categories contain a range of biometric indicators. Therefore, to change risk categories, individuals' biometric indicators would have to change substantially or individuals would have to be on the edge of a risk category. Blood pressure risk category showed more variation. It appears that most participants sampled in 2013 and 2014 experienced an increase in blood pressure risk, whereas from 2014 to 2015 most participants either stayed the same or decreased in risk. Finally, from 2015 to 2016, most participants either increased risk or stayed the same. This positive and negative variation is an interesting observation and hints that further exploration is necessary to explore both individual and population trends with regards to blood pressure risk. Table 2 also indicates that from 2014-2015 most participants increased in risk classification for blood glucose, and the opposite occurred from 2015-2016. This variation could indicate a generally stable population risk that fluctuates around the average, however, further analysis is necessary to determine the overall trends in blood glucose.

To better understand CVD risk in our village sample, it is necessary to explore trends in the longitudinal data sample involving continuous measurements rather than risk categories. To do this, we analyzed sub-samples with complete data across three or four years. The reference tables displaying the complete three-year and four-year subsamples' biometric means and distributions in each year appear in Appendix C. These reference tables illustrate that the means for BMI and blood glucose were generally within the normal limits, whereas the means for blood pressure are at a hypertensive level. Although merely averages, this hints that hypertension may be particularly problematic for our cohort. Additionally, the averages of each of the biometric indicators seemed to oscillate across the three or four-year time span, hinting that risk level may be relatively stable. Given that these descriptions are based on averages, and do not consider individual biometric variation, additional analyses that incorporate individual participant variation can clarify these overall trends.

3.1.2 Linear Mixed-Effect Models (LMMs) Analysis for Longitudinal Risk

To understand the role of individual participant variation, the next step in the analyses used Linear Mixed-Effect Modeling (LMM). These LLM tests enabled exploration of models for the complete three-year cohort and the complete four-year longitudinal cohort. For this study, the linear trend model provides the most clinically significant test because a linear result over three to four years of data provides insight into whether the overall cohort is increasing, decreasing, or staying the same with regards to CVD risk. Additionally, the linear model adds to the interpretability of the result. Though other models are possible (parabolic, logarithmic, etc.), such models could yield clinically uninterpretable results.

Prior to each of the following LMMs, initial exploratory analyses examined the hypotheses for the longitudinal trends. The results from these exploratory analyses appear in Appendix D as graphs of the averages for each biometric indicator over three or four years of data. Simple linear models assume that the biometric indicators from different years are independent from one another. The current longitudinal data violates this assumption, however, as individuals' biometric measurements in each year are not independent from their measurements in other years. Given the lack of independence, the central analyses for this study used LMMs to account for individual variation in change over time for each indicator.

LMM can separate out trends in the cohort from individual trends via incorporating fixed-effect and random-effect factors into the model. This model required a simplifying assumption that participants generally follow the population trend. There were not enough data points to estimate if individuals had their own individual trends. The model equations used were:

$$Y_{it} = \beta_o + \alpha_i + \beta_i x_{it} + \varepsilon_i;\ \varepsilon_i \sim N(0,\sigma^2)$$

$$\alpha_i = \alpha_o + \upsilon_i\ ;\ \upsilon_i \sim N(0,\tau^2)$$

Essentially, this model examines overall trends in the sample while accounting for individual longitudinal data, which prevents global population trends from overwhelming individual trends. The analysis procedure used LMMs for both the three- and four-year subsamples with complete data on BMI and blood pressure. Because the assessment of blood glucose began in the second year, the corresponding analysis was the three-year complete subsample. The analysis procedure analyzed the complete three-year subsample because the complete four-year subsample alone did not contain longitudinal blood glucose and the greater number of longitudinal participants increased the power of the models for BMI and blood pressure. The specifics of each LMM appear in Appendix E. Each of the biometric LMMs derive from the following null and alternative hypotheses:

H_0: $\beta_{year} = 0$

H_A: $\beta_{year} \neq 0$

All LMMs resulted in failing to reject the null hypotheses that the given biometric indicators were not changing overtime. Therefore, the conclusion of no clear linear trends for any of the biometric indicators within our longitudinal sample is most plausible. Given that the LMMs consider individual variation, the finding that no biometric indicators have linear time trends indicates that on average, participants have maintained their same risk levels over the course of the study. The graphs depicting individual trends for the complete three-year and four-year subsamples appear in Appendix G. These graphs provide a helpful visual of the biometric measurement's stability overtime.

3.1.3 Conclusion

The lack of significant trends in any of these biometric indicators (BMI, blood pressure, and fasting blood glucose) is not a surprising result. CVD is a chronic disease with both modifiable and non-modifiable risk factors.[2] Therefore, CVD biometric indicators are unlikely to dramatically change over a three to four-year period without medical interventions. Per the survey responses, medical interventions were rare. The lack of statistically significant trends in the 4-year period of this study may indicate that CVD risk is relatively stable in our sample. While decreasing trends in biometric measurements would be favorable, it is encouraging that trends are stable rather than increasing. Given that our sample is not entirely random, we cannot generalize this conclusion of stable risk to the rest of the population of the rural parish.

3.2 Rural and Urban Relative Risk

Comparison of the cross-sectional 2016 village sample and the 2016 market sample seeks to answer the following study aim:

II. Are market workers (more urban cohort) or villagers (more rural cohort) more at risk of CVD, as assessed by the biometric indicators?

To compare the two cohorts, the analysis procedure began with a chi-squared test. This initial analysis involved the distributions of risk categories rather than the numerical distributions of the indicators due to interest in relative risk rather than interest in relative numerical values. Graphical depictions facilitate describing relative risk as does exploration into the percentage of individuals in each cohort at highest risk in multiple biometric indicators.

3.2.1 Chi-squared Analysis

The binned categorical risk for each biometric indicator in both the village and the market worker cohorts appears in Table 3, as well as the results of a chi-squared analysis for each biometric indicator. Three chi-squared tests of homogeneity examined the relative frequency of biometric risk between the two cohorts. Due to the small sample sizes, we used a simulated version of Fisher's exact test because it is more robust and lacks a minimum cell count condition.

The null hypotheses of the chi-squared tests were that the cohorts had homogenously distributed risk for all three biometric indicators, with a significance level of 0.05.

Table 3

Chi-Square Tests for Differences between Village Sample and Market Worker Sample by *Risk Group Status (2016)*

CVD Variable by Group (Value)	Number of Cases by Sample: Villagers n = 141	Market Workers n = 50	Chi Squared ($\chi 2$)	p-value
Body Mass Index				
Underweight	17	0	21.775	0.000999
Normal	74	14		
Overweight	25	18		
Obese	25	18		
Blood Glucose Level				
Hypoglycemic	36	25	10.805	0.00999
Normal	91	23		
Pre-Diabetic	4	1		
Potential Diabetic	10	1		
Blood Pressure				
Optimal	17	3	10.09	0.06593
Normal	22	5		
High Normal	18	14		
Stage 1	36	12		
Stage 2	24	4		
Stage 3	25	12		

Note. The BMI groups include: underweight (<18.5), normal (18.5-24.9), overweight (25-29.9), and obese (≥30). Blood glucose coefficients refer to mg/dL grouped as hypoglycemic (<70), normal (70-100), pre-diabetic (100-126), and potential diabetic (>126). Blood pressure in mmHg has four levels: optimal (<120), normal (<130), high-normal (130-139), stage 1 (140-159), stage 2 (160-179), and stage 3 (≥180).

The chi-squared for BMI and blood glucose (p-values <0.001 and 0.01), allowed us to conclude that BMI and blood glucose risk differed between the market worker and villager cohorts. Conversely, the chi-squared statistic for blood pressure was greater than 0.05, therefore we failed to reject the null hypothesis and conclude that the two cohort's risk profiles were likely homogenously distributed. The lack of homogenous distribution in both risk for BMI and blood glucose indicates that there are differences in risk distribution between the cohorts. The graphs below illustrate these differences.

3.2.2 Graphical Depictions

Given significant differences in risk distributions for BMI and blood glucose, further analysis sought to illustrate how CVD risk differs between the two cohorts. Therefore, we utilized graphs of the percentage of each cohort within the biometric risk categories. Although this is merely descriptive, it hints at difference in risk between the cohort and therefore why the chi-squared tests for BMI and blood glucose indicated non-homogenous distribution.

Figure 1

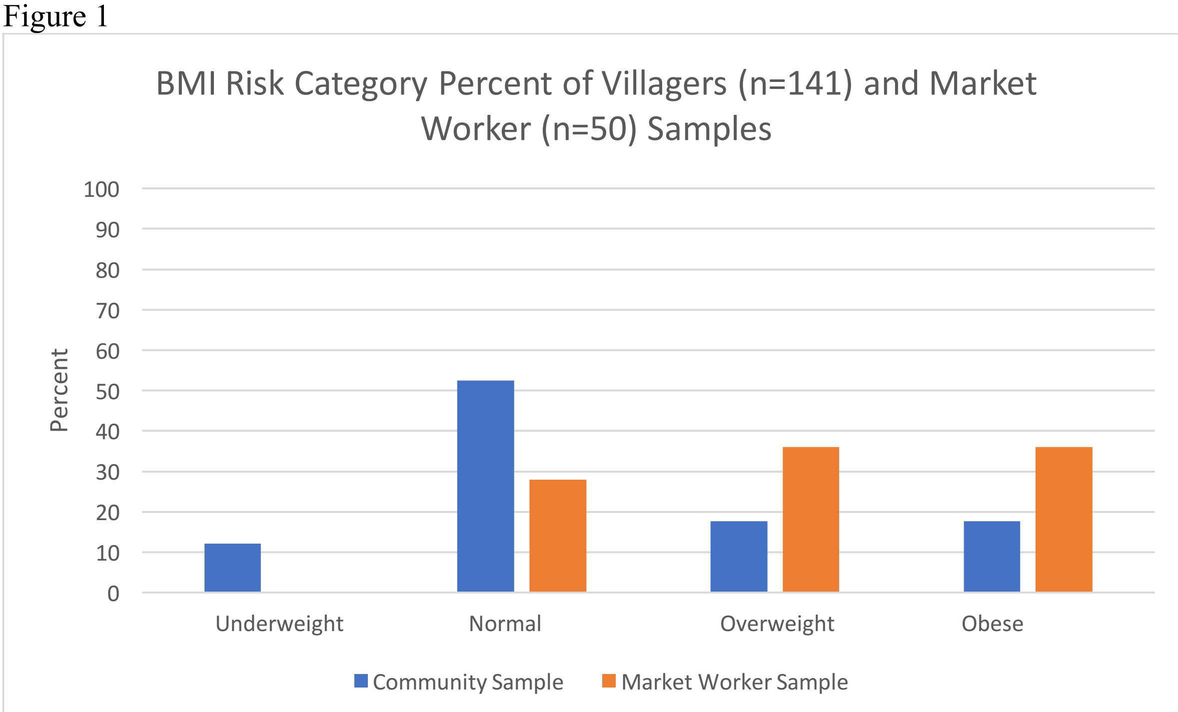


Figure 1 illustrates that a greater percentage of market workers were overweight or obese, as compared to the greater percentage of villagers that were underweight or normal weight. This variation could be due to the sedentary nature of the market workers' job. The survey data indicated generally that market workers were sedentary, selling their product for most of the work day, whereas most of the villagers were active, working as farmers. Additionally, the market worker cohort reported higher processed food consumption than the villager cohort.

Figure 2

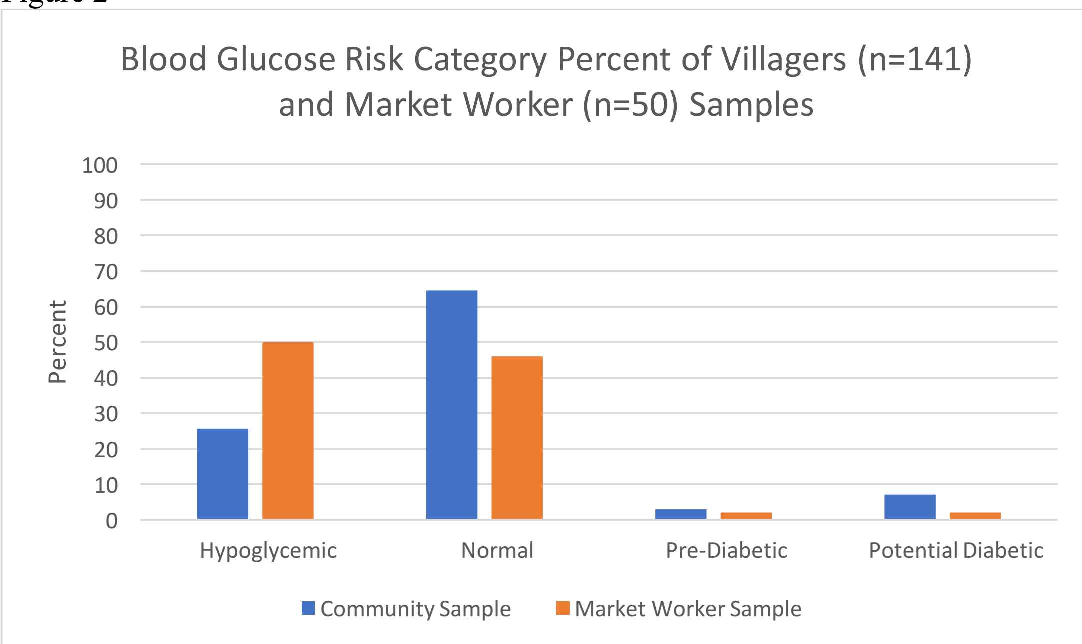


Figure 2 illustrates that the market worker cohort had higher rates of hypoglycemia compared to the village cohort, which had higher rates of normal fasting blood glucose. Pre-diabetic glucose levels and potential diabetic glucose levels were relatively similar between the cohorts.

Figure 3

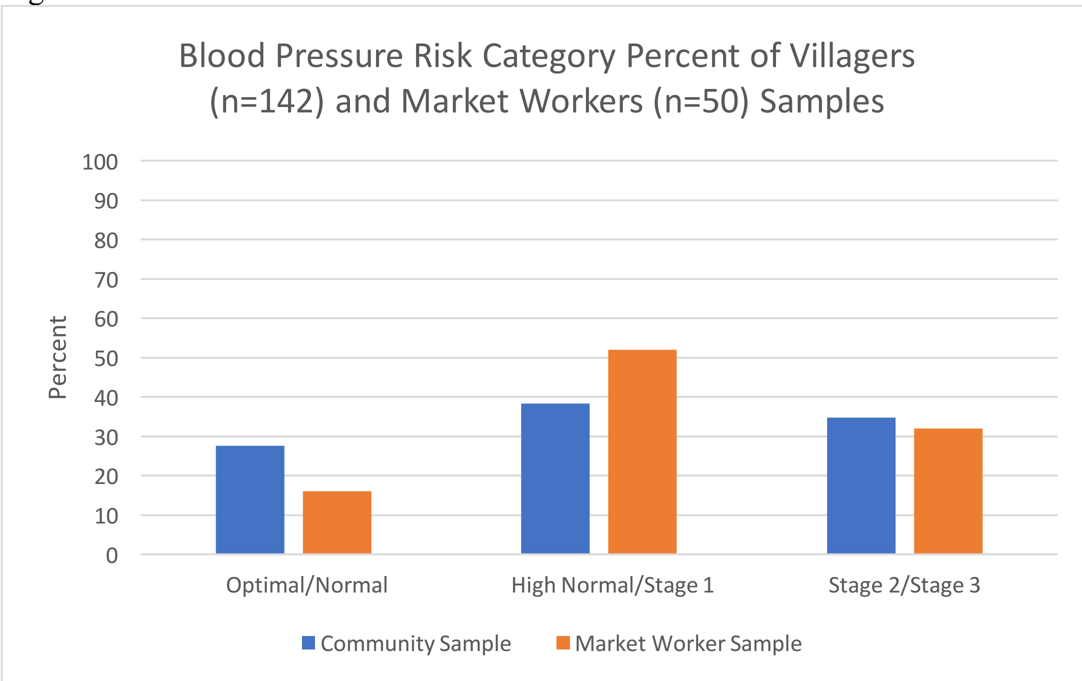


Figure 3 illustrates that the village sample had a higher percentage of individuals with optimal or normal blood pressure levels, whereas the market worker cohort had a higher percentage of individuals with high normal or stage 1 hypertension. Additionally, the market worker and villager cohorts had roughly equal percentages of individuals with stage 2 or stage 3 hypertension. This graph indicates an overall greater percentage of the market worker cohort has elevated blood pressure (high normal to stage 3) compared to the villager cohort.

3.2.3 Chi-squared Analysis for Risk in Multiple Biometric Indicators

In addition to the analysis of individual biometric risk indicators, we explored the number of participants with two biometric indicators in the highest risk categories. This is helpful because elevated biometric measurements are merely risk factors, therefore the greater number of elevated biometric indicators, the higher the risk for CVD. Examining the relative numbers of individuals with the highest risk in two categories will help further elucidate the relative risks of the two cohorts. Highest risk refers to obese for BMI, stage 2 or stage 3 hypertension for blood pressure, and potential diabetic for fasting blood glucose. Table 4 details the counts of individuals at highest risk in multiple categories for the two cohorts as well as the results of a chi-squared test to investigate differences in distribution between the two cohorts.

Table 4

Number of Highest CVD Risk Indicators: Village Sample vs. Market Worker Samples (2016)

	Cardiovascular Risk Factors			Sample			
Number of Highest Risk Indicators	Body Mass	Blood Pressure	Blood Glucose	Villagers (n=142)	Market Workers (n=50)	Chi Square ($\chi 2$)	p-value
Three				1	0		
Two				7	1	7.175*	0.0180
				2	0		
				5	9		

Note. BMI highest risk includes those classified as obese. BP highest risk refers to those classified as stage 2 and stage 3 hypertension. BGL highest risk includes those classified as potential diabetic.
*The chi square test refers to the presence of two factors.

As illustrated in Table 4, one individual in the village sample was at the highest risk in three categories while no one in the market worker sample was at the highest risk in all three categories. This low frequency precluded statistical testing for group differences on three risk factors. For two risk factors, however, chi-squared testing was possible using a simulated version of Fisher's exact test. The test revealed a low p-value (0.018) sufficient to reject the null hypothesis and support a conclusion that the distribution of individuals at highest risk for two biometric indicators differed between the two cohorts. As illustrated in Table 4, roughly 10% of the village cohort and 20% of the market worker cohort were in the highest risk category for two of the three biometric indicators. This finding indicates that market workers, compared to villagers, showed a higher likelihood of having two indicators of highest CVD risk. The addition of the one individual who scored high on all three indicators in the village sample would not change the conclusion that proportionally more market workers are at the highest risk in two biometric indicators.

3.2.4 Conclusion

Ultimately these descriptive and statistical analyses indicate that market workers and villagers may be differentially at risk of CVD, with market workers at higher risk. The chi-squared analysis of homogeneity of blood glucose and BMI and the chi-squared analysis of homogeneity of highest risk in multiple indicators both support the conclusion that the two cohorts are at differential risk. Graphical depictions illustrating a greater percentage of overweight and hypertensive market workers, compared to villagers, and the finding that two times the percentage of market workers were at the highest risk in multiple indicators both support the conclusion that that market workers are at higher CVD risk than the village sample.

3.3 Knowledge Assessment

To better understand CVD risk in the community, the survey included a knowledge assessment. Documenting existing knowledge levels will guide the understanding of CVD in the local context, provide a useful comparison between cohorts, and help inform future educational interventions. Specifically, these survey questions and subsequent analyses seek to answer the following study aim:

III. What knowledge levels exist surrounding CVD risk factors and how does knowledge vary between cohorts?

3.3.1 Knowledge Score

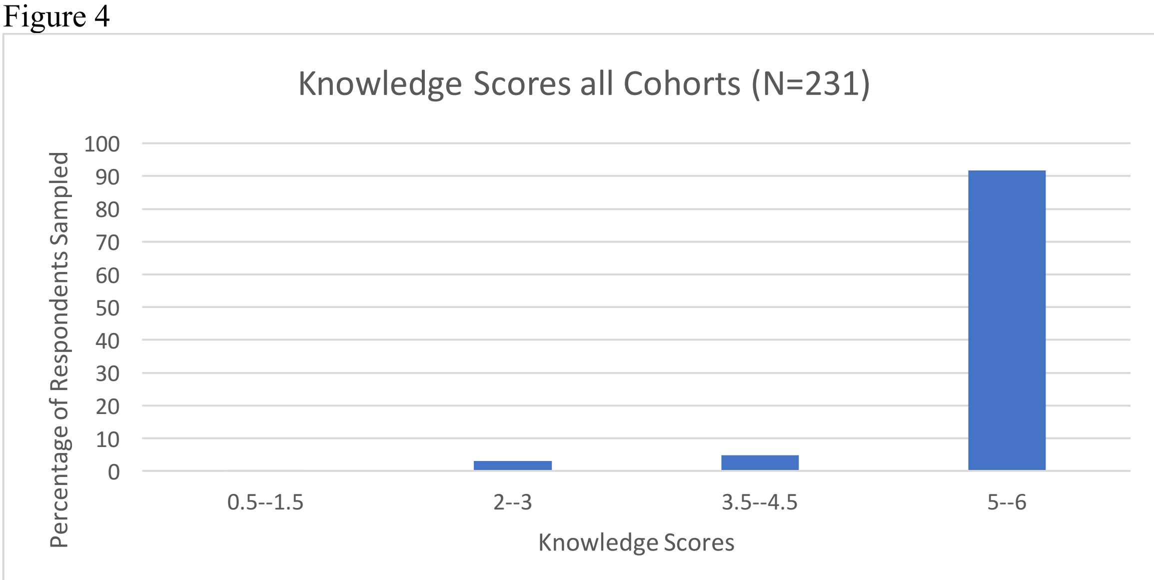
The survey instrument included a CVD risk factors knowledge assessment. Based on the World Health Federation's recommendations, the risk factors included the following: unhealthy diet, sedentary lifestyle, alcohol consumption, tobacco use, family history, and elevated stress.[2] Additionally, unhealthy diet was subdivided into fried food consumption and excessive salt consumption based on previous research in the parish, which identified fried food and salt consumption as primary factors of unhealthy diets.

For each risk factor, respondents indicated if the factor contributes to cardiovascular risk. Each risk factor corresponded to one point on the knowledge scale and the two factors contributing to unhealthy diet corresponded to a half point. Therefore, the possible scores were in 0.5 increments with a possible range of 0-6. This calculation of the overall knowledge score omitted items in the survey section that focused on religious observance.

3.3.2 Knowledge Results

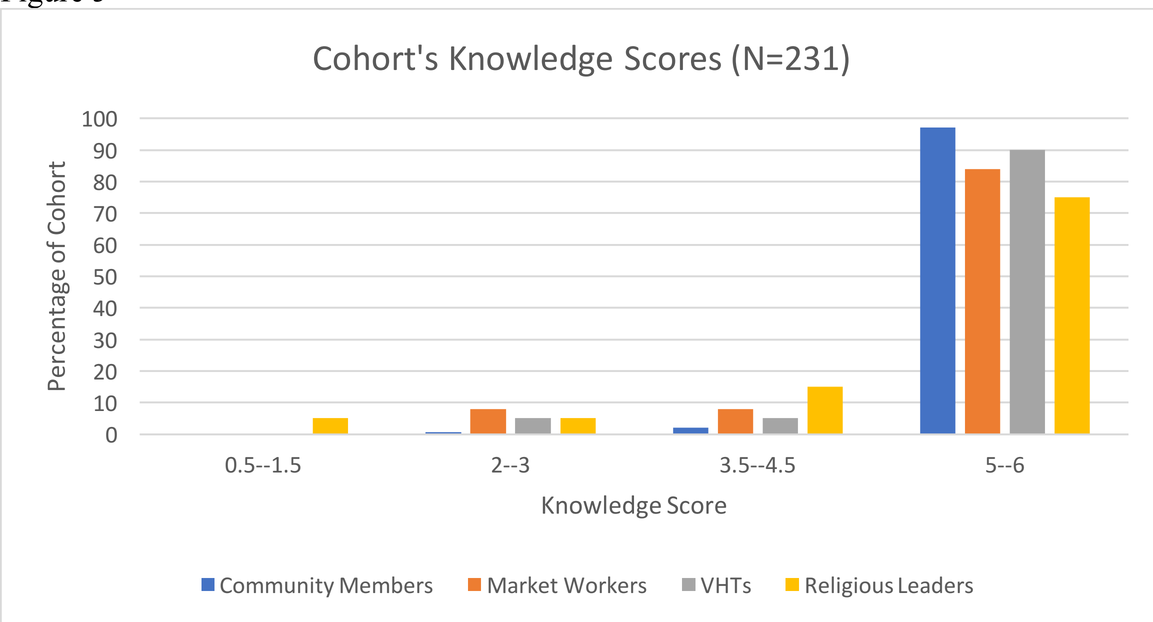
Figure 4 presents the knowledge score results for all cohorts combined by percentage for each score range. Knowledge score ranges start with the lowest score of any respondent, 0.5.

Figure 4



As evident in Figure 4, most respondents had high knowledge of CVD risk factors (scoring 5-6). The least commonly identified item was knowing that genetic history influences CVD. Within the cohorts, only 54.6% of villagers, 36% of market workers, 55% of VHTs, and 60% of religious leaders correctly identified family history as a risk factor. Figure 5 illustrates the knowledge level scores for each cohort.

Figure 5



Note. Villagers (n=141), Market Workers (n=50), VHTs (n=20), and Religious Leaders (n=20).

While all cohorts had relatively high knowledge scores, the village cohort had the greatest percentage of participants who scored in the highest knowledge range (5-6), even greater than VHTs and religious leaders. While the sample sizes are widely disparate, it is interesting to note that the relatively less-educated village cohort scored so highly, which could be due to their participation in the SRT CVD program in previous years. As evident in the data, knowledge scores were unrelated to overall education level. The religious leader cohort had the highest level of education and most had attended a higher education institution. The lack of direct relationship between education level and CVD knowledge is not entirely unexpected given that further formal education does not necessarily mean greater instruction on health-related topics.

Additionally, the health workers do not appear to have elevated knowledge scores compared to the other cohorts, a concerning finding.

3.3.3 Knowledge Survey Conclusion

These knowledge assessment results indicate that most individuals sampled have high knowledge of the most basic CVD risk factors. However, knowledge of genetic risk factors remains low in all cohorts. Furthermore, villagers, on average, had the highest knowledge levels, then VHTs, market workers, and religious leaders. While these knowledge scores are based on questions susceptible to various interpretations and translation complications, it is important to note that community leaders may benefit from educational CVD campaigns. In this case, VHTs and religious leaders could greatly benefit from a CVD education campaign, given that they both play a trusted and meaningful role in community life.

3.4 Perception Assessment

As with the knowledge assessment, perceptions about CVD inform individuals' behavior and lifestyle choices. Religion also plays a role in perceptions and choices impacting CVD risk. Perceptions and religion also hold potential for developing interventions that reduce risk. Because of these considerations, the perceptions analyses sought to answer the following study aims:

IV. How is CVD perceived and how does perception vary among cohorts?

V. How does religion inform local perceptions of CVD and how does the influence of religion vary between cohorts?

In addition to the survey responses, religious leaders and VHT workers also provided qualitative data when they wished to clarify their answers regarding the role of religion on CVD development.

3.4.1 Perceptions Instrument

Five questions aimed to assess perceptions of CVD and perceptions of religion's influence on CVD. The questions included whether individuals believed CVD was a problem for their community, was curable, or was preventable. The nuances of these questions will be explored later in this section, however, in survey design 'curable' indicates an ability to eliminate CVD and 'preventable' indicates an ability to prevent CVD onset, even if incomplete. The final two questions assessed whether individuals believed religion played a role in the development of CVD or the alleviation of symptoms.

3.4.2 Perceptions Results

Table 5 displays the results from the five questions assessing perceptions. Chi-squared tests of independence assessed potential differences across the four cohorts. Due to small row counts, a simulated version of Fisher's exact test enabled the chi-squared analysis for two questions regarding beliefs that: (a) CVD is a problem and (b) religion alleviates CVD symptoms. For all tests, the p-value of 0.05 served as the significance level for testing the null hypothesis that survey responses and cohort were independent.

Table 5

Percent Holding Specific Beliefs about CVD in Village, Market Worker, VHT, and Religious Leader Samples (2016)

	Holding Belief within Subsample Percent (Ratio)					
Specific Belief Held	Villagers $n = 141$	Market Workers $n = 50$	VHTs n = 20	Religious Leaders n = 20	Chi Square ($\chi 2$)	p-value
Believe CVD is a problem	96.4 % (135/140)	100 % (50/50)	100 % (20/20)	100 % (20/20)	3.73	0.196
Believe CVD is curable	68.3 % (88/138)	56 % (28/50)	50 % (10/20)	70 % (14/20)	2.66	0.447
Believe CVD is preventable	40.3 % (56/139)	42 % (21/50)	60 % (12/20)	75 % (15/20)	10.48	0.015*
Believe religion affects CVD development	68.8 % (97/141)	82 % (41/50)	45 % (9/20)	50 % (10/20)	12.38	0.006*
Believe religion can alleviate CVD symptoms	95 % (134/141)	94 % (47/50)	90 % (18/20)	95 % (19/20)	0.86	0.906

* $p < 0.05$.

Note. Participants' affirmation "yes" in response to the question indicates that the belief is held.

Belief that CVD is preventable and belief that religion affects the development of CVD showed statistically significant different responses among the cohorts. Although the other question responses did not differ significantly across cohorts, the patterns reveal potentially valuable information as discussed below.

3.4.2.1 CVD Problem for the Community

Differences in responses to belief that CVD is a problem in their community reflect the sense of urgency in the community. If many people believe that CVD is not a problem, interventions need to first address this discrepancy. On the contrary, the opposite result emerged.

Nearly every person in every cohort perceived CVD as a problem, indicating potential receptivity to community-level CVD interventions.

3.4.2.2 Curability of CVD

Within the study, 50-70% of all cohorts reported believing that CVD is curable. CVD is manageable but not curable, so these perceptions of CVD as curable may limit prevention efforts or lessen immediate action after developing CVD. Additionally, belief in its curability could lead to lower compliance with CVD medication after the initial dose or doses. Interviews in prior years of the dataset previewed this continuing misperception of CVD as curable. Many respondents in those interviews who had been diagnosed with CVD reported that they had been "cured" after taking prescribed medications for a short time. In addition to the behavioral effects, the belief that CVD is completely curable may indicate a basic misperception of CVD and support the recommendation that more nuanced education surrounding CVD development, management, and treatment is necessary.

3.4.2.3 Preventability of CVD

Religious leaders were the most likely to believe CVD was preventable (75%), then the VHTs (60%), market workers (42%), and villagers (40.3%). Belief that CVD was preventable reflected the degree of agency individuals might feel about their cardiovascular health. When respondents indicated that they believed CVD was preventable, the interviewer asked, "How?" Participants could mention as many preventative factors as they preferred. Importantly, this section in the survey occurred before the knowledge assessment, which involved specific prompts regarding prevention and risk. Consequently, the open-ended responses about preventing CVD were not influenced by subsequent prompts in the survey.

A total of 104 participants gave specific answers for how to prevent CVD, which included 56 villagers, 21 marker workers, 12 VHTs, and 15 religious leaders. Within the village cohort, the most commonly cited way to prevent CVD was regular medical check-ups (25/56 people). Other common prevention measures included improved diet (15/56 people), education (9/56 people), following medical personnel advice (7/56 people), exercise (4/56 people), and stress reduction (4/56 people). Within the market worker cohort, the primary prevention strategies mentioned were medical check-ups (9/21 people), improved diet (6/21 people), and following medical personnel's advice (5/21 people). For VHTs the most commonly cited prevention strategies were diet changes (9/12 people) and education (3/12 people). Religious leaders were the only cohort to have a participant (1/15 person) mention reducing tobacco or alcohol consumption to reduce CVD incidence. For this cohort, the most common responses were changes in diet (11/15 people), education (7/15 people), exercise (5/15 people), and medical check-ups (3/15 people).

A few of these results stand out as particularly interesting and relevant. Regular medical check-ups were the most commonly cited prevention technique within the village and market worker cohorts. This is salient for two reasons. First, given experience on the ground, few people are likely receiving regular medical check-ups as the local clinics are often relatively far and unreliable. Second, the VHT cohort was the only cohort tied to the healthcare community yet not a single VHT mentioned regular medical check-ups as a preventative factor. Perhaps VHTs are more aware of the lack of infrastructure to cater to regular medical check-ups or perhaps they place more responsibility on individuals rather than medical personnel. Differences in reporting use of exercise was also surprising. Not a single VHT or market worker mentioned exercise, whereas substantial numbers of villagers and religious leaders did. Finally, it was curious that only one individual mentioned decreasing tobacco or alcohol use as a method for prevention of CVD.

3.4.2.4 Religion and CVD Development

There were statistically significant differences between cohorts in belief that level or type of religious observance affects CVD development, as seen in the Table 5. Prior to the study, we hypothesized that religious leaders would most widely hold this belief, however, nearly the opposite was true. Most market worker (82%) and villagers (68.8%) held this belief, whereas only half of the religious leaders and just under half of the village health workers shared this belief.

Qualitative data helped to clarify the responses of VHT workers and religious leaders regarding the influence of religion on CVD. Due to time constraints imposed by biometric assessments, the survey for market workers and villagers omitted qualitative follow-up about religious observance and CVD. Of the ten VHTs who answered, “Yes,” eight added clarifications. Three responses focused on specific religious practices that increased stress in people’s lives such as shouting for evangelizing purposes, slaughtering of animals, and lack of sleep. Three other respondents identified religion’s role in reducing stress and therefore guarding against CVD. The remaining two VHTs viewed CVD as divine intervention to punish individuals for lack of devotion. Only two out of eight religious leaders who affirmed religion’s role in development of CVD wished to clarify their response. One attributed the cause to stress from religious teachings that are difficult to follow, such as remaining married in hostile situations leading to personal distress and increased risk for CVD. The other religious leader explained that certain religions allow the consumption of alcohol, thereby increasing the risk of CVD. This wide variety of interpretations from the VHT and religious leaders, however, illustrates the complexity and potential influence of religious belief systems. These findings support the potential of future research that more deeply explores the construction of beliefs that increase or decrease CVD risk. The high percentage of respondents who affirmed this belief (45-82% across the four groups), regardless of underlying interpretation, further illustrates the salience of religion in these cohorts and the potential for religiously-based interventions.

3.4.2.5 Religion Alleviate Symptoms of CVD

Almost all participants (90-95%) held the belief that religious observance can alleviate symptoms of CVD. Therefore, it was not surprising that there was not a statistically significant difference in responses between cohorts. This result further affirms the validity and potential strength of future CVD interventions that implore religious frameworks within this community.

3.4.3 Conclusion

This section on participant's perceptions reveals a variety of key results that can help inform future research and intervention strategies. Most survey respondents believe that CVD is a problem in their community; this belief provides a basis for anticipating receptiveness to the need for intervention. As evidenced by the prominence of the belief that CVD is curable, interventions must first focus on education about the nature of CVD as a chronic disease, which can be managed and partially prevented. Dispelling the myth of curing CVD can foster adopting preventative behaviors and increasing compliance with CVD medications. Quantitative data indicated that there are knowledge gaps surrounding CVD prevention, particularly among market workers and villagers. Moreover, qualitative results indicate the need to educate communities about the risks of alcohol, tobacco, and sedentary lifestyle on CVD incidence. Ultimately, educational interventions are necessary to address the gaps in community understanding of CVD.

Despite the variety of interpretations, the responses to the role of religion in CVD development and management indicate the importance of religion in how individuals in the community perceive and understand CVD. Therefore, a potential intervention incorporating religious understandings or conducted through religious institutions holds valuable potential.

3.5 Predictors of CVD Risk for Village and Market Worker Cohorts

To understand the CVD risk in the village and market worker cohorts, the study survey included questions involving demographics, lifestyle factors, CVD perceptions, and CVD knowledge. These factors are potentially related to elevated BMI, blood pressure, and fasting blood glucose and overall CVD risk. The specific study aim that this section aims to answer is:

VI. What lifestyle factors, demographics, perceptions, and indicators are significant predictors of increased CVD risk?

Demographic variables in this study included gender, age, educational level, number of children, household income, personal experience of chest pain, cardiac family history, and cardiovascular and diabetic family history. Personal experience of chest pain indicated frequency of chest pain among respondents on an ordinal scale (daily, once per week, once per month, once per year). The question regarding cardiac family history had a binary response (yes or no). The question regarding cardiovascular and diabetic family history was also a binary response, however, it asked about family members diagnoses for a series of specific conditions. Cardiac family history and cardiovascular and diabetic family history were both included in the survey to ensure that the survey captured various understandings of CVD within the local context.

The lifestyle factors included tobacco use, alcohol consumption, homemade medication use, distance walking to work, and time sedentary at work. Homemade medication use refers to respondents reporting that they took some type of homemade medications for CVD management or prevention. Distance walking to work and time sedentary at work reflected activity of the respondent. This approach to assessing activity came from previous knowledge of typical lifestyles within the parish.

Perception predictors explored in this model were belief that CVD is a problem for respondent's community and belief that CVD is curable. The knowledge potential predictor was the respondent's knowledge score, explained in the 3.3 Knowledge Assessment section.

To explore these factors as predictors of CVD risk, we used a backward p-value selection in tandem with the Adjusted R^2 approach to linear regression for each of the biometric indicators in four separate models (BMI, systolic blood pressure, diastolic blood pressure, and blood glucose). Applying this regression technique for both the 2016 villager and market worker cohorts ensured that no significant variables were excluded from the model that were either predictive of a specific biometric indicator or contributed to the overall data variation the model explained (Adjusted R^2). We started with a model that contained all the variables from the survey and removed them in order of least significance (largest p-value greater than 0.05). Utilizing convention, if removing the variable from the model resulted in a greater than 10% decrease in the Adjusted R^2 value, the variable was reintroduced and retained in the model. For all linear regressions, female is the reference category for gender.

These predictors have potential to inform future interventions, through providing insight into factors within the community that put people at risk. Because these regression analyses are exploratory, inferences regarding these results are necessarily tentative. Translation, the short-term nature of the study, the uncontrolled sampling environment, and the participant self-reporting all introduce potential limitations to these regression analyses. Despite these limitations, we were interested in exploring the data. Prior to analysis we hypothesized that some variables would relate to increased CVD risk as measured by biometric indicators. The list of variables hypothesized to positively related to CVD included: age, personal experience of chest pain, cardiac family history, income, cardiovascular and diabetic family history, tobacco use, alcohol consumption, and time sedentary at work all increased, all biometric measurements would also increase. In addition, we expected several variables to relate to lower CVD risk including: distance walked to work, educational level, and CVD knowledge.

3.5.1 Multiple Linear Regressions (MLR) Results

Detailed information on the results from the MLR analyses appear in Appendix H (for the villager cohort) and in Appendix I (for the market worker cohort). Table 6 below presents the summary findings from these regressions. As shown in the table, each of the 11 variables predicted one or more biometric indicators for one or both cohorts. The relatively higher number of significant effects (12) in the village sample compared to those in the market worker sample (6) is due in part to the greater statistical power within the larger village sample (141 participants) in comparison to the smaller market worker sample (50 participants).

Table 6

Effect Direction (Positive or Negative) for Significant Regression Findings for Market Worker and Villager Cohorts

	Village Sample – CVD Risk Indicator				Market Workers – CVD Risk Indicator			
Variable	Body Mass Index	Systolic Blood Pressure	Diastolic Blood Pressure	Blood Glucose Level	Body Mass Index	Systolic Blood Pressure	Diastolic Blood Pressure	Blood Glucose Level
Age		+*			+	+	+	
Gender	-							
Education	+					-		
Income		+	+					
Number of Children		-				-		
Chest Pain		+	+					
Any Family History CVD			+					
Family History CVD				-				
Home Made Medications						+		
View CVD as Curable		-						
Knowledge of CVD				+				

*Clinically Insignificant

Given the above findings, it is interesting to consider possible explanations for the results obtained through the MLR analyses. Consistent with the exploratory purpose of the MLR, the inferences that follow serve only as exploratory interpretations designed to stimulate future research or inspire further intervention. For the villager cohort, being a woman and having greater education predicted higher BMI. The gender discrepancy is reasonable in the local village context given the expectations for women to do more work around the house, therefore engaging in less exercise. For the market worker sample, the gender difference may not have emerged due to the limitation of sample size gender imbalance (5 market men vs. 45 market women). The association between increased education and higher BMI may result from the role of education in facilitating higher income and increased access to processed foods. For the market worker cohort, increased age predicted higher BMI, which is consistent with the literature.[2]

Within both cohorts, having more children predicted lower systolic blood pressure. An initial explanation involves income resources. With a greater number of children, there is less disposable income to spend on processed foods. Future analysis could examine the contributions of processed food availability, food costs, and perceptions of the cost among individuals of varying income. Among villagers, higher income and chest pain predicted higher systolic and diastolic blood pressure. Chest pain frequency and increased blood pressure are both indicators of CVD and therefore this association confirms prior CVD findings.[2] Additionally, the belief that CVD was curable was predictive of lower systolic blood pressure in the villager cohort. One possible explanation is that individuals who believe CVD is curable are more aware of lifestyle changes to guard against CVD, leading them to make lifestyle adjustments that lower their blood pressure. Among the market worker cohort, increased age was predictive of increased systolic and diastolic blood pressure, which is consistent with trends in the literature.[2] Moreover among the market worker cohort, increased education was predictive of decreased systolic blood pressure. If education relates to greater knowledge about CVD risk factors, subsequent lifestyle changes may lower blood pressure. Finally, within the market worker cohort, systolic blood pressure and use of homemade medication for CVD was predictive of increased systolic blood pressure. Individuals who take homemade medications may believe their CVD risk is already managed rather than seeking medical treatment. It is curious that this relationship only held for market workers but not for the village cohort, possibly indicating different community understandings of homemade CVD medication and more broadly the ideas surrounding medical pluralism.

MLR models for fasting blood glucose yielded unexpected results. For the market worker cohort, no predictors were significant. For the villager cohort, individuals reporting family history of "heart problems" are predictive of lower levels of blood glucose. This result could be due to a misinterpretation of the question, small sample size, or increased awareness causing better management of blood glucose. Additionally, increased knowledge predicted higher blood glucose. This result is likely due to the narrow range of knowledge scores magnifying the problem of a small sample size.

4 Fieldwork Discussion

The fieldwork portion of this project sought first to collect health data that could inform participants and their health care providers about aspects of their CVD risk, second to better understand CVD risk trends across the parish, and third to help inform future interventions in the region. High risk appears in this rural parish in 2016 with 35% of the sample overweight or obese, 60% in some stage of hypertension, and 10% pre-diabetic or potentially diabetic. This finding is pertinent for making inferences about risk in the sample as well as providing information to individuals about their own risk. Providing individuals information about their own health is particularly important in this setting given low access to screening services. Longitudinal analysis through the LMMs illustrates that this high risk is likely sustained overtime (past 3 to 4 years), given that no time trends emerged within the CVD biometric indicators. Therefore, on average the individuals who were overweight, hypertensive, and pre- or potentially diabetic likely had a similar status in the previous years of the sample. Individuals who fell within the normal range of these biometric indicators likely had normal indicators in the previous years of the sample.

Additionally, market workers are at higher risk than the village sample, given a greater percentage with the highest risk in multiple biometric indicators, a greater percentage overweight, and a greater percentage hypertensive.

One element of the fieldwork that sought to inform future interventions was the knowledge assessment, which showed low knowledge of CVD genetic factors. Additionally, the villagers had the highest overall knowledge scores. While we cannot test, or claim that the augmented knowledge in the village sample is due to their previous involvement in the study, the study has included some CVD education and service counseling each year which could be confounding the results. Additionally, VHTs had lower knowledge scores compared to the villagers, and the religious leaders had the lowest average knowledge. This is concerning as VHTs are the first-line healthcare providers and therefore should have greater CVD knowledge. Observing lower knowledge among religious leaders and VHTs is a potentially important finding as it indicates that they could be effective target groups for an educational intervention. The widely-held misconception that CVD is completely curable and the insufficient knowledge of preventative factors for CVD also indicated prominent knowledge gaps. Particularly, participants lacked awareness that alcohol, tobacco, and sedentary lifestyle are risk factors for CVD. Ultimately, educational interventions are necessary to address the gaps in understanding of CVD, including the chronic nature of the diseases and the lifestyle changes to prevent them.

The survey results revealed high agreement across cohorts that religion affects the development and alleviation of CVD. Religion plays an important role in how individuals in the community perceive and understand CVD. Therefore, a potential intervention would integrate religious understandings or utilize religious institutions.

Given that participants who were older, women, and had higher income, tended to have higher CVD risk, educational interventions should attempt to reach individuals with these characteristics. The use of homemade medications as a significant predictor of increased systolic blood pressure in the market worker cohort indicates the potential benefit of an educational intervention addressing the idea of medical pluralism. This intervention could inform individuals about the benefits of biomedical approaches for CVD, rather than push against the use of homemade medications. This approach may facilitate dual use of these traditional medications alongside biomedical recommendations. This could decrease the use of traditional medicines in lieu of biomedical recommendations, which is likely driving the observed effect.

4.1 Limitations

Although initially designed as a random sampling plan, the village cohort deviated from the randomization ideal. Therefore, the village cohort results cannot be generalized to the rest of the rural parish. Elements of the study make the village sample inherently incomplete, including the practical inability to keep the same recruitment methods over time and the shifting composition of the cohorts. The shifting composition was due in part to the interest in reaching and servicing more community participants, which led to adding new participants up through 2015 and expanding the sample to include men in 2014. These methods reflected the reality of different researchers each year learning the needs on the ground and developing understandings with our community partners around their interests and the best approaches to address CVD.

Along with the advantages of the introduction of new cohorts in 2016, there are several limitations. First, the market worker cohort is relatively small (50 people). Although the market workers were intended to be a randomly selected group, the original list was possibly incomplete. This is because the market leader compiled the list through making his way around the market, recording workers' names. Therefore, the market worker sample may have had some selection bias. The inherent lack of complete random assignment to either market workers or villagers precludes causal conclusions regarding differing risk between the two cohorts.

The VHT and religious leader cohorts were also relatively small (20 people each). The VHT cohort did constitute a completely random sample as the Head VHT had a complete list of all VHTs in the villages. Conversely, the religious leaders were a nomination sample and therefore their knowledge and perceptions have limitations on generalizability to religious leaders in the rural parish, Mityana town, and surrounding areas. However, the religious leader cohort was comprised of a large percentage of the religious leaders in the region. Although there is no way of certainly knowing the full percentage of religious leaders sampled, we hypothesize that we captured around 70-90% of the religious leaders in the rural parish and Mityana town. Therefore, these results are likely relatively comprehensive.

There are two potential causes of error in the biometric measurements. First, the error associated with only taking measurements once per participant at the time of data collection. Although the research team assessed the equipment quality and took great care in the measurements, there is a degree of error that accompanies only taking measurements once. Additionally, only sampling participants' biometric indicators once per year introduces a further gap between measured and true score, as individuals could have significant fluctuations in these biometric measurements, even daily. Ideally, monthly assessment of blood pressure provides a more accurate index, however, this was not possible in the context of this field study. Blood glucose measurements were subject to additional error if some participants claimed to have fasted overnight when they may not have, as the researchers had no way to be certain participants had fully fasted. Despite utmost effort in collecting clean, valid data, field studies have biases that are hard to control across all aspects of the study, such as with translation. There is potential for participants to misinterpret questions and researchers to misinterpret responses, despite close collaboration between the translator and researchers.

5 Policy and Program Interventions

The results from the fieldwork evidence the expected sustained, high risk of CVD in local context. The prevalence of risk observed among the participants exposes the urgent need for interventions aimed at reducing CVD risk. This section explores ways to address this high burden, pursuing the specific study aim:

VII. What are potential policies or programs within the local context to improve cardiovascular health among the population?

To explore this question, this section presents the results from a literature review on CVD interventions. From the review of prior interventions studies, three themes emerged relating to education, policy, and programs. In the following section, for each of these three themes, one intervention is explored further as a future intervention strategy within the local study context.

5.1 Literature Review of Policy and Program Interventions

5.1.1 Method for Selecting Sources for the Literature Review

The literature review summarized here explores CVD interventions with application to the local Ugandan context. The search encompassed intervention strategies from a local to a national level, including behavioral, educational, and policy interventions. Search terms included cardiovascular disease, developing countries, low-income countries, Africa, Uganda, intervention, policy, program, programme, control, and management. The initial search began with Scopus without publication date restrictions. A secondary search of PubMed captured additional recent articles that may have been too recent to be appear in Scopus. This search included all article types including literature reviews, observational studies, experimental studies, qualitative studies, and quantitative studies. Elimination criteria included studies only characterizing or examining prevalence or risk, studies not related to CVD, and studies that omitted interventions. Discovery of a source that referenced another relevant article resulted in additional searches for specific articles. This literature review focused on exploring intervention possibilities rather than a complete, systematic search of all previous studies. The overall literature review revealed three main categories of CVD interventions: education, policy, and programs.

5.1.2 Categories of Intervention Based on the Literature Review

5.1.2.1 Educational Program Interventions

A commonly cited and tested educational intervention was bolstering community health workers (CHWs) ability to screen for CVD and educate their community about risk factors, lifestyles changes, medication adherence, and other related topics. CHWs in many regions have limited knowledge, highlighting the need for educational interventions to facilitate lay health workers' ability to effectively help their communities.[18,19] Furthermore, these CHWs can be at high-risk of CVD themselves and lack knowledge of preventative measures for CVD.[19] Various studies demonstrated that educational programs with CHWs can fortify their healthcare capabilities and thereby facilitate their administration of effective health programs within their communities.[20,21] For example, a Ghanaian study found decreases in salt intake and subsequently blood pressure among local villagers following a CHW-led 4-year health education program.[20] Another study corroborated the effectiveness of CHWs in diverse country contexts for the purposes of CVD screening.[21] In addition to its effectiveness, screening is also cost-effective, adding QALYs to the usual standard of care.[22]

Other education-related articles focused on long-term health promotion within communities, use of existing community groupings for educational interventions, and cost-effectiveness of community-based education programmes. For example, a 4-year community-based study conducted in South Africa involved education surrounding nutrition, cooking, and smoking cessation while also incorporating awareness (fliers, billboards, etc.), engagement of local businesses, and community events (fun runs and family walks).[23] Analysis of the results of this study illustrated the effectiveness of long-term health promotion strategies to reduce CVD risk.[24] Other studies advocated for the use of pre-existing social groupings as entry points for education, including schools, churches, mosques, primary healthcare centers, and community halls.[25,26] Cost analysis of community-based educational programming for CVD risk factor reduction has been found to be cost-effective, primarily in communities in which public knowledge is limited.[27]

5.1.2.2 Policy Interventions

A significant body of work in the CVD intervention literature involves policy solutions. In this context, policy refers to any laws or strategies that a governing body implements, including local to national levels of government. Although many policy solutions noted below focus on the national level, they can be adapted for implementation at local and regional levels. Calls for policy change in the literature fall within four broad areas: food policy, standardization of care policy, substance-use policy, and health system policy.

Interventions involving food policy presented in the literature included salt and fat policies as well as general food policy. Salt reduction policy involves both campaigns targeting individual voluntary reduction of salt added to prepared foods as well as policy to limit salt in processed and sold foods.[28] An intervention involving voluntary individual and industry salt reductions through a sustained mass-media campaign was found to be cost-effective in a model for 23 LMICs.[29] Another food policy initiative is fat modification policy, which involves replacing trans-fat and saturated fat with polyunsaturated fat.[27] These changes are cost-effective as they are accomplished through voluntary industry alterations or via legislative regulation.[27] Other food policies involve restricting marketing, food taxes and subsidies, and healthy food policies in schools; restrictive marketing and food taxes have both proven to be cost-effective.[30]

Another potential policy change involves standardization of care through country-wide use of the WHO/ISH assessment tools.[26,31] The WHO/ISH risk assessment tools are designed specifically for geographical regions and predict 10-year risk of CVD using indicators such as age, gender, diabetes, smoking habits, blood pressure, and cholesterol.[26] There are also adaptations of the tool for circumstances in which certain measurements, such as cholesterol, are not available.[26] Uganda has CVD guidelines, yet screening relies on individual risk factors rather than utilizing a global risk assessment tool.[31] This tool would facilitate accurate assessment and management among non-physician health workers, given that it removes provider subjectivity in risk assessment.[26]

Substance-use policy discussed in the literature included tobacco and alcohol policy. Tobacco policy can encompass restricting smoking areas, requiring warnings, enforcing advertising bans, and raising taxes on tobacco.[30] Tobacco policy is considered extremely cost-effective in terms of DALYs averted in relation to cost to implementation.[27,30,32] Of the various tobacco potential policy interventions, taxation on tobacco yields lowest cost per DALY averted.[27] Alcohol policy is similar and involves restricting sales, enforcing bans on advertising, raising taxes, and enforcing drunk driving laws.[30] All of these policies have been found to be low-cost solutions and cost-effective towards decreasing alcohol-use and subsequently decreasing DALYs due to CVD.[30]

Within the realm of health system policy, cases arose advocating for policy changes regarding system structuring, supply, and financing. Multiple pieces advocated for changes in national policy to facilitate an integrative strategy, addressing CVD and all NCDs alongside communicable diseases, rather than separately.[33,34] Multiple sources highlighted the problem of CVD equipment deficits and CVD medication stock-outs and the subsequent harms on CVD care and management.[13,35,36] Equipment needs to be prioritized in health budget policies and plans. One policy solution to address medication stock-outs is to establish revolving fund pharmacies (RFPs), which act as a back-up to government pharmacies, using slight surge charges on medications to constantly restock the pharmacy.[35] Other solutions include policies that pool procurement, regulate prices and mark-up charges, monitor distribution, and encourage generics.[37] These recommendations partially address some of the larger financial concerns regarding the health system in Uganda. Broader health system financing policy involves an emphasis on allocation and the need to allocate greater than 0.01% of the total Ministry of Health budget to NCDs.[13]

5.1.2.3 Program Intervention

In addition to results relating to educational interventions and policy interventions, the literature yielded interventions relating to program implementation. While this category of intervention does incorporate elements of policy and education, it does not strictly fall into these realms. When incorporating education and policy, these interventions utilize other sectors for implementation, such as technology or existing social and institutional structures. Proposed program interventions in the literature fell into four key areas: task-shifting, faith-based programming, mHealth interventions, and multidrug regimens.

In addition to involving CHWs in screening and treating CVD as noted above, the intervention literature explicitly supports an expansive view of task-shifting. Multiple sources illustrate the effectiveness of nurse-led care to reduce the physician burden, improving CVD care and outcomes.[38,39] The success case in Rwanda, in which two or three nurses lead the NCD disease clinics under the supervision of the chronic care team, supports the implementation of non-physician led NCD care.[40] Ojji et al. supports this model detailing that non-physician providers should be able to prescribe medication, given regular physician supervision.[26]

Faith-based institutions offer another basis for many of the important program implementations. As pre-existing social groups, religious institutions offer an easy point of entry for educational opportunities.[26] Faith-based organizations generally outnumber health centers and therefore could reach more individuals.[18] Furthermore, these organizations include entire families and communities of people, which could provide psychosocial support for those affected and encourage preventative behaviors in the rest of the community.[18,41]

Like most diseases, mHealth or mobile health has applications to CVD. Multiple studies showed success in SMS's ability to increase CVD drug adherence in developing nations.[42,43] Another study found improved patient self-efficacy through SMS-facilitated lifestyle modifications and symptoms management.[44] One study in China utilized a mobile app to aid in therapeutic lifestyle changes (smoking cessation and salt reduction) as well as medication adherence.[45] In this study, only the medication adherence improved and the lifestyle habits did not change.[45] The variation in effectiveness of mHealth interventions on lifestyle modifications indicates the importance of tailoring the implementation to the local context. Mobile applications have also been utilized for CHWs' CVD screening and have proved to be more time-efficient in training and application, less error prone, and more cost-effective.[22,46]

Finally, the idea of multi-drug regimens, also referred to as the 'polypill,' emerged as a potential CVD intervention. This drug contains a combination of medications commonly used for CVD prevention.[39] Many sources cite this as an extremely cost-effective strategy,[27,47] however Stewart & Silwa question this assumption claiming that costs of the health professionals to support this drug and thorough testing of it have not been addressed.[48]

5.1.3 Summary

This literature review evidences effective intervention strategies including educational programs, addressing CVD risk and lifestyle modification, administered to CHWs or pre-existing social groups. Results also indicate the potential to curb CVD risk through policy interventions, specifically addressing food policy, standardization of care, substance-use policy, and health system policy. Last, the results indicate the value of task-shifting, faith-based programming, mHealth interventions, and multidrug regimens as effective programs to address CVD burden. The next section illustrates one solution in each of these three categories based on particularly promising interventions in the local context.

5.2 Promising Policy and Program Interventions

Fieldwork results explored earlier, experience and observations on the ground, and evidence in the literature all deeply informed the three interventions detailed below as particularly promising in addressing CVD burden within the local study context. The three interventions identified fall into the three broad categories that emerged from the literature review: education, policy, and program. The three interventions explored are an educational program for CHWs, national level policy change to address CVD medication availability, and a faith-based program to address CVD risk.

5.2.1 Educational Intervention: Educating CHWs

An important intervention program will involve an educational program for VHTs (the local name for CHWs) to increase their knowledge of CVD and their ability to conduct programming for their community. This program would explore the principle of task-shifting to provide screening, education, and care more thoroughly to rural communities. The WHO emphasizes the importance of CHW training on prevention and control of NCDs[49] and the prevention of disability and death via screening interventions.[50] In addition to this benefit, if CHWs took the knowledge gained from the trainings and conducted educational programming for their community, community cardiovascular health would likely improve, given results from various CVD health education and promotion studies.[23,26,51] Additionally, this program should have an evaluation component to insure adequate knowledge acquisition of the participating VHTs.

The results from a cross-cultural study conducted in Bangladesh, Guatemala, Mexico, and South Africa suggest a potential intervention within the rural parish context.[21] In this cross-cultural study, CHWs were trained to screen for CVD using a risk assessment tool (involved testing blood pressure and BMI) and evaluated to ensure competency prior to screening their local community.[21] The training program utilized an education manual to train lay health workers and various health professionals (physicians, nurses, and nutritionists) conducted sessions via a combination of lectures and interactive components.[21] Registered nurses and physicians verified the risk scores the CHWs calculated in the field to determine the accuracy of the screening and thereby the effectiveness of the intervention.[21] The study found 96.8% agreement between the CHW and health professional's risk assessment.[21] These findings corroborate the use of a standardized assessment tool to facilitate more accurate assessments, particularly among non-physician health workers.[26] Moreover, the study indicated that the provided training was effective in increasing CHWs' CVD knowledge and could potentially be incorporated into primary care delivery programs that target NCD prevention.[21]

The fieldwork study results indicate the applicability of this study to the local parish. In the Fieldwork Results section, Figure 5 displays cohort knowledge scores, illustrating that community members had, on average, higher CVD knowledge scores than VHTs. Despite the lack of a statistical significance test, these results are still concerning given that VHTs are the first-line of care for health in the rural parish, entrusted by their communities as knowledgeable health workers. Moreover, all health workers should have sufficient knowledge regarding CVD risk factors. This finding supports the need for a VHT-based educational support.

Specifically, a VHT intervention in the local parish should incorporate the training methods utilized in cross-cultural study explored above, given its proven effectiveness in a variety of cultural contexts. Additionally, this local intervention should utilize existing structures on the ground. The Hypertension and Diabetes Clinic at Mityana Hospital provides an appropriate starting point for a CVD educational intervention. This clinic already completes outreach in rural villages involving health talks and screening. The district hospital, however, serves a vast region with an extensive scope for outreach, which necessitates limited contact within any given village. If the clinic trained VHTs to screen and educate community members surrounding CVD risk, the intervention could reach more people and have more sustainable implications. Moreover, the district hospital providers training VHTs provides a possible model that could be scaled-up to other regions of Uganda.

One potential barrier to this intervention is financial. In addition to education surrounding screening, necessary equipment would need to be provided to VHTs: including minimally a scale, tape measure, and automatic blood pressure device.[21] Experience in the field as well as sentiments in the literature support the idea that lack of compensation to VHTs is another important financial barrier.[21,49] Although barriers, these costs are relatively low compared to

CVD treatment and therefore the MOH or NGOs could be willing to help finance the program. Additionally, continued education for VHTs would enhance and maintain the expertise needed to educate their community about CVD and the skills to screen for CVD. This continuing education element would require the district hospital healthcare personnel to have a sustained commitment to the villages in their region. As mentioned the Mityana Hypertension and Diabetes Clinic already does some regular outreach, so perhaps the continuing education would not be a barrier. Ultimately, these barriers are not insurmountable and a VHT educational intervention program could be extremely effective to manage local CVD risk.

5.2.2 Policy Intervention: National Policies to Increase CVD Drug Accessibility

A major barrier to CVD care identified during fieldwork was lack of access to medications due to stock-outs in government facilities and prohibitive out-of-pocket costs to purchase the medications. This problem has been documented throughout Uganda, particularly in public health facilities, though the problem also still exists in private facilities.[52,53] A recent study provides a more comprehensive understanding of access to CVD medication in Uganda through examination of availability and affordability of CVD and diabetes medications and diagnostic tools within public and private sectors.[53] This study illustrated that in Uganda, most medications and diagnostics essential in the management of CVD and diabetes are available in less than 50% of sampled sites and are unaffordable (costing >3 days' wages for the average Ugandan per month).[53] The study also reported lower availability in public facilities as compared to private facilities for both medications and diagnostics.[53] Cost calculations for CVD medications used for prevention (beta blocker, ACEI, statin, and antiplatelet) yielded a minimum total cost of 18.3 USD per month, equivalent to 14.1 days' wages, far exceeding the affordability standard.[53] Additionally, the WHO defined complete CVD risk assessment (proteinuria, ECG, FBG, lipid profile, and serum electrolytes measurement) would cost minimally 25.8 days' wages.[53] Primary care needs to be strengthened to combat these high costs of secondary and tertiary care. Moreover, availability needs to be addressed through improving health financing, procurement, and forecasting.

The preliminary literature review exposed ways to increase medication access in terms of more reliable purchasing avenues for individuals and price stabilization for these avenues, including RFPs and regulated mark-up prices. While helpful, these do not address the problem of Ugandans' lacking personal funds to purchase medications that the government facilities ostensibly provide. Therefore, national policy needs to change to ensure adequate stocking of CVD medications in government facilities to alleviate the burdens of individual purchasing pressures. Ensuring that those in need of CVD medication have access will ultimately improve CVD risk management, diminishing the catastrophic health expenditure in Uganda.

An underlying reason there may be inadequate CVD medications and diagnostics is the lack of adequate health care allocation for CVD. CVD funding resides within the NCD program which receives 0.01% of the total Ministry of Health budget (27,000 USD per year) and 270,000 USD from the World Diabetes Federation (WDF).[13] Therefore, 90% of the NCD program funding is externally financed. Although mirroring the whole Ugandan MOH budget, which is 91.7% external financed, policy makers advocate for less reliance on external aid to ensure greater stability.[13] The small fraction of the MOH budget allocated to NCDs illustrates the low priority of NCDs in Uganda. Financial commitment to CVD and NCDs more broadly should be augmented, particularly given that they are responsible for an increasing percentage of deaths and currently account for 10.24% and 29.37% of deaths in Uganda, respectively.[7]

In addition to lack of funding, current drug procurement practices play a role in stock-outs.[54] The most relevant aspect of procurement to this study is that district health centers acquire drugs from the National Medical Stores (NMS) via conditional grant or credit line systems. Additionally, sub-district level facilities request drugs from the district health officials who then order from the NMS or the Joint Medical Stores (JMS).[54] Ideally, this system would run smoothly with no shortages, no bottlenecks, and reasonable efficiency. However, there are stock-outs, delays, and wastage due to problems with information systems, forecasting, synchronization, and complicated procurement.[54] Simplification of dissemination procedures and better regulation of procurement would help address many of the shortfalls of current procurement.[54] Communication and collaboration should be promoted between all levels of the supply chain as well as systematic monitoring of the flow of essential medicines.[54]

Another policy intervention to decrease stock-outs is to require that all public health facilities are provided a vehicle.[55] A study investigating pharmaceutical availability in Sub-Saharan Africa found that facilities with a vehicle had significantly lower stock-outs of essential drugs, potentially due to greater autonomy and responsibility in drug procurement within healthcare facilities.[55] Implemented alongside national procurement policy reform, improved communication along the supply chain, and increased funding, there would be fewer stock-outs of CVD medications along with all essential drugs. In the context of the rural parish, decreasing local stock-outs via these national policies would vastly improve overall cardiovascular care.

5.2.3 Program Intervention: Faith-based CVD Program

In designing the fieldwork study, the research team considered the potential of a faith-based CVD intervention program. A faith-based CVD intervention is beneficial as it uses natural groupings of people who share some similar key characteristics. Additionally, the sense of trust attached to religious institutions facilitates a sense of commitment to interventions sponsored by faith-based organizations. For these reasons, the 2016 study piloted an examination of how people perceive religion's influence on CVD and added a cohort of religious leader participants. Additionally, a faith-based intervention approach is supported in the literature.

A robust literature exists regarding faith-based interventions within the context of the United States as illustrated by several key studies described below. In addition to U.S. illustrations, this section presents several faith-based CVD interventions in Africa to offer a more reasonable parallel to the study context, and then closes with recommendations for the study community. Numerous studies in the United States have illustrated that faith-based organizations are an effective means of improving health outcomes, specifically regarding NCDs including CVD.[56] Educational programming within black churches has been shown to improve health-related behaviors and decrease cholesterol.[57] Nurse-led educational and screening programs in African-American churches have increased CVD knowledge and decreased blood pressure.[58,59] An intervention that combined scripture study and health programming significantly decreased community members' weight and blood pressure.[60] In all of these studies, conducting the intervention within religious communities facilitated lifestyle changes through increased social support, expanding the reach of the cardiovascular health initiatives beyond those actively seeking out medical care.

Two key studies conducted in Africa (South Africa and Ghana) provide proximal applications for interventions in Uganda. The first study, featured in the World Health Organization Bulletin, was conducted in Accra, Ghana.[61] This study proposes the development of CHW programmes within religious organizations because of (a) the large proportion of Ghanaians who attend religious activities and (b) the existing mission of faith-based organizations to improve community health.[61] The study investigated the possibility of CHW-driven CVD prevention programmes in faith-based institutions via in-depth interviews, focus groups, and surveys with religious leaders, health committee members, and congregants.[61] All the religious institutions studied were already facilitating programming in which health professionals both led the programs and trained lay people to lead further programming.[61] This approach parallels the Community-Based Health Planning and Services Initiative (CHPS) in which religious leaders serve as health officers within religious organizations and religious spaces function as health compounds for service delivery.[61]

The second study was a randomized control trial conducted in Pretoria, South Africa to explore the efficacy of a church-based programme to address hypertension and elevated blood glucose.[62] This study involved a control group randomly selected from the 12 churches to receive a pamphlet about health, diet, and exercise.[62] The intervention group received this pamphlet along with educational programming over a 6 to 8-month period.[62] Lay health promoters, dieticians, and physiotherapists facilitated this educational programming within the context of the 12 churches in the study.[62] The lay health promoters also facilitated support groups among the intervention cohort.[62] The study is ongoing and preliminary outcomes are not yet available. Successful results from this randomized control trial study will strengthen support for CVD educational programming within religious institutions in an African context.

Potential barriers to fully implementing a CHW-run CVD programme within religious organizations are similar to those likely found in traditional CHPS initiatives, including financial shortage, limited human workforce, inadequate program evaluation, and insufficient ties to healthcare services.[61] The benefits of this approach include the physical space for service delivery, established institutional respect and acceptance, and decreased cost due to fee assistance from outside partners.[61] In addition to support for faith-based interventions in the literature, fieldwork results indicated that these interventions may be particularly effective in the rural parish.

As explored in the Fieldwork Results section, most market workers (82%) and villagers (68.8%) reported belief that religious devotion affects the development of CVD, whereas only half of the religious leaders and just under half of the VHTs shared this belief. Moreover, 90 to 95% of all cohorts reported believing that religious practice alleviates CVD symptoms. Although qualitative analysis of these answers illustrated a variety of interpretations, these results support the idea that religion is intricately intertwined with not only general health but also specifically cardiovascular health. This strengthens the case that interventions directly instituted through faith-based organizations could be particularly effective in this area. The study results also indicated that religious leaders on average had lower knowledge scores than other cohorts. Therefore, interventions through religious institutions would reach individuals especially in need of CVD education. Given the importance of religion in the community, limited knowledge amongst religious leaders, physical space for service delivery, acceptance of the institutions, and lessened cost with financial contributions from outside partnerships, a faith-based intervention could be a successful way to address CVD in this context.

5.2.4 Conclusion

Considering the fieldwork results, CVD in this rural parish may be following general global trends of increased CVD burden in LMICs. This indicates a potentially serious problem in need of interventions to address the current and growing burden. From experience on the ground and evidence in the literature, CHW education programs, policies to decrease CVD medication stock-outs, and faith-based CVD programming could all potentially gain community acceptance and be effective at decreasing risk.

6 Final Conclusions

The overall purpose of the project was to document and better understand CVD risk in a rural region in Uganda and to have the study results and existing literature inform intervention recommendations to address the CVD burden at the local level. In pursuit of this purpose, data collection and subsequent data analysis discovered that the longitudinal sample of villagers is at high and expected sustained risk of CVD. Additionally, compared to the village sample, the market workers had higher rates of obesity and hypertension. This hints that the market worker cohort is at greater CVD risk, concurring with the literature that people in more urban setting are at greater CVD risk.[3]

The knowledge and perceptions assessment portion of the project informed potential interventions for the local context. Given relatively lower CVD risk factors knowledge, VHTs and religious leaders could benefit from an education intervention. The perceptions assessment corroborated the need for education interventions to address the gaps in understanding of CVD as chronic and the lack of thorough knowledge of preventative lifestyle factors. These fieldwork results regarding knowledge gaps, along with supporting literature, facilitated the recommendation of an VHT CVD educational program that would enable them to screen and educate their community.

The fieldwork finding of a high percentage of participants reporting that religion affects development of CVD and alleviation of CVD symptoms supported the conclusion that religion strongly affects how individuals in the community perceive and understand CVD. This finding, along with the existing literature regarding the efficacy of faith-based intervention programs, led to the intervention recommendation of CVD education and programming through religious organizations.

The third major intervention recommendation involved a variety of policy changes seeking to address the problem of CVD medication stock-outs in government facilities, a problem experienced on the ground and extensively documented in the literature. The need for more macro-level policy change entails recommendations for an increased national budget for CVD, greater simplification and regulation of drug procurement, and increased communication within the supply chain.

6.1 Next Steps

If the community is receptive to the intervention ideas, small scale versions of the VHT education intervention program and faith-based CVD programming could be conducted as pilot studies to assess their effectiveness. In addition to exploring the local efficacy of these interventions, future research could explore more comprehensively why market workers might be a greater risk than villagers. For example, employing pedometers to assess activity levels could elucidate if their increased CVD risk is due in part to physical inactivity. Intervention research tailored to the market workers' urban setting can compensate for the lack of VHTs in this setting. Such interventions could employ resources from Mityana Hospital, located nearby the market, or from local clinics within Mityana town.

In addition to future research, next steps should include CVD grass-roots advocacy, through partnerships with Dr. Fred Lwasampijja and the local VHTs, to increase the national priority of CVD. This advocacy should also involve raising awareness about issues with CVD medication stock-outs and encouraging the simplification and regulation of drug procurement.

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8 Appendices

Appendix A: Demographic Tables

Appendix A1

Frequencies (Valid Cases) for Biometric Variables: Body Mass Index, Blood Pressure, Blood Glucose (2013-2016)

	Data Year				Frequency (Valid Cases)		
Complete Data by Years	’13	’14	’15	’16	Body Mass Index	Blood Pressure	Blood Glucose
All Four Years					23	23	na
The Last Three Years							
2014, 2015, 2016					69	71	63
The Last Two Years							
2015, 2016					115	117	84
At Least One Year							
2013					119	119	na
2014					152	153	149
2015					145	148	145
2016					141	142	141

Appendix A2

Subsample Demographic Data (2016): Village Member, Market Worker, Health Worker, and Religious Leader

	Frequency (Percent)			
Demographic Variable Value	Village Members *n* = 142	Market Workers *n* = 50	Health Workers *n* = 20	Religious Leaders *n* = 20
Gender				
Female	107(75.35%)	45(90.00%)	14(70.00%)	2(10.00%)
Male	34(23.94%)	5(10.00%)	6(30.00%)	18(90.00%)
Age				
< 20	2(1.41%)	0(0.00%)	0(0.00%)	0(0.00%)
20-29	9(6.34%)	12(24.00%)	1(5.00%)	2(10.00%)
30-39	15(10.56%)	10(20.00%)	3(15.00%)	5(25.00%)
40-49	29(20.42%)	13(26.00%)	6(30.00%)	4(20.00%)
50-59	28(19.72%)	10(20.00%)	6(30.00%)	6(30.00%)
60-69	30(21.13%)	5(10.00%)	3(15.00%)	2(10.00%)
70+	29(20.42%)	0(0.00%)	1(5.00%)	1(5.00%)
Education				
None	10(7.04%)	3(6.00%)	0(0.00%)	0(0.00%)
Primary	98(69.01%)	26(52.00%)	3(15.00%)	1(5.00%)
Secondary	34(23.94%)	21(42.00%)	16(80.00%)	5(25.00%)
University	0(0.00%)	0(0.00%)	1(5.00%)	14(70.00%)
Religion				
Christian	123(86.62%)	35(70.00%)	19(95.00%)	16(80.00%)
Muslim	19(13.38%)	15(30.00%)	1(5.00%)	4(20.00%)
Number of Children				
0	13(9.15%)	2(4.00%)	0(0.00%)	7(35.00%)
1-3	32(22.54%)	21(42.00%)	2(10.00%)	1(5.00%)
4-6	45(31.69%)	22(44.00%)	9(45.00%)	4(20.00%)
7-9	36(25.35%)	4(8.00%)	6(30.00%)	4(20.00%)
10+	15(10.56%)	1(2.00%)	3(15.00%)	3(15.00%)
Not Reported	1(0.70%)	0(0.00%)	0(0.00%)	1(5.00%)

Note. Education refers to the highest-level institution the participant attended.

Appendix A3

Subsample Residential Village (2016): Village Member, Market Worker, Health Worker, and Religious Leader

Residential Village	Village Members *n* = 142	Health Workers *n* = 20	Religious Leaders *n* = 20
J	10(7.04%)	2(10.00%)	1(5.00%)
H	13(9.15%)	2(10.00%)	0(0.00%)
C	8(5.63%)	1(5.00%)	1(5.00%)
N	10(7.04%)	2(10.00%)	0(0.00%)
E	11(7.75%)	2(10.00%)	0(0.00%)
D	11(7.75%)	2(10.00%)	1(5.00%)
F	7(4.93%)	1(5.00%)	1(5.00%)
I	10(7.04%)	1(5.00%)	1(5.00%)
K	12(8.45%)	1(5.00%)	0(0.00%)
G	10(7.04%)	0(0.00%)	0(0.00%)
A	10(7.04%)	2(10.00%)	0(0.00%)
M	13(9.15%)	2(10.00%)	7(35.00%)
B	9(6.34%)	0(0.00%)	2(10.00%)
L	8(5.63%)	2(10.00%)	1(5.00%)
Other	0(0.00%)	0(0.00%)	5(25.00%)

Note. This table presents does not present the living demographics of market workers as none of them lived in the villages. All market workers lived in or near Mityana town, where the market was located.

Appendix A4

Occupations of Village Member and Village Health Team (VHT) Worker Subsamples

	Frequency (Percent)	
	Villagers	VHTs
Occupation	*n* = 142	*n* = 20
Farmer	113(79.58%)	16(80%)
Fisherman	4(2.82%)	0(0.00%)
Entrepreneur	12(8.45%)	1(5.00%)
Business Employee	5(3.52%)	2(10.00%)
Teacher	0(0.00%)	1(5.00%)
Retired	3(2.11%)	0(0.00%)
Religious Leader	1(0.70%)	0(0.00%)
None	4(2.82%)	0(0.00%)

Note. Across the four subsamples, only two samples vary in occupation: Village members and VHTs, who had a primary occupation in addition to their VHT work. The market workers all had market work as their primary occupation. Religious leaders varied in their specific roles, (e.g., priest, pastor), but all were religious leaders as their primary occupation. Also, for participants who indicated two occupations, only their primary occupation is reported above. Entrepreneur includes: Retail shop owner, shopkeeper, business woman, trader, boda driver, and market worker. Business employee includes: Bar operator, salon operator, hairdresser, snack sales, mechanic, and night guard.

Appendix B: Measurement Classifications

Appendix B1

The World Health Organization International classification of BMI for adults

Classification	BMI(kg/m^2)	
	Principal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe thinness	<16.00	<16.00
Moderate thinness	16.00 - 16.99	16.00 - 16.99
Mild thinness	17.00 - 18.49	17.00 - 18.49
Normal range	18.50 - 24.99	18.50 - 22.99
		23.00 - 24.99
Overweight	≥25.00	≥25.00
Pre-obese	25.00 - 29.99	25.00 - 27.49
		27.50 - 29.99
Obese	≥30.00	≥30.00
Obese class I	30.00 - 34.99	30.00 - 32.49
		32.50 - 34.99
Obese class II	35.00 - 39.99	35.00 - 37.49
		37.50 - 39.99
Obese class III	≥40.00	≥40.00

Appendix B2

The European Society of Hypertension and the European Society of Cardiology classification of blood pressure for adults

Category	Systolic (mm Hg)		Diastolic (mm Hg)
Optimal	<120	and	<80
Normal	<130	and	<85
High-Normal	130-139	or	85-89
Hypertension			
Stage 1	140-159	or	90-99
Stage 2	160-179	or	100-109
Stage 3	>=180	or	>=110

Appendix B3

The American Diabetes Association classification of fasting blood glucose levels for adults

Category	**Measurement (mmols/L)**	**Measurement (mg/dL)**
Normal	3.9-5.5	70-100
Pre-diabetic (Impaired glucose tolerance)	5.5-7.0	100-126
Potential diabetic	>7.0	>126

Appendix C: Biometric Reference Tables for Complete Three and Four-Year Village Sub-Samples

Prior to statistical analysis, Tables C1 and C2 were created to present averages and distributions of the biometric indicators in these complete sub-samples. It is important to note that all the individuals analyzed in the four-year longitudinal data (2013-2016) also appear in the three-year longitudinal data (2014-2016).

Table C1

Cardiovascular Risk in the Village Sample: Longitudinal Subsample with Complete Data Across Years (2013-2016)

		Year				
Cardiovascular Risk Indicator		2013	2014	2015	2016	N-Size
Body Mass Index:	*Mean*	24.75	23.71	23.91	23.66	23
	SD	(4.91)	(5.02)	(5.44)	(5.53)	
Blood Pressure (Sys):	*Mean*	135.39	141.35	133.87	143.26	23
	SD	(28.77)	(24.90)	(24.68)	(31.35)	
Blood Pressure (Dia):	*Mean*	85.09	88.00	84.91	85.48	23
	SD	(11.40)	(12.78)	(10.43)	(14.33)	

Note. This table presents the means for cases that had complete data across years for the cardiovascular risk indicator.
Note. This sample is all women as only women were sampled in 2013.
Note. This sample does not include blood glucose because it was not tested until 2014.

Table C2

Cardiovascular Risk in the Village Sample: Longitudinal Subsample with Complete Data Across Three Years (2014-2016)

Cardiovascular Risk Indicator		2014	2015	2016	N-Size
Body Mass Index:	*Mean*	24.58	24.70	24.6	69
	SD	(5.27)	(5.64)	(5.65)	
Blood Pressure (Sys):	*Mean*	148.04	141.66	152.11	71
	SD	(27.04)	(24.95)	(32.66)	
Blood Pressure (Dia):	*Mean*	90.41	85.70	90.77	71
	SD	(14.36)	(11.24)	(15.79)	
Blood Glucose:	*Mean*	85.86	101.56	83.38	63
	SD	(27.15)	(18.23)	(29.32)	

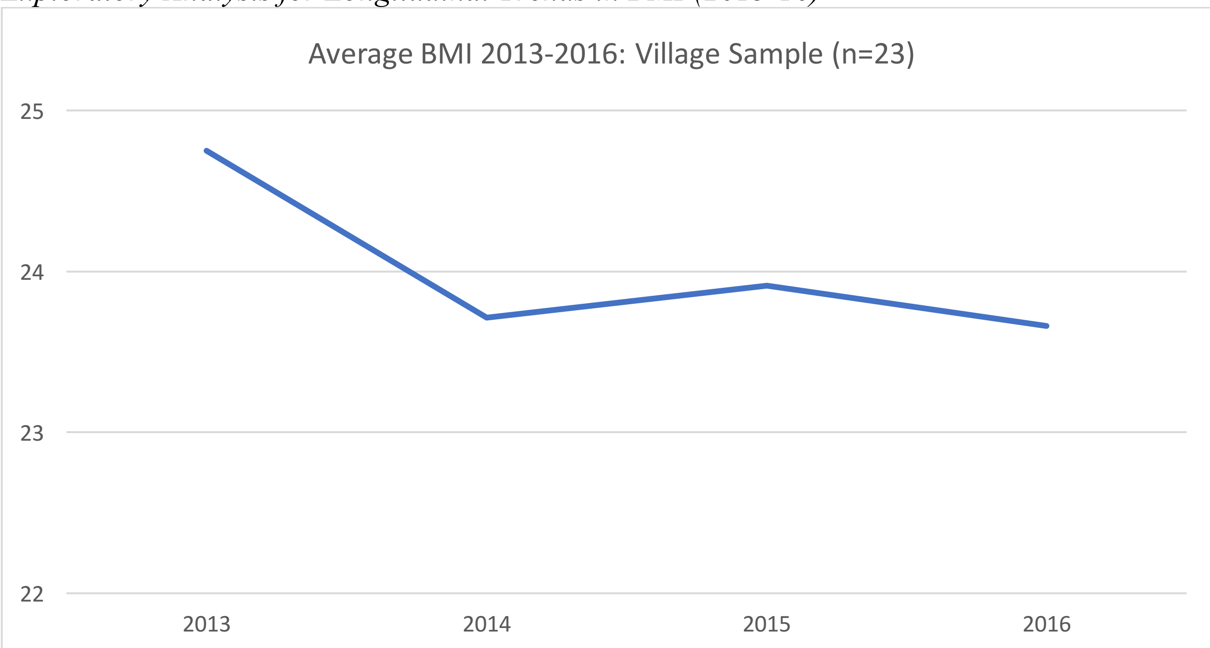
Note. This table presents the means for cases that had complete data across years for the cardiovascular risk indicator.

Tables C1 and C2 hint that potentially BMI has been relatively stable within the sub-samples given that the largest variation in cohort average BMI between years is 1 point, which is not a clinically meaningful change. These averages all fall within the normal range of BMI, however, cohort averages obscure individual data and therefore does not indicate that all participants are at low risk.[14] Averages indicate that systolic and diastolic blood pressure increased from 2013 to 2014 and decreased from 2014 to 2015. The averages for blood pressure all fall within the high-normal or stage 1 range, indicating that the cohorts may have high prevalence of hypertension.[15] Regarding blood glucose, averages indicate a potential increase in 2015 and subsequent decrease to 2016. The averages in 2014 and 2016 fall within the normal range of blood glucose, whereas the 2015 average falls in the pre-diabetic range.[17] These descriptions are all based on averages and do not consider individuals' variation of biometric measures and therefore further descriptive analysis and statistical testing must be done to examine if there are any overall trends in the data.

Appendix D: Exploratory Analysis for Longitudinal Analysis

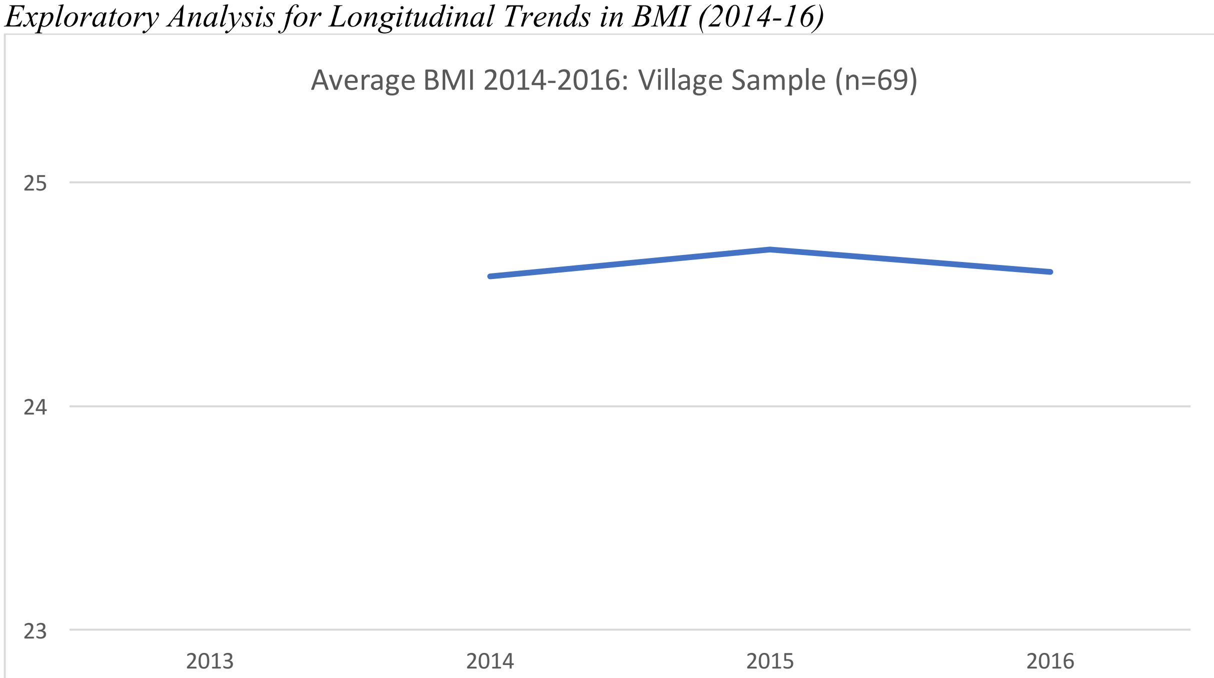
Appendix D1

Exploratory Analysis for Longitudinal Trends in BMI (2013-16)



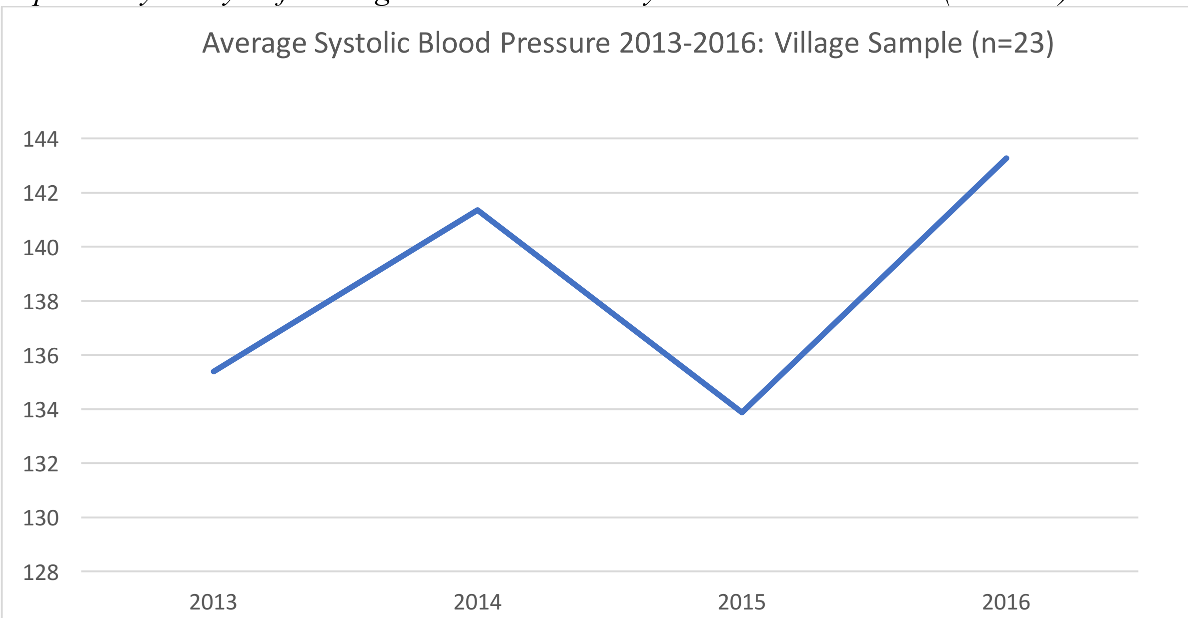
Appendix D2

Exploratory Analysis for Longitudinal Trends in BMI (2014-16)



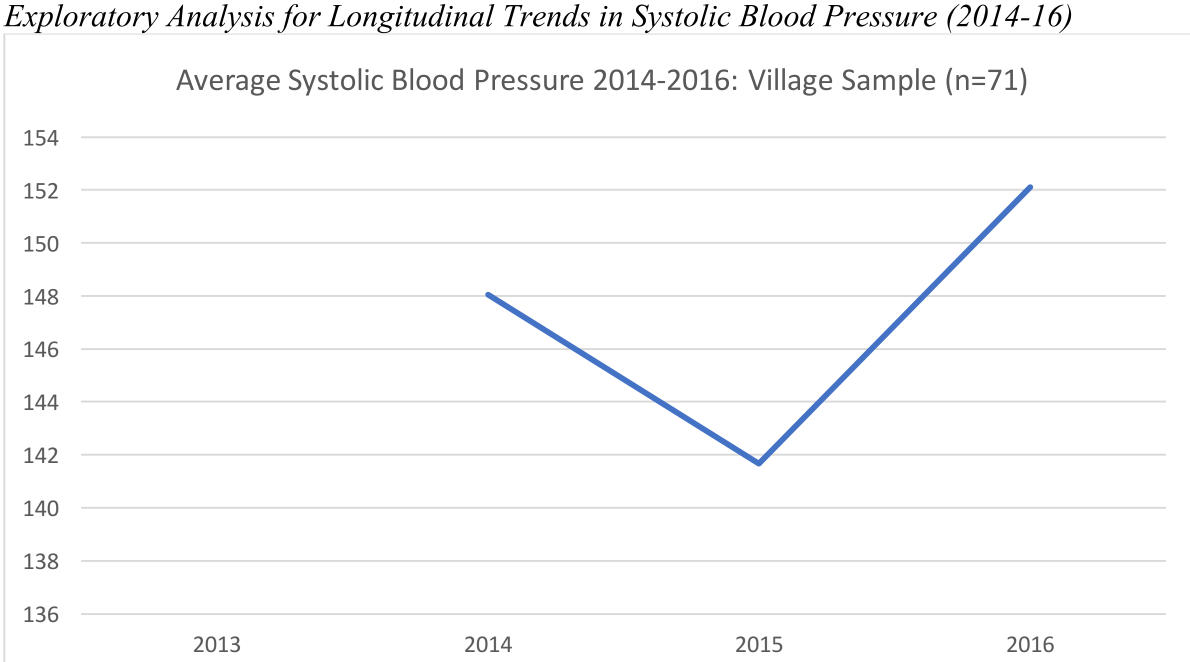
Appendix D3

Exploratory Analysis for Longitudinal Trends in Systolic Blood Pressure (2013-16)



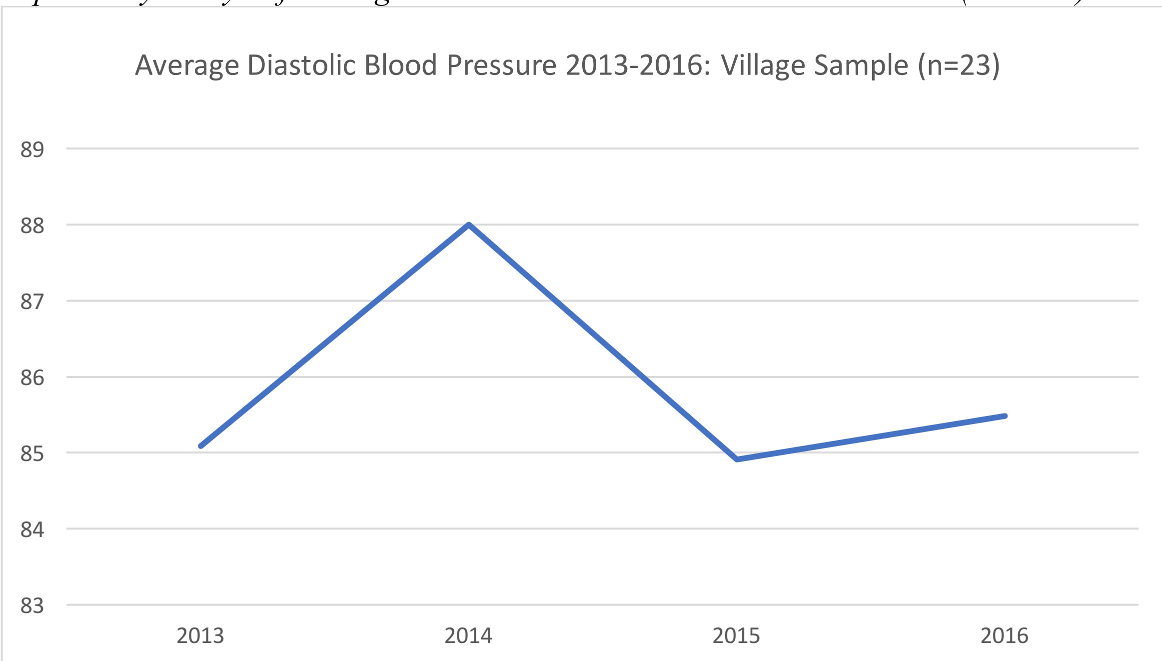
Appendix D4

Exploratory Analysis for Longitudinal Trends in Systolic Blood Pressure (2014-16)



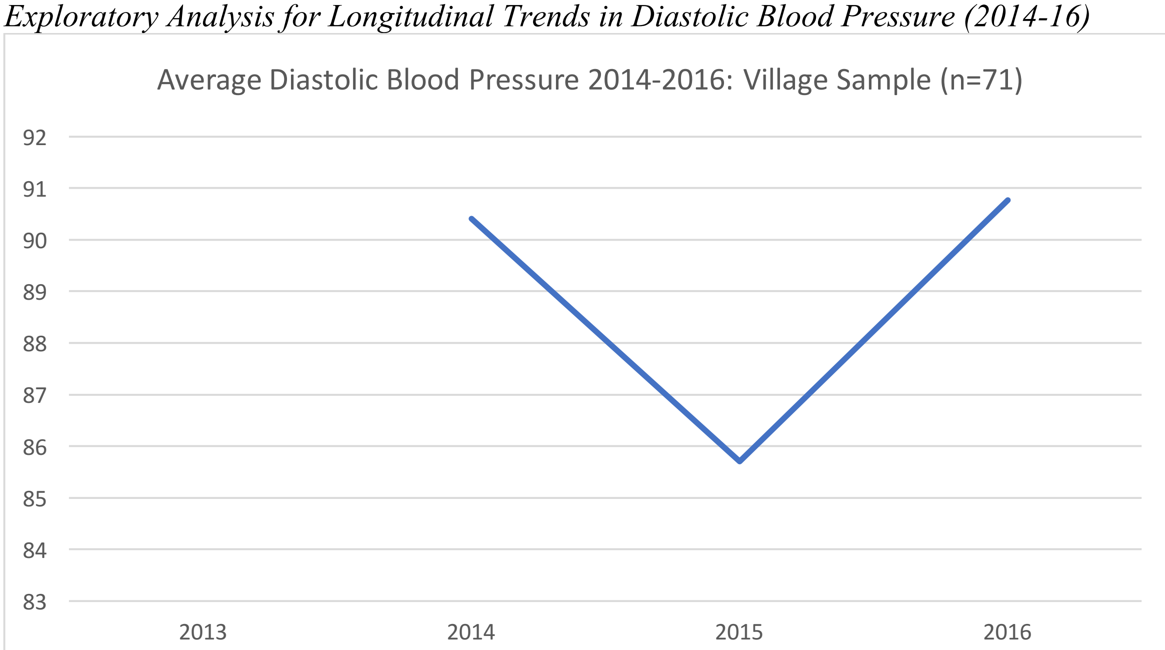
Appendix D5

Exploratory Analysis for Longitudinal Trends in Diastolic Blood Pressure (2013-16)



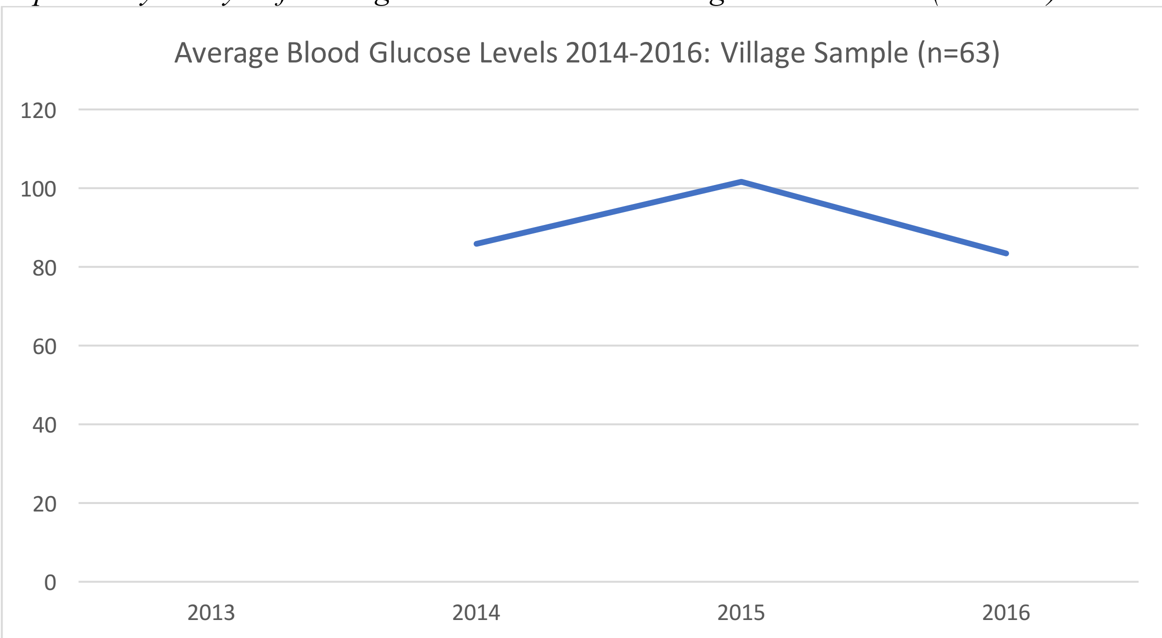
Appendix D6

Exploratory Analysis for Longitudinal Trends in Diastolic Blood Pressure (2014-16)



Appendix D7

Exploratory Analysis for Longitudinal Trends in Fasting Blood Glucose (2014-16)



Appendix E: Longitudinal Analysis Linear Mixed-Effect Models (LMMs)

Appendix E1: BMI LMM

Exploratory analysis, visualized in Appendix D1and D2, facilitated the hypothesis that BMI may be decreasing overtime within our longitudinal sample. Checking the conditions, the LMM appeared to accurately represent the data as a linear model with all conditions met for both the four-year and three-year longitudinal data (Appendices F1 and F2). LMMs were fitted with the following hypotheses:

H_0: β_{year} (slope of BMI units/year) = 0

H_A: β_{year} (slope of BMI units/year) $\neq$ 0

The output for the four-year longitudinal data was:

Table E1

LMM Output Complete Four-Year Sample BMI

	Estimate	Std. Error	t value
(Intercept)	645.1588	342.1611	1.886
FourYearsBMI$Year	-0.3083	0.1698	-1.815

The coefficient for time denoted FourYearsBMI$Year has a p-value of 0.074 and the 95% confidence interval for this beta estimate was (-0.5915, 0.0251).

Given that the confidence interval does contain zero**,** we failed to reject the null hypothesis that the time coefficient is zero. Therefore, we conclude that there is no clear linear time trend in BMI within our longitudinal sample. To explore this relationship further, the three-year longitudinal LMM was fitted. The model output for the three-year longitudinal data was:

Table E2

LMM Output Complete Three-Year Sample BMI

	Estimate	Std. Error	t value
(Intercept)	-7.21568	220.98380	-0.033
ThreeYearsBMI$Year	0.01581	0.10967	0.144

The coefficient for time denoted ThreeYearsBMI$Year has a p-value of 0.886 and the 95% confidence interval for this beta estimate was (-0.1654, 0.1970).

The confidence interval contains zero; therefore, we fail to reject the null hypothesis and conclude that there is no clear linear time trend in BMI within our longitudinal sample. This confirms the trend observed within the four-year complete subsample above.

Appendix E2: Systolic Blood Pressure LMM

Exploratory analysis, visualized in Appendices D3 and D4, facilitated the hypothesis that systolic blood pressure was stable with no increasing or decreasing overall trend in our longitudinal cohort over the last three to four years. Checking the conditions, the LMM appeared to accurately represent the data as a linear model with all conditions met for both the four-year and three-year longitudinal data (Appendices F3 and F4). LMMs were fitted with the following hypotheses:

H_0: β_{year} (slope of mmHg/year) = 0

H_A: β_{year} (slope of mmHg/year) $\neq$ 0

The output for the four-year longitudinal data was:

Table E3

LMM Output Complete Four-Year Sample Systolic Blood Pressure

	Estimate	Std. Error	t value
(Intercept)	-3111.009	2922.315	-1.065
FourYearsSysBP$Year	1.613	1.451	1.112

The coefficient for time denoted FourYearsSysBP$Year has a p-value of 0.2701 and the 95% confidence interval for this beta estimate was (-0.8073, 4.0333).

Given that the confidence interval does contain zero, we fail to reject the null hypothesis that there is no linear relationship between systolic blood pressure and year within the four-year longitudinal cohort, which confirmed the hypothesis made from the exploratory analysis (Appendices D3 and D4). The model output for the three-year longitudinal data was:

Table E4

LMM Output Complete Three-Year Sample Systolic Blood Pressure

	Estimate	Std. Error	t value
(Intercept)	-3953.678	2759.119	-1.433
ThreeYearsSysBP$Year	2.035	1.369	1.486

The coefficient for time denoted ThreeYearsSysBP$Year has a p-value of 0.1395 and the 95% confidence interval for this beta estimate was (-0.2321, 4.3021).

Both LMMs yielded results with extremely high p-values and confidence intervals for the time coefficient containing zero. From these we fail to reject the null hypothesis and conclude that there is no clear trend in systolic blood pressure within our longitudinal sample.

Appendix E3: Diastolic Blood Pressure LMM

Exploratory analysis, visualized in Appendices D5 and D6 facilitated the hypothesis that diastolic blood pressure was stable, no increasing or decreasing overall trend, in our longitudinal cohort over the last three to four years. Checking the conditions, the LMM appeared to accurately represent the data as a linear model with all conditions met for both the four-year and three-year longitudinal data (Appendices F5 and F6). LMMs were fitted with the following hypotheses:

H_0: β_{year} (slope of mmHg/year) = 0

H_A: β_{year} (slope of mmHg/year) $\neq$ 0

The output for the four-year longitudinal data was:

Table E5

LMM Output Complete Four-Year Sample Diastolic Blood Pressure

	Estimate	Std. Error	t value
(Intercept)	471.2522	1394.7013	0.338
FourYearsDiaBP$Year	-0.1913	0.6923	-0.276

The coefficient for time denoted FourYearsDiaBP$Year has a p-value of 0.7834 and the 95% confidence interval for this beta estimate was (-1.346, 0.9635).

Given that the confidence interval does contain zero, we fail to reject the null hypothesis that there is no linear relationship between diastolic blood pressure and year within the four-year longitudinal cohort. The model output for the three-year longitudinal data was:

Table E6

LMM Output Complete Three-Year Sample Diastolic Blood Pressure

	Estimate	Std. Error	t value
(Intercept)	-279.9812	1768.5562	-0.158
ThreeYearsDiaBP$Year	0.1831	0.8777	0.209

The coefficient for time denoted ThreeYearsDiaBP$Year has a p-value of 0.8348 and the 95% confidence interval for this beta estimate was (-1.2704, 1.6366).

Both LMMs yielded high p-values and confidence intervals for the time coefficient containing zero. From these, we fail to reject the null hypothesis that diastolic blood pressure is not changing overtime and conclude that there is no clear linear trend in diastolic blood pressure within our longitudinal sample. This agrees with the lack of observed linear trend in the LMM for systolic blood pressure, which is expected as the systolic and diastolic measures within an individual are highly correlated.

Appendix E4: Fasting Blood Glucose LMM

Fasting blood glucose levels were only tested from 2014-2016, therefore, no four-year longitudinal analysis is possible. 63 individuals were sampled all three years (2014-2016). If individuals did not fast for 10-12 hours before the test, their blood glucose measurement was not taken. Exploratory analysis, visualized in Appendix D7 facilitated the hypothesis that fasting blood glucose was stable, no increasing or decreasing overall trend, in our longitudinal cohort over the last three years. Checking the conditions, the LMM appeared to accurately represent the data as a linear model with all conditions met for the three-year longitudinal data (Appendix F7). LMM was fitted with the following hypotheses:

H_0: β_{year} (slope of mg/dL/year) = 0

H_A: β_{year} (slope of mg/dL/year) $\neq$ 0

The model output for the three-year longitudinal data was:

Table E7

LMM Output Complete Three-Year Sample Fasting Blood Glucose

	Estimate	Std. Error	t value
(Intercept)	2585.026	3224.035	0.802
ThreeYearsBGL$Year	-1.238	1.600	-0.774

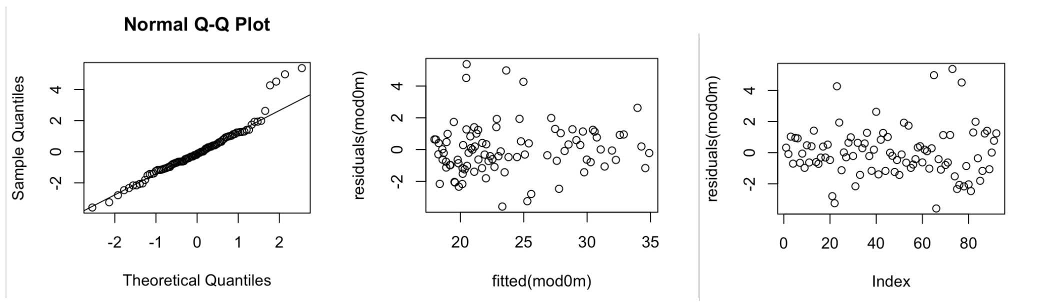
The coefficient for time denoted ThreeYearsBGL$Year has a p-value of 0.4404 and the 95% confidence interval for this beta estimate was (-2.4681, 2.8343).

Given that the confidence interval does contain zero, we fail to reject the null hypothesis that fasting blood glucose is not time dependent and conclude that there is no clear trend in fasting blood glucose within our longitudinal sample.

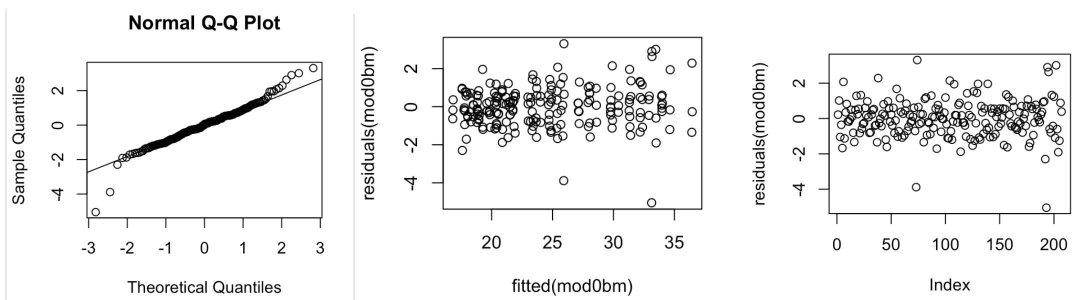
Appendix F: Conditions Plots for Longitudinal Analysis Linear Mixed Models

Each of the below Appendices presents the plots that assessed the conditions for the LMMs, including normality of error distribution, and homoscedasticity.

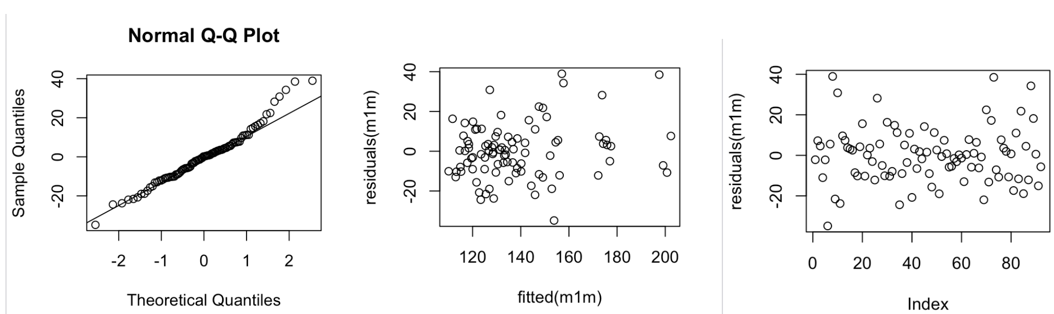
Appendix F1: Condition Plots for Linear Mixed Model: Four-year BMI



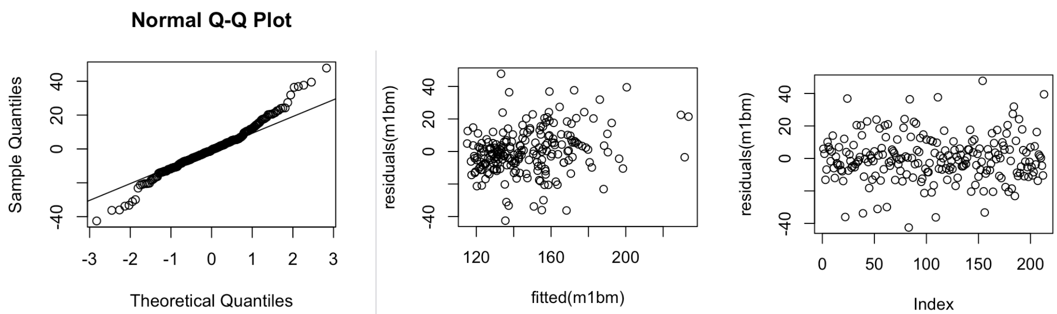
Appendix F2: Condition Plots for Linear Mixed Model: Three-year BMI



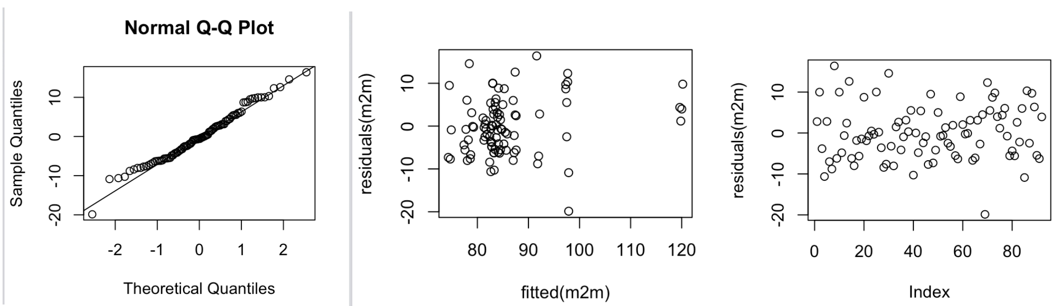
Appendix F3: Condition Plots for Linear Mixed Model: Four-year Systolic Blood Pressure



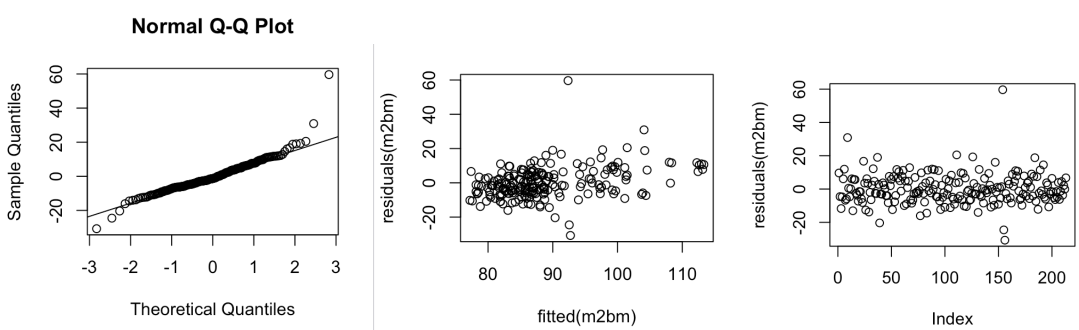
Appendix F4: Condition Plots for Linear Mixed Model: Three-year Systolic Blood Pressure



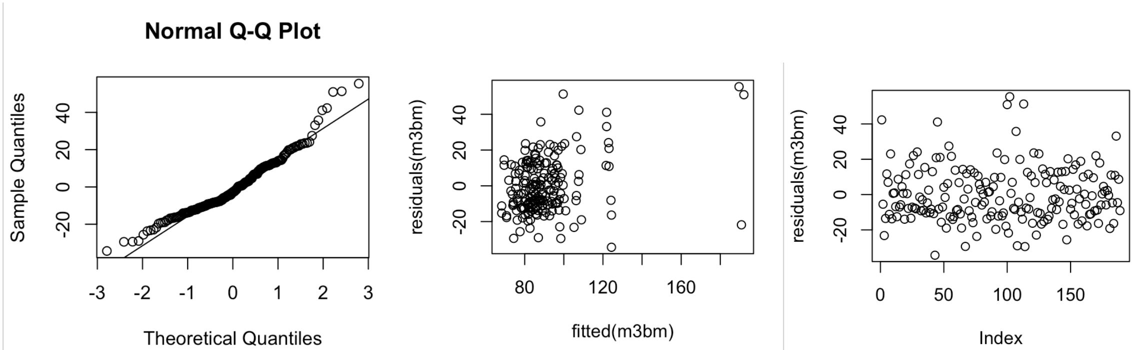
Appendix F5: Condition Plots for Linear Mixed Model: Four-year Diastolic Blood Pressure



Appendix F6: Condition Plots for Linear Mixed Model: Three-year Diastolic Blood Pressure

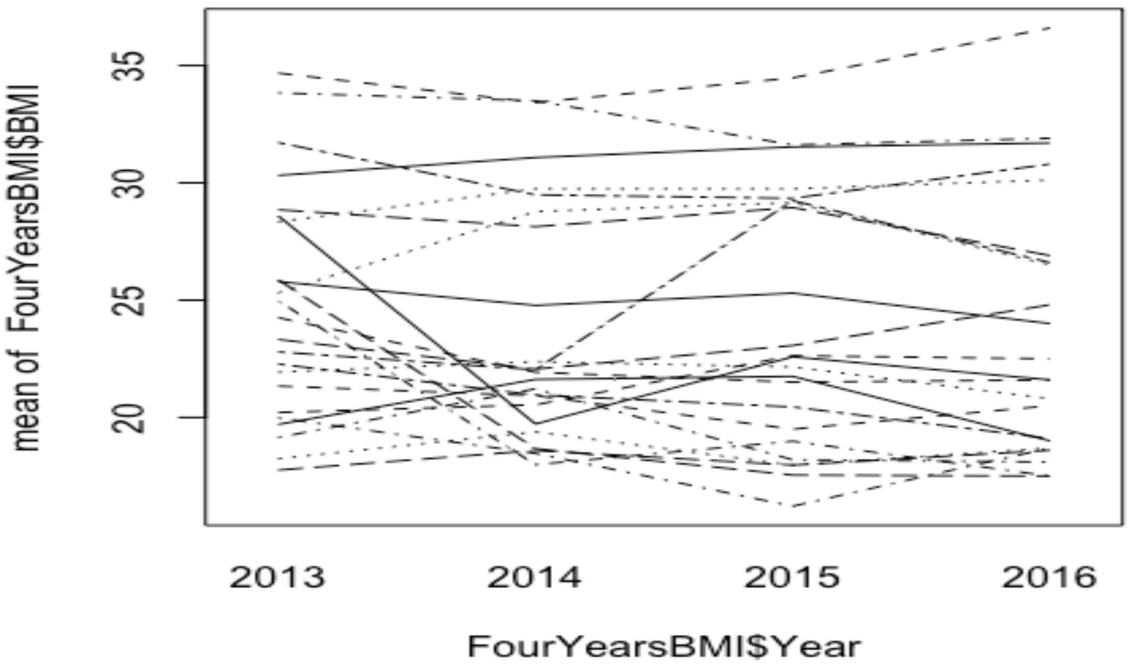


Appendix F7: Condition Plots for Linear Mixed Model: Three-year Fasting Blood Glucose

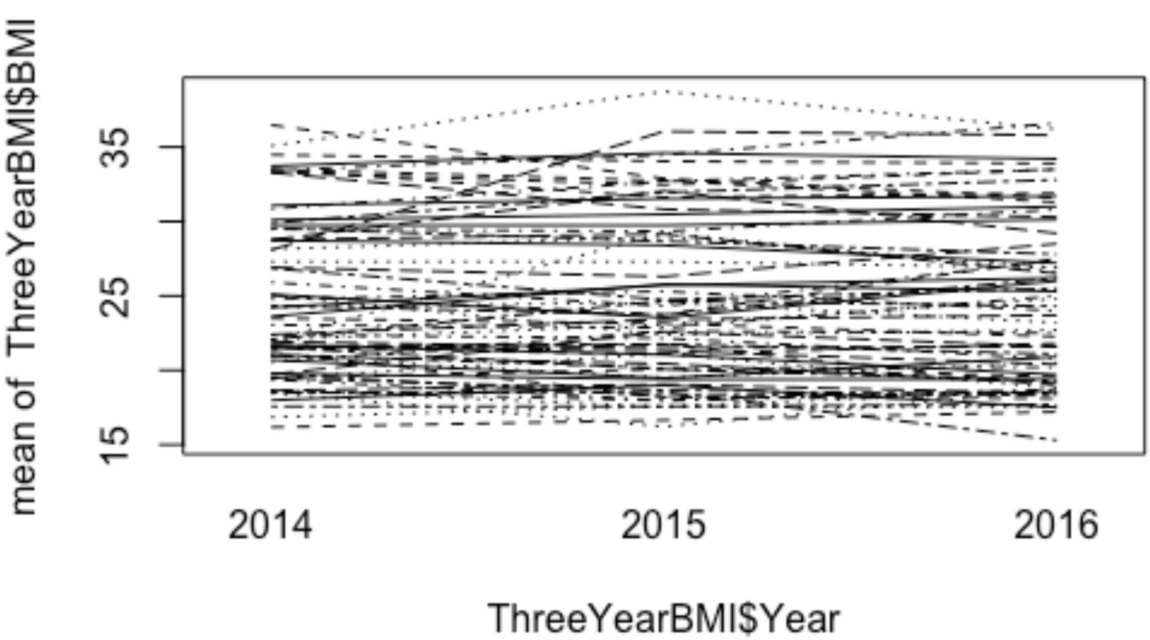


Appendix G: Individual Trend Lines for Biometric Measurements of Complete Subsamples

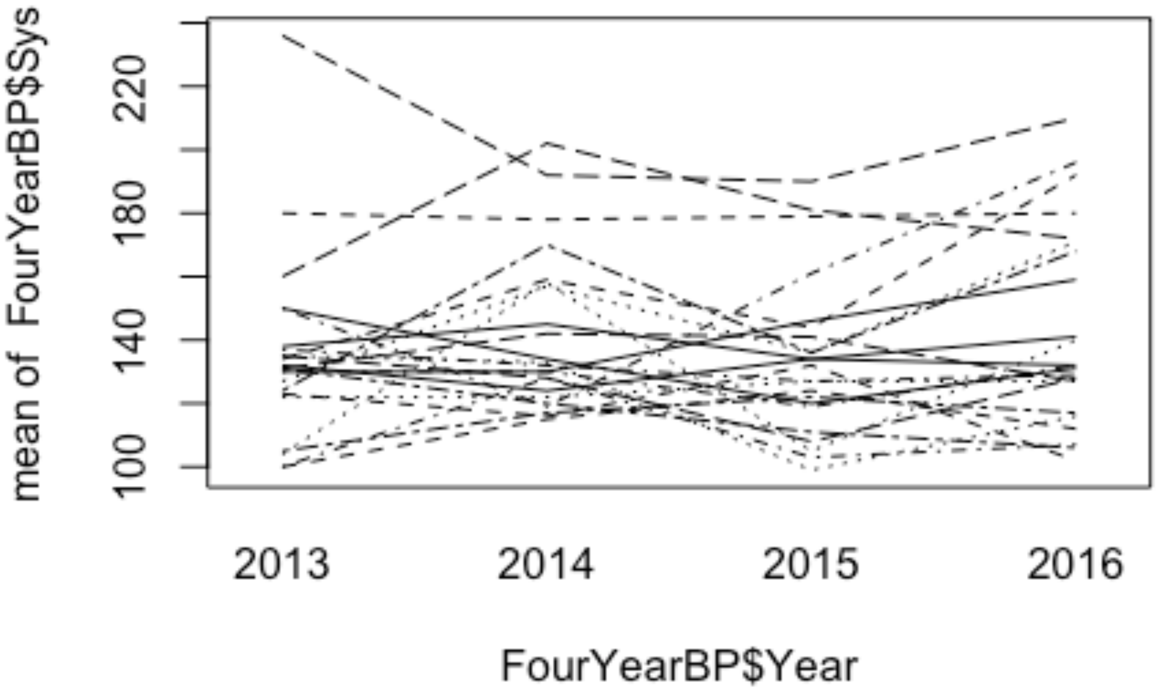
Appendix G1: Individual Trend Lines for Complete Four-Year BMI Subsample



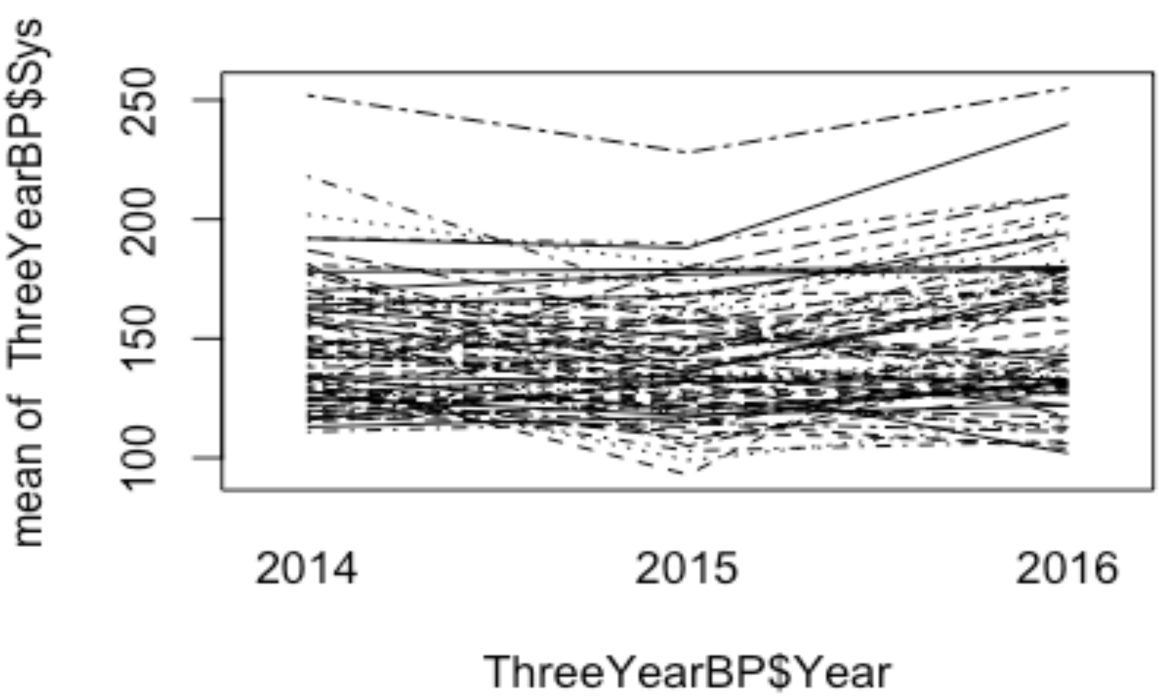
Appendix G2: Individual Trend Lines for Complete Three-Year BMI Subsample



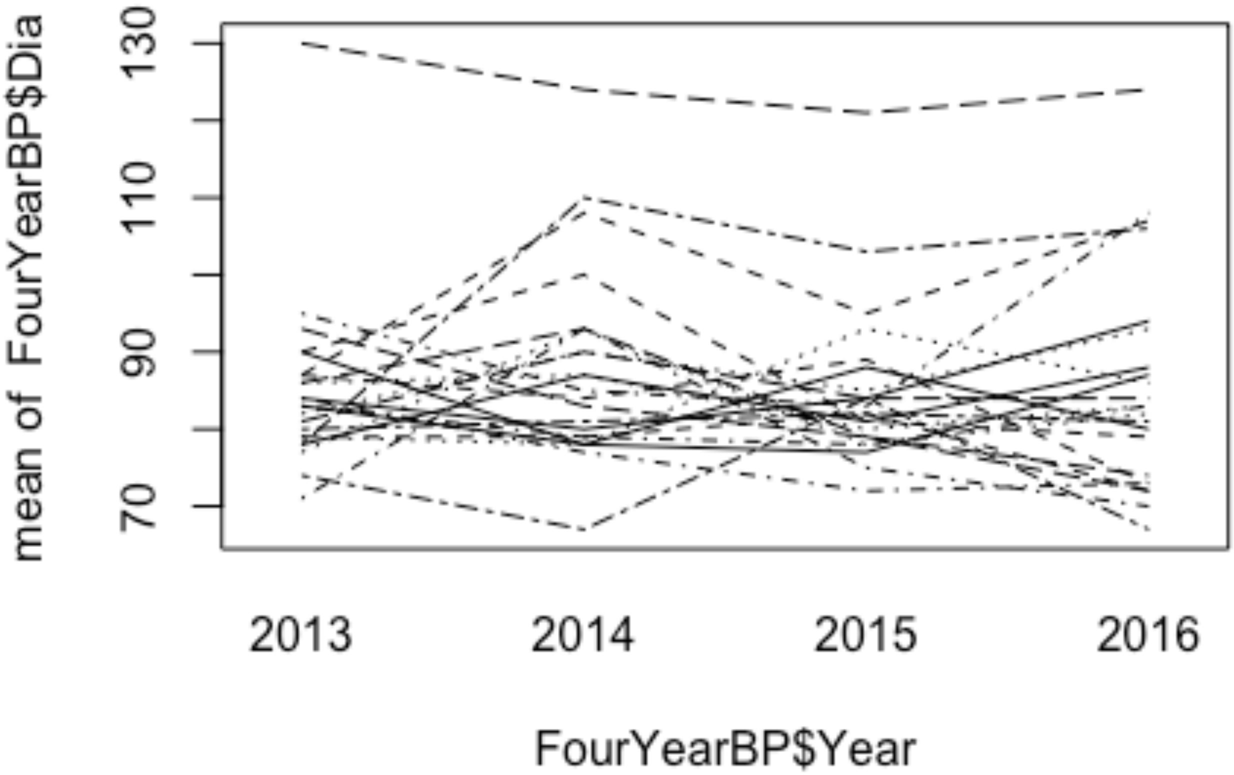
Appendix G3: Individual Trend Lines for Complete Four-Year Systolic BP Subsample



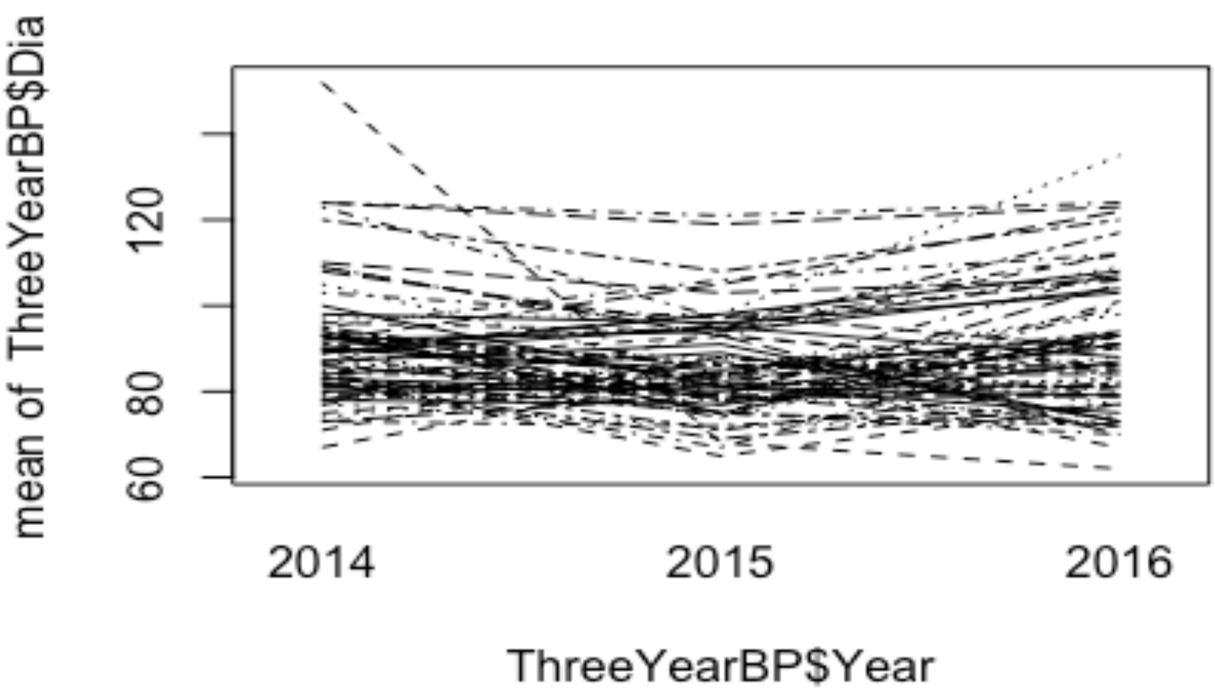
Appendix G4: Individual Trend Lines for Complete Three-Year Systolic BP Subsample



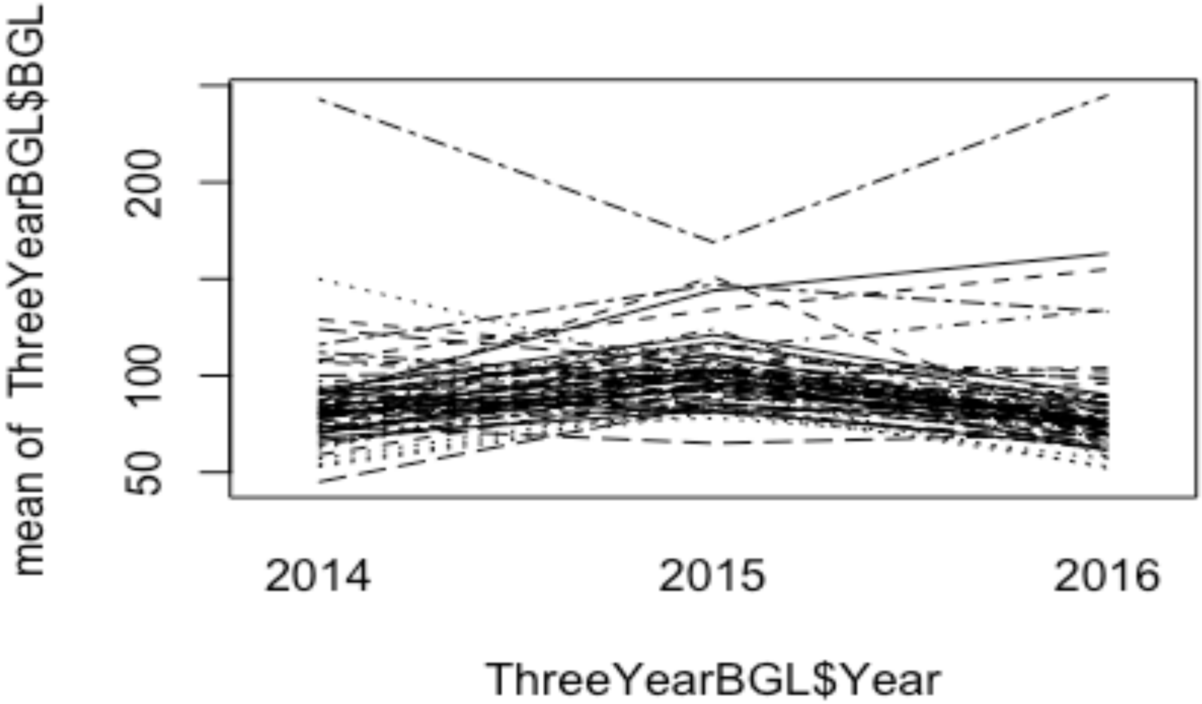
Appendix G5: Individual Trend Lines for Complete Four-Year Diastolic BP Subsample



Appendix G6: Individual Trend Lines for Complete Three-Year Diastolic BP Subsample



Appendix G7: Individual Trend Lines for Complete Three-Year Blood Glucose Subsample



Appendix H: Multiple Linear Regression Village Cohort

Appendix H1: BMI MLR for 2016 Villager Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables, surveyed in the study, and BMI within the cross-sectional 2016 villager cohort. This MLR model weakly predicted the observed BMI data (Adjusted R^2: 0.108). Using the backward p-value selection Adjusted R^2 approach, the best model was found to include gender and education, with an Adjusted R^2 of 0.1423. The significance of these predictor variables is seen in Table H1.

Table H1

Summary of Best Prediction Model for BMI (Village Members, 2016)

Variable	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	21.1418	1.0108	20.916	<0.0000
GenderM	-3.5884	1.0256	-3.499	0.0006
Education	0.6031	0.1513	3.985	0.0001

This model indicates that men would be expected on average to have 3.5884 units lower BMI than women, controlling for all other variables. These results also indicate that all else held constant, for each additional year of education, BMI on average is expected to increase 0.6031points. There are few hypotheses that could explain this observation, based on experience on the ground. First, increased education may influence the occupation and day to day activities of the individuals. Individuals with little education may do more of the manual labor on family farms, providing exercise which may be acting as a protective factor for elevated BMI. A second explanation is associated with income. Higher educational levels may be associated with increased income and higher income associated with greater access to increasingly available processed and unhealthy foods, which is a relationship corroborated in the literature.[3]

Appendix H2: Systolic Blood Pressure MLR for 2016 Villager Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables, surveyed in the study, and systolic blood pressure within the 2016 cross-sectional villager cohort. This MLR model weakly predicted the systolic blood pressure data observed, although more strongly than for BMI (Adjusted R^2: 0.2739). Using the approach of backward p-value selection with the Adjusted R^2, the best model included age, income, number of children, personal experience of chest pain, and belief CVD is curable, with an Adjusted R^2 of 0.2268. The significance of these predictor variables is seen in Table H2.

Table H2

Summary of Best Prediction Model for Systolic Blood Pressure (Village Members, 2016)

Variable	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	116.5	9.097	12.805	<.00000
Age	.07128	0.1538	4.634	<.00000
Income	.00007	.00002	2.776	.00633
Kids	-1.620	0.5925	-2.734	.00714
Chest Pain	5.496	2.446	2.247	.02636
Curable	-12.32	4.704	-2.619	.00987

This model indicates that all else held constant, as age increases one year, on average systolic blood pressure is expected to increase 0.07 mmHg. Although this value is statistically significant, it is not clinically meaningful in the context of blood pressure. A meaningful result was indicated between income and systolic blood pressure, which is not immediately apparent from the small beta value. Because income denotes ten-thousand shilling (UGX) increments with a large range from 0 to 800,000 UGX, however, the result shows that for every 10,000 UGX increase in income, systolic blood pressure is expect to rise 0.7 mmHg. This is a clinically significant finding, given the wide income range. This phenomenon could be related to the hypothesis mentioned before that greater income corresponds to greater access to processed and unhealthy foods.

The model indicated that all else held constant, for every additional child, on average individuals' systolic blood pressure is expected to be 1.62 mmHg lower, a practically significant finding. The relationship between increasing number of children and decreasing systolic blood pressure could be related to income; more children corresponds to lower income per person, decreased disposable income, and thereby reduced access to unhealthy and processed foods. This model indicated that all else held constant, as chest pain frequency increases, on average systolic blood pressure is also expected to increase. As chest pain and elevated blood pressure are both indicators of CVD, this correlation supports existing CVD research.[2]

Lastly, this regression indicated that all else held constant, individuals that believe CVD is curable are predicted to have 12.32 mm Hg lower systolic blood pressure. Although CVD is not completely curable, having this misconception interestingly seems to act as a protective factor. This relationship could be related to individuals who believe CVD is curable having elevated awareness of CVD risk factors and subsequently making healthier lifestyle choices.

Appendix H3: Diastolic Blood Pressure MLR for 2016 Villager Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables and diastolic blood pressure within the villager cohort. This MLR model weakly predicted the diastolic blood pressure data observed (Adjusted R^2: 0.0901). Using the backward p-value selection Adjusted R^2 approach, the best model included belief that CVD is curable, household income, alcohol consumption, personal experience with chest pain, cardiovascular and diabetic family history, and time spent at rest at work, with an Adjusted R^2 of 0.1128. Within this model, household income, personal experience with chest pain, and cardiovascular and diabetic family history were found to be statistically significant. The other variables included in the model are not statistically significant, however, to be conservative, these variables are included in the model since they contribute positively to the overall data variation the model explained (Adjusted R^2). The variables for the best MLR model and their significance is seen are Table H3.

Table H3

Summary of Best Prediction Model Diastolic Blood Pressure (Village Members)

Variable	Estimate	Std. Error	t value	Pr(>|t|)
		All Variables in the Model		
(Intercept)	84.40	2.660	31.725	< 0.0000
Curable	-4.467	2.510	-1.780	0.0776
Income	.00003	.00001	2.017	0.0459
Drinks/Week	0.5843	0.3263	1.791	0.0758
Chest Pain	2.886	1.317	2.192	0.0303
Family History	6.373	2.491	2.559	0.0117
Time Rest	-.3072	6.053	-0.508	0.6127
		Significant Variables Only		
Income	.00003	.00001	2.017	0.0459
Chest Pain	2.886	1.317	2.192	0.0303
Family History	6.373	2.491	2.559	0.0117

The model for diastolic blood pressure illustrates the same trends for the predictors of income and personal experience of chest pain as did the systolic blood pressure model; higher income associated with higher diastolic blood pressure and greater chest pain associated with higher diastolic blood pressure. This model also illustrates that all else held constant, individuals that reported cardiovascular and diabetic family history would be expected on average to have 6.373 mm Hg higher systolic blood pressure, also supported in the literature.[2]

Appendix H4: Fasting Blood Glucose MLR for 2016 Villager Cohort

A MLR model was conducted to analyze the relationship between the potential predictor variables and blood glucose level within the villager cohort. This MLR model weakly predicts the observed blood glucose levels (Adjusted R^2: 006031). Using the backward p-value selection Adjusted R^2 approach, the best model included cardiac family history, cardiovascular and diabetic family history, and CVD knowledge, with an Adjusted R^2 of 0.05521. Within this model cardiac family history and CVD knowledge were found to be statistically significant. The variable cardiovascular and diabetic family history is included in the model despite its lack of statistical significance to be conservative, since it positively contributes to the overall data variation the model explained (Adjusted R^2). The variables for the best linear regression model and their significance are seen in Table H4.

Table H4

Summary of Best Prediction Model for Blood Glucose Levels (Village Members)

Variables	Estimate	Std. Error	t value	Pr(>|t|)
	All Variables in the Model			
(Intercept)	18.535	26.401	0.702	0.4838
FamilyWithHeartProblems	-16.836	8.492	-1.983	0.0494 *
Family History	13.741	7.898	1.740	0.0842
Knowledge	11.780	4.843	2.433	0.0163 *
	Significant Variables Only			
FamilyWithHeartProblems	-16.836	8.492	-1.983	0.0494 *
Knowledge	11.780	4.843	2.433	0.0163 *

This regression indicates that all else held constant, individuals that report a family history of cardiac conditions would be expected to on average have 16.836 mg/dL lower blood glucose. This unusual result could be due to individual awareness of CVD and subsequent alterations in lifestyle to reduce risk. It is more probable, however, that there are other factors influencing this result. It is possible there was a misinterpretation of the question as family history of CVD and diabetes, was nearly significant and showed that as family history increased, blood glucose levels increased. As discussed previously, both questions were obtained to best capture family history risk in a culturally competent way. Perhaps the participants interpreted "heart problems" as diseases, disorders, and states outside the typical classification of cardiac conditions. Knowledge also predicted an unusual result: all else held constant, for everyone one point increase in knowledge, blood glucose on average is expected to increase 11.78 mg/dL. The original hypothesis would have assumed the opposite, that knowledge of CVD would decrease risk and therefore decrease observed glucose levels. This result could be confounded due to other lifestyle issues or be due to the little variation in knowledge scores amongst the sample.

Appendix I: Multiple Linear Regression Market Worker Cohort

Appendix I1: BMI MLR for Market Worker Cohort

A MLR model was conducted to analyze the relationship between the predictor variables, and BMI within the market worker cohort. This MLR model weakly predicted the BMI data observed (Adjusted R^2: 0.08598). Using the backward p-value selection Adjusted R^2 approach, the best model included age and income, with an Adjusted R^2 of 0.167. The variable income is included in the model despite its lack of statistical significance because it positively contributed to the overall data variation the model explained (Adjusted R^2). The variables for the best linear regression model and their significance is seen in Table I1.

Table I1

Summary of Best Prediction Model for Body Mass Index (Market Workers, 2016)

Variables	Estimate	Std. Error	t value	Pr(>|t|)
		All Variables in the Model		
(Intercept)	2.035e+01	2.425e+00	8.392	1.6e-10 ***
Age	1.671e-01	5.395e-02	3.097	0.00348 **
Income	6.520e-06	4.703e-06	1.387	0.17291
		Significant Variables Only		
Age	1.671e-01	5.395e-02	3.097	0.00348 **

From this regression age is expected to be the only predictor variable for BMI in the market worker cohort. With all else held constant, as age increases one year, on average BMI is expected to increase 0.1671 points. This may initially seem like a practically insignificant value, however, if this were a true stable trend, it could have profound impacts over an individual's lifetime. The literature supports this trend of increasing BMI with age.[2]

Appendix I2: Systolic Blood Pressure MLR for Market Worker Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables and systolic blood pressure within the market worker cohort. This MLR model weakly predicted the systolic blood pressure data observed (Adjusted R^2: 0.5069). Using the backward p-value selection Adjusted R^2 approach, the best model was found to include age and income, with an Adjusted R^2 of 0.5019. The variable income is included in the model despite its lack of statistical significance because it positively contributed to the overall data variation the model explained (Adjusted R^2). The variables for the best linear regression model and their significance are seen in Table I2.

Table I2

Summary of Best Prediction Model for Systolic Blood Pressure (Market Workers)

Variables	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	137.8	16.33	8.438	<.00000 ***
Age	1.034	0.2893	3.575	.00095 ***
Education	-4.043	1.077	-3.755	.00057 ***
Kids	-3.255	1.569	-2.074	.04470 *
Homemade Medications	17.89	8.480	2.110	.04137 *

This model indicates that all else held constant, as age increases one year, on average systolic blood pressure is expected to increase 1.034 mmHg in the market worker cohort. International CVD research corroborates this correlation.[2] All else held constant, for every additional child, on average systolic blood pressure is expected to be 3.255 mmHg lower. This is the same relationship discovered within the villager cohort and similarly, could be related to income. With more children, a family would have lower income per person proportionally, which could decrease their disposable income and thereby reduce access to unhealthy and processed foods. This model indicated that all else held constant, for every additional year of education, on average systolic blood pressure is expected to be 4.043 mmHg lower. This trend aligns with the original hypothesis that increased education decreases CVD risk.

Lastly, this regression indicated that all else held constant, individuals that took homemade medications for CVD on average are expected to have 17.89mmHg higher systolic blood pressures. This is a dramatic difference for systolic blood pressure. One hypothesis to explain this trend is that individuals using homemade medications are less likely to comply with other CVD medications or the health professional's instructions because they believe they are managing their condition themselves.

Appendix I3: Diastolic Blood Pressure MLR for Market Worker Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables and diastolic blood pressure within the market worker cohort. This MLR model weakly predicted the diastolic blood pressure data observed (Adjusted R^2: 0.06973). Using the backward p-value selection Adjusted R^2 approach, the model included age and income, with an Adjusted R^2 of 0.249. The variable income is included in the model despite its lack of statistical significance because it positively contributed to the overall data variation the model explained (Adjusted R^2). The variables for the best linear regression model and their significance is visualized in Table I3.

Table I3

Summary of Best Prediction Model Diastolic Blood Pressure (Market Workers)

Variables	Estimate	Std. Error	t value	Pr(>|t|)
		All Variables in the Model		
(Intercept)	61.83	7.419	8.334	<.0000
Age	.6564	.1650	3.977	.0003 ***
Income	.00002	.00001	1.236	.2232
		Significant Variables Only		
Age	.6564	.1650e-01	3.977	.0003***

From this regression, age was the only significant predictor variable for diastolic blood pressure in the market worker cohort. With all else held constant, as age increases one year, diastolic blood pressure is expected to increase on average 0.6564 mmHg. This may seem like a practically insignificant value; however, age increases greatly overtime. Therefore, if this were a true stable trend, it would have profound impacts over an individual's lifetime. This trend in increasing diastolic blood pressure with age parallels the trend observed with increasing systolic blood pressure and age, supports trends observed in international literature.[2]

Appendix I4: Fasting Blood Glucose MLR for Market Worker Cohort

A MLR model was conducted to analyze the relationship between potential predictor variables and fasting blood glucose levels within the market worker cohort. None of the predictors were found to be significant.

9 Acknowledgements

This thesis would not have been possible without the ongoing commitment of many phenomenal people. I am incredibly grateful to everyone that made this work possible. Thank you to my participants for their willingness to be part of the study. The VHTs were amazingly dedicated in recruiting participants and facilitating data collection. A special thank you to Nathan Lam for assistance with data collection in the field and Abbas Zaidi for statistical analysis support. I have immense gratitude for Edward Kiggundu and Robinah Nakafeero for their roles as translators and community facilitators. I want to thank Lysa MacKeen and DGHI support staff for their role in facilitating the logistics of the program before, during, and after the fieldwork.

My co-major advisors and thesis committee members, Dr. David Toole and Dr. Gary Bennett, provided excellent advice and ongoing feedback on the project. Gratitude also extends to Dr. Christopher Kigongo for his role as a fieldwork supervisor, establishing the community partnership, and providing continuous guidance in design and implementation of the project.

Finally, a special thank you goes to Dr. Sumedha Ariely, who has been a dedicated primary advisor and mentor throughout this process. She was an invaluable part of the research design, study implementation, data analysis, and thesis compilation. Without her guidance and supervision, this project would have been possible.